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Geography, Trade Patterns, and Economic Policy

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Abstract

This paper presents a geographical theory of location and interregional trade. Location is treated as an endogenous variable by firms, consumers and perfectly mobile workers in a two-sector economy. Space plays a central role owing to transportation costs, market access, and distance from polluting industrial centers. The model is used to examine: (1) aspects of a compensating-differential theory of regional unevenness, (2) the theoretical formulation of a gravity theory of trade patterns, (3) the geographic basis for industrial and environmental policy, and (4) the interaction between reductions in transportation costs, location patterns, and technological improvements.

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Contents

Summary

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The model determines the potential range of locations of industrial centers and land-use patterns; unevenness in measured real wages arises according to geographic location. However, under perfect labor mobility, compensating differentials in nonmarket variables, such as the intensity of pollution, lead to an equilibrium in which there is no incentive to relocate. These compensating differentials are location specific. Measured differentials in regional income and observed geographic dispersion of economic activities reflect the equilibrating role of nonpecuniary compensating differentials. Even in otherwise fully convergent processes, this form of unevenness remains as a residual divergence.

Explanations of bilateral trade flows frequently rely on the so-called gravity model, which stresses that economic size relates positively to trade and that transportation costs cause distance to relate negatively to bilateral trade flows. The basic notions of the gravity model are formalized and extended by examining the roles of distance and transportation costs in a model in which space and distance enter explicitly. The positive roles of economic size and associated specialization in trade are validated in our analysis, but the impact of distance is shown to be more complicated--"unnatural" trade between distant partners emerges endogenously from factor endowments and regional location decisions.

Technological change in this model can arise from the agricultural, manufacturing, and transportation sectors. For certain parameter values, reductions in transportation costs promote industrial expansion; for other values, reductions in transportation costs result in less industrial variety up to a certain point, after which industrial variety increases. At very low levels of transportation cost, a paradox emerges: advances in communications enhance the mass of industrial concentration but also give rise to greater dispersion in agriculture. Finally, the model's comparative static results show that the source of technological change cannot be determined simply by looking at the measured expansion of sectors' sizes and productivities.

I. Introduction

Recent developments in the world economy have raised a number of issues in which the dimension of space plays a central role. Of paramount importance is the economic analysis of interregional trade, the environment, and their relation to economic development. Yet, there is no body of theory or general equilibrium models that can help us understand the delicate interaction between endogenous technological development, location patterns and environmental factors.

International trade theory originates in the notion of separate economies that differ in terms of factor endowments and national policies. Current theory focuses on the conditions under which these economies interact and the benefits achieved through trade. This paradigm requires modifications to deal with recent developments in the world trading system, especially the trend toward integration. The European Single Internal Market, and to a large extent the North American Free Trade Agreement, are converting international trade into interregional trade. Within these markets factor mobility prevails. Integration is proceeding in Asia and further European integration may involve Eastern Europe. The economics of location and the impact of each region's environmental policies have naturally come to the foreground in public discussions.

This paper focuses on the geographic and regional basis for development, trade, and the environment. A geographical theory of interregional trade is developed, which can be used to examine policy issues in economic development and in environmental protection. Location is treated as an endogenous variable by firms, consumers and perfectly mobile workers. The model determines the potential range of locations of industrial centers and of associated land and labor use patterns. Space plays a central role owing to transportation costs, access to markets, and distance from polluting industrial centers.

The analysis presented here has interesting implications for central issues in regional development, trade, environment, and optimal government policy. This paper stresses:

(1) aspects of an equilibrium compensating-differential theory of regional unevenness,
(2) the theoretical formulation of a "gravity" theory of trade patterns,
(3) the geographic basis for industrial and environmental policy,
(4) the interaction between technological change in transportation, location patterns, and other types of technological improvements.

One of the main traits of development is the regional unevenness in incomes. Even when convergence is observed, residual unevenness remains (Barro and Sala i Martin (1991, 1992a, 1992b)). Unevenness in intra-country per capita income is sustained in the face of labor mobility and national policies that are uniformly applied across regions. Region-based factors, such as regional and local policies, must be introduced to account for these divergencies (see García-Milá and McGuire (1992), and Garcia-Milá, McGuire, and Porter (1993)).

The model presented below focuses on compensating differentials-based unevenness. These compensating differentials are location-specific and exhibit a regional component. Hence, the equilibrium factor rewards and utilization are location-dependent. Since labor is fully mobile, regional wage differentials reflect compensating differentials related to transportation costs and pollution levels. These compensating differentials offset the adverse effects of conditions such as high pollution levels or a high cost of living. As such, they remain as measured residual unevenness even when regional convergence is otherwise fully achieved. These regional disparities are associated with the determination of regional trade patterns.

Explanations of bilateral trade flows frequently rely on the so-called "gravity" model. The gravity model stresses that economic size relates positively to trade while transportation cost barriers cause distance to relate negatively with the extent of bilateral trade flows. While the gravity theory has been widely applied, its theoretical foundations are still not fully developed. As Frankel (1993a, p. 7) argues: "Although the importance of distance and transportation costs is clear, there is not a lot of theoretical guidance on precisely how they should enter."

Our model extends and formalizes the basic notions of the gravity model. The roles of distance and transportation costs are introduced in a geographic model in which space and distance enter explicitly. In particular, we examine how the interaction between size, distance and the divergence in regional productive structures lead to trade. The positive role of economic size and associated specialization in trade is validated in our analysis but the impact of distance is shown to be more complicated.

The role of distance is shown to depend crucially on regional specialization patterns. For instance, consider a region that is far away from the center and specializes in commodity x, for which it attains an above-average production concentration (i.e., it is a big exporter). This peripheral region engages in greater trade with the y-specialized center than with other regions that stand nearer to the center and specialize in x, but are not major centers of its production (i.e., they are small exporters or even importers of x). In this context, it is easy to see how the regional specialization effect explains the exchanges of machinery and beef between England and Argentina in the nineteenth century. At that time Argentine trade was far greater with Great Britain than with other Latin American countries. In our model this "unnatural" trading between distant partners emerges endogenously from factor endowments and regional location decisions.

An interesting industrial policy arises because agglomeration forces lead to multiple equilibria in industrial city locations. We show that there is a natural role for government to push the economy toward the utility-maximizing industrial center location. The location of government services and infrastructure investments entail an implicit industrial policy that can be used to achieve optimality. The sort of industrial policy that results is quite different from the usual discussions of industrial targeting. As with other expenditures, such as education, the government can steer the economy toward an optimal equilibrium. But there is no industrial targeting in the sense of choosing one industry over another. Actually, in this model manufacturing products are entirely symmetric and there is no basis for targeting one product over another.

The model is used to examine the interaction between transportation costs, location patterns and technological change. Technological change in this model can arise from the agricultural, manufacturing and transportation sectors. The analysis illustrates how change in the transportation technologies feeds back into new industrial technological developments. We show that the effects these developments have on location depend crucially on how strong the centralization forces are in particular industries. Reductions in transportation costs promote industrial expansion and hence growth and concentration in industrial centers. At the same time lower transportation costs push some activities away from the city. These are activities in which centralization forces are not strong. Increased industrial pollution thus causes a reallocation of resources away from the center. Paradoxically, this process enhances the mass of industrial concentration while simultaneously giving rise to a flight-to-the-periphery phenomenon if industrial transportation costs are sufficiently small.

Finally, the model also illuminates the sectoral basis for technological change. The model's comparative static results show that the source of technological change cannot be determined by simply looking at the expansion in size and productivity of individual sectors. These findings pose a number of caveats on recent studies of sectoral technological change that correlate the sources of technological change with high productivity growth or rapidly expanding sectors.

The analysis formalizes how the historical reductions in transportation costs encourage both industrial improvements and reallocation of regional resources. A reduction in transportation costs is equivalent to an increase in market size, which encourages innovation that is driven by market-size. Whether concentration or regional decentralization occurs depends on the nature of individual industries. Reductions in transportation costs lead to further concentration of industries that grow in response to such concentration. On the other hand, lower transportation costs encourage decentralization of those industries that are by nature not dependent on major industrial centers. Thus, in this case lower transportation costs operate to effectively bring the periphery and the center closer together and can lead to further decentralization. This two-way impact can help to explain how greater industrial concentration can subsist with increased dispersion of decentralized activities.

We proceed to briefly review models of trade that incorporate cities, regions, and the spatial variables. Sections II and III develop a theoretical model of economic geography and trade that analyzes location, environmental, and regional development issues. Regional inequalities and interactions are endogenously specified within the model. Section IV examines a number of policy issues relating to employment, agriculture and the environment. The conclusion considers extensions and limitations of the analysis.

II. Models of Location, Agglomeration and Trade

1. The advent of regional analysis

Work on regional analysis became an active field during the 1950s and has proceeded in the areas of regional planning, urban economics, and a host of related fields. A number of studies have addressed such issues as central market theory, land-rent gradients, and regional development and convergence (or divergence patterns). In a real sense much of the most recent work on regional economics reexamines work that has been conducted independently since that time.

Regional development must establish a balance between the opposite forces of agglomeration and those that work for the dispersion of economic activities. The outcome of this equilibrating process yields regional trade patterns as a by-product. A basic test of any regional theory is to model and illuminate the stylized facts that incorporate the consistency between the forces of agglomeration and dispersion.

Analysts have begun to construct new varieties of models of intra-country or regional development. An emerging theory of trade and development introduces explicitly the variable of space and models the location and interaction between economic agents in a geographic context. Most of these theories incorporate some form of regional specialization and interregional competition. The discussion that follows contains a highly-selected review of work on economic geography. This review is only intended to place this paper in the context of recent related work and does not purport to be a full or even a comprehensive survey of the subject.

2. Models of regional development

Henderson (1974, 1988) assumes localized external economies in production and contrasts the associated centripetal forces with the centrifugal ones, which stem from increasing land rents. The first factor generates pressures for agglomeration while the latter puts a cap on city expansion. A competitive market framework is utilized to examine the factors determining the number and the size of cities. The relative location in space is, however, not considered.

The models by Fujita (1988) and F. L. Rivera-Batiz (1988a) specify sources of the localized increasing returns to scale and consider the effects of imperfect competition among producers. F. L. Rivera-Batiz (1988a) develops a model with nontraded intermediate goods, a form of increasing returns to scale provided by diversity in services, and endogenous city size among a number of potential city locations (open cities model). Migration incentives and city population profiles in alternative locations are based on the exploitation of the localized benefits from nontraded services. Agglomeration permits the exploitation of economies of scale (and scope) but agglomeration is limited by the escalation of land values that accompanies economic aggrandizement. An equilibrium emerges in which city population, output, and variety of productive services are endogenously determined and made consistent with the dispersion of economic activities.

Fujita (1988) considers a model with nontraded intermediate goods and city size as determined by urban concentration. Increasing returns to scale are based on Marshall-type economies of scale. Both Rivera-Batiz and Fujita derive increasing returns from the existence of a monopolistically competitive nontraded goods sector that exhibits increasing returns. The role of space is not made explicit and transportation costs are ignored.

Krugman (1991a, 1991b) uses a two-region model in which regions are regarded as dimensionless points. The equilibrium that obtains is interpreted as the endogenous differentiation between an industrialized "core" and an agricultural "periphery". Manufacturing firms chose a single location in order to maximize the gains from increasing returns to scale in production at the plant level; they locate in the higher-demand region in order to minimize transportation costs and to have greater access to markets.

3. Explicit spatial models

In all the models reviewed above, location along a space dimension is not explicitly modeled. Cities are treated as dimensionless points that interact with one another. There is no explicit treatment of the distance between locations, or of distance-related factors such as transportation costs, the set of communication facilities, or market access. A number of papers have introduced a more detailed specification of the space variable.

F. L. Rivera-Batiz (1988b) develops a model of intra-city activities and land use. He presents a three-level stratified spacial urban model. The city consists of a circle subdivided into three distinct layers. These comprise an industrial center (export node) around which lies a central business services district, and a peripheral residential zone. The population and activity level of each region are endogenous. The model is utilized to examine city population size, its effects on productivity, and the determinants of emigration or immigration. However, the total amount of space devoted to industrial, service and residential purposes are considered fixed, as is the position of each on the circle. Since transportation costs are ignored, neither the size nor the distance between the different layers within a city affect the results.

Rauch (1991) constructs an explicit spatial model in which location is endogenous and international trade is explicitly considered. The model exhibits local external economies and offers a limited number of potential location sites. Transportation costs increase with the distance from an external trading partner. Trade takes the form of importation of a raw input and distance from trading center is measured as distance from the coast. City or regional size is a function of transportation costs in relation to a fixed point. The largest cites are located near the coast and city size declines as the distance from the coast increases, that is, as one moves inland. Rauch's model is based on the exploitation of the natural comparative advantage enjoyed by the coast location, and its interaction with the assumed local external economies.

Krugman (1992a) develops a model of endogenous location in continuous space, along a line and along a circle. The two-sector model consists of an agricultural sector and a manufacturing sector with increasing returns that produces a given number of differentiated goods sold in a monopolistically competitive market. Increasing returns at the manufacturing plant level are introduced through the presence of a fixed setup cost. All goods are considered tradable and manufacturing transportation costs vary directly with the distance between the production origin and the final market. No external economies are assumed and there are no transport costs in agriculture.

Manufacturing plant location decisions are based on the interaction of economies of scale at the manufacturing plant level (i.e., at individual production facilities), and transportation costs of final goods. At some equilibria no center emerges, but for some parameter values only one location becomes dominant, that is, a metropolis develops. A single metropolis develops if transportation costs are low enough. The metropolis has the character of a manufacturing center with increasing returns to scale that services the agricultural hinterland sector.

The center has a natural comparative advantage in manufacturing because of its location. In Krugman's model, however, the equilibrium is influenced also by created comparative advantages. Natural comparative advantages are viewed as first nature to the center's location. Created advantages, such as market access due to agglomeration in particular locations, are second nature to the locations but can nevertheless be dominant in determining the location of the metropolis. Multiple locational equilibria -- the set of equilibria is represented as a band around the center -- occur due to the fact that agglomeration points are to some extent arbitrary. Manufacturing can not be located far away from the center but it does not have to be at the heart of the center.

Krugman (1992c) develops a dynamic spatial model that examines how locational patterns evolve over time, how multiple agglomerations evolve, and how the location patterns change when exogenous variables change. Analytical solutions are difficult to obtain in the dynamic, multiregional case so the author relies (as do we, below) on numerical examples. Locations grow by adding new products to the center's. Metropolises are characterized by product availability and diversity.

Fujita and Krugman (1992) and Fujita (1993) extend Krugman's (1992c) model to generate diverse patterns of spatial agglomeration and multiple metropolises. They accomplish this by introducing multiple types of symmetric groups of manufacturing goods, which are subject to transport costs. The firms within each group agglomerate but different kinds of manufacturing goods can center at different places.

The spatial models discussed above and the related work by Thisse (1993) and others represent some first steps into a general equilibrium analysis of interregional trade. They provide us with a portfolio of economic geography models with which to work. For instance, the papers by F. L. Rivera-Batiz and Rauch focus on the analysis of intra-city and coastal location. The papers by Krugman examine a wide range of issues concerning location and number of cities as well as of economic geography, as broadly understood.

The influential papers by Krugman (1992a, 1992b, 1992c) rely on a number of strict assumptions will be relaxed below. Agricultural and industrial labor are treated asymmetrically. The manufacturing sector is characterized by full locational mobility of workers but agriculture is assumed to utilize an immobile factor, agricultural labor (used as a proxy for land immobility). The one-to-one association between agricultural labor and land is accomplished by assuming that labor is permanently attached to the land. This means that agricultural labor cannot move from one parcel of land to another and cannot migrate. The fact that agricultural labor is attached to land generates population dispersion across space and provides a force against full concentration of economic activities in the city. This dispersion condition, however, is not a result of the model but, rather, is achieved by construction. On the other hand, migration of manufacturing workers is allowed and is needed to generate agglomeration of the urban population.

Since neither agricultural capital nor land are explicitly considered, agricultural production --both total and at each location-- is given in this model. There is no possible intersectoral substitution and production conditions in agriculture play no role in the analysis (the only role of agriculture is to generate population dispersion). Furthermore, labor mobility from agriculture to industry is not allowed, which means that farmers are immobile both across locations and across industries. This model's property stems from the assumption of sector-specific labor in manufacturing and in agriculture.

III. A General Model of Interregional Trade

This section develops a two-sector general equilibrium model of location and interregional trade in a static framework. The two sectors, manufacturing and agriculture, use labor and land as inputs. The allocation of labor to agriculture and manufacturing, and along space, is endogenized by allowing workers to decide on their workplace, the choice being between manufacturing and agriculture as possible lines of work. Agricultural production decisions allocate labor to each plot of land along a line of range [0,1]. Labor allocation decisions for manufacturing are discussed more fully below.

Location is treated as an endogenous variable by firms, consumers and perfectly mobile workers. Space plays a central role owing to transportation costs, access to markets, and distance from polluting industrial centers. The quality of land depends on its location in a nontrivial way. Total land availability and the fixed location of each plot plays the role of multiple differentiated, fixed factors. The model determines the potential range of locations of industrial centers and of associated land use patterns. In this paper we determine the range of parameters from which there is a single industrial center equilibrium and focus on this case.

Industrial interdependence arises from the benefits of a concentration of demand at one point and the associated reduction in transportation costs. Industrial firms prefer to locate where there are other industrial firms, and hence markets for their products. This interdependence in firms' location decisions means that the site of an industrial center is indeterminate within a band along the linear space [0,1]. As a result there are multiple equilibria in terms of city location and the associated resource allocation.

Initially, the industrial center will be fixed and the focus is on one particular equilibrium among those possible, that is, the focus is on a generic central point and the equilibrium attached to it. The analysis is general because the equations used are applicable to each central location, which are denoted by x_c, within the set of equilibria. There is no presumption that x_c must lie at the center in real space --the midpoint of the interval [0,1]. Note, however, that $x_c = 0.5$ is an element of the equilibrium set in all cases (see Asilis and Rivera-Batiz (1993a)). Section IX characterizes the multiple equilibria that arise in the single-city equilibrium case.

1. <u>Consumers' choice of a consumption-residence location</u>

In a geographic setting, consumers and firms face a two-stage decision problem. Consumers choose (1) a location in which live and work, and (2) the allocation of consumer spending within a given budget constraint. The two decisions are related because the location determines both the consumer's budget and the prices of the goods he buys. In turn, the location decision must take into account wage and cost of living differentials. Let us examine the household budget allocation problem.

a. <u>The budget allocation problem</u>

Consumption decisions depend on income and the relative costs and availability of consumer goods. Both decisions are closely linked since the workplace location determines both the wages earned by the agent and the location where the agent makes purchases (and hence the cost of the goods purchased and the location-dependent utility obtained from them).

For any given location the consumer's budget allocation problem can be expressed in terms of a set of market commodities (c_i; i=1,...,N), the agricultural good c_A, and monetary income Y:

$$\max_{[c_A, c_i;\ i=1,\ldots,N]} \left[\sum_{i=1}^{N} c_i^{\frac{\sigma-1}{\sigma}}\right]^{\mu_M \frac{\sigma}{\sigma-1}} c_A^{\mu_A}, \qquad (1)$$

$$s.t. \sum_{i=1}^{N} p_i c_i + P^A c_A \leq I,$$

The demand function for a manufacturing good c_i is given by:

$$c_i = \left(\frac{\mu_M}{\mu_M+\mu_A}\right)^{\sigma} \frac{I^{\sigma}}{\left(\sum_{i=1}^{N} c_i^{\frac{\sigma-1}{\sigma}}\right)^{\sigma} p_i^{\sigma}} = \left(\frac{\mu_M}{\mu_M+\mu_A}\right) \frac{I}{\left(\sum_{i=1}^{N} p_i^{1-\sigma}\right) p_i^{\sigma}}. \qquad (2)$$

Multiplying both sides of equation (2) by p_i and summing up all manufacturing goods yields $\Sigma p_i c_i = (\mu_M/(\mu_M+\mu_A))I$, showing that the expenditure share of the aggregate of manufactures is the constant $(\mu_M/(\mu_M+\mu_A))$.

b. The consumer-worker location decision

The consumer's budget problem is not fully solved because the income I is not given but is determined endogenously by the consumer's location decision. The location decision will take into account both the location-specific wages and the difference in the cost and quality of living across locations. The cost of living differs across locations owing to a number of factors. First, prices of manufacturing goods paid by consumers are inclusive of transportation costs and are higher the farther away a location is from the center. Second, the cost of agricultural products could be higher or lower in the periphery than in the center depending on whether they are sold directly at the source or have to be taken to the center prior to distribution. Both cases can be incorporated into the model but, for simplicity, we will assume that agricultural goods transportation costs are zero and focus on the environment factor.

The quality of living is introduced through a consumption diseconomy -- called pollution-- that is generated by the agglomeration of industrial centers. Pollution spreads in space and is higher near the city and declines at a decreasing rate with distance from the city. It affects location decisions of workers and generates a demand for rural residence (commuting is ignored here). It provides a balance to the strong centralization forces in the model given that the cost of manufacturing goods makes the cost of living higher in the countryside.

As we move farther away from the city, residential location puts a value on the declining impact of pollution. This utility value is represented by a residential location utility factor of the form:

$$R_x = R_{x_c}\ (1+|x-x_c|)^{\gamma} = R_{x_c}\ e^{\gamma \ln(1+|x-x_c|)} \qquad 0<\gamma<1, \tag{3}$$

where γ represents a positive health parameter associated with less incidence of pollution toward the countryside. A greater γ represents a superior quality of environment stemming from the lower incidence of pollution in the rural areas. The health factor $\gamma\ln(1+|x-x_c|)$ also embodies the condition that housing services are superior the farther away one is from the polluting focus (the industrial center x_c).

Since environment is a public good, the quality of the environment does not have an explicit market price, but it enters as a factor in utility maximization. The individual's consumption balance yields that the relative shadow price between residence at x and residence at the city or industrial center x_c is:

$$p_x^R = p_{x_c}^R\ e^{-\gamma[\mu_M + \mu_A]\ln(1+|x-x_c|)}. \tag{4}$$

Since residential location, not housing space, is being considered, the supply is constant at every location. Residential utility services R are normalized at x_c to unity so that $R_x = \exp[\gamma\ln(1+|x-x_c|)]$.

In the presence of perfect labor mobility, real wages received by agricultural workers living at location x must be equal to those paid at the center (i.e., the city). The "full" agricultural real wage rate is computed by taking into account a cost of quality living that in turn incorporates the effects of pollution (i.e., the shadow price of residential utility).

The full real wage w_x^A/P_x at point x relative to that at point x_c corresponds to:

$$\frac{\frac{w_x^A}{P_x}}{\frac{w_{x_c}}{P_{x_c}}} = \frac{w_x^A}{w_{x_c}}\frac{P_{x_c}}{P_x} = \frac{w_x^A}{w_{x_c}}\frac{(p^A)^{\mu_A}(p_{x_c})^{\mu_M}(p_{x_c}^R)^{1-\mu_M-\mu_A}}{(p^A)^{\mu_A}(p_x)^{\mu_M}(p_x^R)^{1-\mu_M-\mu_A}} =$$

$$\frac{w_x^A}{w_{x_c}} e^{[-\tau\mu_M + \gamma(\mu_M+\mu_A)(1-\mu_M-\mu_A)]\|x-x_c\|} = \frac{w_x^A}{w_{x_c}} e^{-D\|x-x_c\|}, \qquad (5)$$

$$D \equiv \tau\mu_M - \gamma(\mu_M+\mu_A)(1-\mu_M-\mu_A),$$

$$\|x-x_c\| \equiv \ln(1+|x-x_c|),$$

where P represents the cost of living and p^A and p the prices of agricultural and manufacturing goods, respectively. The last equality obtains because manufacturing prices at x can be computed from those at x_c by simply multiplying by the transportation cost factor $(1+|x-x_c|)^{\tau}=\exp[\tau\ln(1+|x - x_c|)]$, while agricultural prices in locations x_c and x are equalized because of the assumed absence of transportation costs for agricultural goods. Also recall that the shadow price of the residential utility factor at x relative to that at x_c equals $\exp[-\gamma(\mu_M+\mu_A)\ln(1+|x-x_c|)]$.

Real wage equalization means that in equilibrium w_x^A equals the center wage multiplied by $\exp(D\|x-x_c\|)$. The parameter $D \equiv \tau\mu_M - \gamma(\mu_M+\mu_A)(1-\mu_M-\mu_A)$ represents a location compensating differential. When $D > 0$, nominal wages will be higher in the periphery that in the center. If $D < 0$, rural workers will receive lower nominal compensation in equilibrium.

The compensating differential $D \equiv \tau\mu_M - \gamma(\mu_M+\mu_A)(1-\mu_M-\mu_A)$ formalizes two geographic factors --transportation costs and environmental pollution-- that enter into workers' residence-work decisions. The factor D increases with a higher transportation cost factor τ, and a lower pollution-free health factor γ. Whether a rural workplace-residence commands premium wages or is offered at a discount depends on the relative size of these effects. The costs of transporting manufacturing goods to the periphery require a positive compensating differential to attract workers; the offsetting force comes from the benefits of being away from city-sourced pollution and other agglomeration-related disutilities.

In this model consumers face location-specific wages and prices but are identical and have full geographical mobility. Labor market equilibrium must be such as to eliminate the incentives for worker migration. For this reason, location is undetermined from the point of view of the individual. For the economy as a whole, residential patterns are uniquely determined as a function of the industrial center's location x_c. For each equilibrium x_c, the allocation of resources between agriculture and manufacturing is uniquely determined. The spatial distribution of productive activities implies the spatial shape of the population and associated trade patterns.

We have formulated a model of location-specific compensating differentials. To solve the model, wages and prices need to be determined at each location. In order to do this the productive sectors must be considered. First, production decisions and wage determination are examined in a model of dispersed agriculture. We will obtain a relationship between wages at different locations and the wage at the center. Subsequently, the requirements of full employment and labor market mobility across locations and between industry and agriculture are utilized to determine wages in the center, and the associated productive and spatial structure of the economy.

IV. The Geography of Employment, Agriculture and Pollution Externalities

The agricultural sector produces a homogeneous product with labor and land inputs. Transportation costs in agriculture are ignored so that the agricultural price $p_x^A = p^A$ will be the same at all locations x, and will not affect the relative allocation of agricultural labor across space.

We consider a production function of the form $\int F(L_x^A, x)\,dx$ with labor and land inputs L and $x \in [0,1]$. This production function exhibits what we denote as *space additive separability.* This property means that the productivities of labor at different plots of land are independent of each other. For any given point x in space at which a good is produced, labor use does not affect labor productivity in other plots no matter how close the plots of land are.

Space additive separability simplifies our spatial allocation problem because it allows point by point maximization over space in allocating labor over available land. In order to work out a computable equilibrium we specialize the form for the function F to the following:

$$F(L_x^A, x) \equiv f(L_x^A) = \frac{1}{(1-\rho)}(L_x^A)^{1-\rho}, \qquad 0 < 1-\rho < 1. \tag{6}$$

Profit maximization leads to the equalization of the agricultural wage rate w_x^A and the value of the marginal product of agricultural labor. We obtain: $w_x^A = p^A\,(L_x^A)^{-\rho}$, where $F_L(L_x^A, x) = (L_x^A)^{-\rho}$ is the marginal product of labor. Given the fixed prices and wages faced agricultural firms face, the latter equation determines the amount of labor allocated to any given point in space.

The nominal wage w_x^A has a location-specific component. This is due to the need to compensate workers for cost of living and residential utility differentials. We have already shown that "full" real wage equalization across locations implies that $p^A(L_x^A)^{-\rho} = w_x^A$ equals the center wage multiplied by $\exp(D\|x-x_c\|)$. This condition allows us to rewrite the agricultural labor allocation relationship as:

$$L_x^A = [w_{x_c} \frac{e^{D\|x-x_c\|}}{p^A}]^{-\frac{1}{\rho}}. \tag{7}$$

Figures 1 and 2 show two illustrative plots of the spatial allocation of agricultural labor. When a positive ($D > 0$) compensating differential is required to attract workers to the countryside, agricultural employment concentrates near the cities and gradually declines as we move away from the center on both sides (Figure 1). This pattern emerges because the real cost of labor is greater the farther the location is from the center. Consequently, the marginal productivity is greater the farther locations are from the center, implying that labor will be used less intensively the farther away from the center the production occurs.

On the other hand, when the rural sector carries a negative compensating differential, a U-shaped agricultural employment pattern arises, and real wages are lower in the pollution-free countryside. If the manufacturing goods transportation cost parameter τ goes up, D increases, the compensating rural-urban differential increases, and the population becomes more concentrated in the urban sector. An opposite centrifugal force arises if the health factor γ increases.

V. Industrial Centers Servicing Widespread Heterogeneous Markets

The decision process of manufacturing firms can be decomposed into two related stages. One stage entails allocating sales across spatially separated markets, given the production location. The other decision involves choosing the production place. In both stages firms take as given the spatial distribution of the population and the schedule of transportation costs from the production point to every possible market. As mentioned earlier, there is a band along which the manufacturing location might be centered in equilibrium (see Section IX and Asilis and Rivera-Batiz (1993b)). The focus here is on a generic point x_c in the equilibrium set. The equations used are equally valid at any central equilibrium location so the analysis below is general.

1. Location-specific monopolistic competitive pricing

The pricing and sales allocation problem is modeled in terms of the Dixit-Stiglitz monopolistic competition framework, which is extended to allow sales in different locations. The producer enjoys a monopoly in each location because the firm is the only source of the differentiated good it specializes in and makes pricing decisions on the basis of two location-specific elements. First, the producer must take into account the transport costs of sending goods from the production base to each specific location. Second, the producer takes as given the spatial distribution of the population that in general is not uniform along the space dimension. Each market-location will thus bring about a different demand and fetch a different price.

Pricing-sales decisions are realized to maximize profits from total sales, given the production location at the industrial center x_c. Since demand at any given location does not depend on the price at other locations and because cost functions are linear, the firm's problem can be decomposed into individual maximization problems at each location.

The firm's decision at any given location is to choose its price and associated sales --which in the monopolistic competition case equals total consumption there-- so as to maximize gross profits (of fixed costs). Since the firm is producing at the central location x_c, gross profits from sales at x are given by the solution to the following problem:

$$\max_{[c_x]} \; p_x \, e^{-\tau \|x-x_c\|} \, L_x^A \, c_x - \beta \, w_{x_c} \, L_x^A \, c_x . \tag{8}$$

The parameter β represents the labor input-output coefficient, and is assumed to be constant. Notice that the price received by the seller equals $p_x \cdot \exp[-\tau \ln(1+|x-x_c|)]$, that is, the price received by the firm is net of the transaction cost. The relevant wage rate is the one prevailing at the central location x_c, which is the point of production.

Using equation (2) again, for the price derived from the demand for manufactures, we obtain an explicit expression for the price (gross of transportation costs) in terms of wages:

$$p_x = \left(\frac{\sigma}{\sigma - 1}\right) \beta w_{x_c} e^{\tau \|x-x_c\|} = p_{x_c} \, e^{\tau \|x-x_c\|} \tag{9}$$

The previous equation is a spatial version of the traditional markup equation in monopolistic competition models. It tells us the price charged by the firm; in this framework firms will charge different prices at different locations in order to cover transportation costs. The price received by the firm is simply the markup $(\sigma\beta/\sigma\text{-}1))$ over the wage at the central location.

2. <u>Geographical sales allocation</u>

In order to solve for resource allocation in the manufacturing sector, quantities sold at different locations must be specified. That is, total quantities sold by a manufacturing firm located at x_c are given by the sum of two components: of manufacturing goods sold to L^M manufacturing workers at x_c and of sales to agricultural workers dispersed across the [0,1] interval.

Aggregate quantity demanded from a manufacturing firm located at x_c, q^d, is the sum of manufacturing workers' demand at x_c, plus the integral sum of agricultural workers' demand located over the interval [0,1]:

$$q^d = \left(\frac{\mu_M}{\mu_M+\mu_A}\right) \frac{p_{x_c}^{1-\sigma}}{\sum_{i=1}^{N} p_{x_c}^{1-\sigma}} \frac{\sigma-1}{\beta\sigma} \left[L^M + \left(\frac{w_{x_c}}{p^A}\right)^{-\frac{1}{\rho}} \int_0^1 e^{[D(1-\frac{1}{\rho})-\tau]\|x-x_c\|} dx\right]. \quad (10)$$

Expression (10) is obtained by adding up the previous demand expressions (2), and using (9). Since all goods $i=1,\ldots,N$ enter symmetrically in demand, have the same cost function, and are produced at the same location, the previous equation applies equally to all manufactured goods.

Expression (10) neatly illustrates a number of points that we want to formalize. The first term shows the unambiguously positive demand effect of the center's economic size as measured by its wage bill and negative substitution effect (including the term $p^{-\sigma}$). The second term incorporates the positive income demand effect of agricultural wages as well as the negative one resulting from the substitution effect and the inverse relationship between the agricultural population and the real wages at each location. Notice that a higher agricultural price p^A will increase the number of workers at location x and thus result in increased demand. The demand effect of the agricultural sector also depends on the value of the term $D(1-1/\rho) - \tau$, with $D = \tau\mu_M - \gamma(\mu_M+\mu_A)(1-\mu_M-\mu_A)$. It is instructive to take a close look at this term.

The integral term in (10) shows the complex role of distance in product demand. Transportation costs entail a price demand effect (related to the factor $\exp(-\tau)$). The distance of the agricultural workers' residence from the center induces an income effect (related to the factor $\exp(D)$) through the level of wages needed to induce workers to settle in a particular location. The sign of the income effect of greater distance from the center is ambiguous because the sign of the compensating differential D cannot be ascertained a priori. Finally, there is the population density effect of the level of wages which is required to compensate workers for transportation and pollution costs (related to the factor $\exp(-D/\rho)$). The population density effect strengthens demand when the compensating differential D has a negative sign and weakens it when D is positive.

In order to ascertain the net demand effect of a greater distance from the center the different channels of influence on demand must be taken into account. In this model the net demand effect of increasing the distance from the center is ambiguous because the compensating differential is ambiguous.

VI. The Gravity Theory of Trade Patterns

A widely-used model in the empirical literature of trade patterns is the so-called "gravity theory." This theory was first applied by Armington(1969a and 1969b) and has recently been used by Frankel(1993) and others.

The "gravity theory" stresses that trade operates in a manner that is similar to the force of gravity on space. In the same way that larger and closer-positioned bodies attract each other, trade increases with size and proximity between trading patterns. Operationally, the gravity theory is taken to mean that the importance of trade declines with the distance between trading partners and increases with the economic size of the trading partners.

The model presented in this paper determines interregional trade patterns by the interaction between a manufacturing region that imports agricultural goods and an agricultural region that imports manufactured goods from the center. It can also assess the role of distance and size. In this model, interregional trade patterns entail the interaction between a manufacturing region that imports agricultural goods and an agricultural region that imports manufactured goods from the center.

The geographical nature of trade patterns in our model can be determined by computing the ratio of exports to output at each point in space. The result of the calculation (see Asilis and Rivera-Batiz (1993a)) embodies the geographic position explicitly:

$$\left(\frac{exports}{output}\right)_x = 1 - \frac{e^{\frac{D}{\rho}\|x-x_c\|}}{constant}. \tag{11}$$

The relation between distance from the center and trade with it relates to the sign of the parameter $D = \tau\mu_M - \gamma(\mu_M+\mu_A)(1-\mu_M-\mu_A)$. Figures 3 and 4 depict two possible patterns.

The hump-shaped pattern shown in Figure 3 illustrates the negative relation between distance and trade suggested by the gravity theory. The export-output ratio is higher near the center and declines as we move away from it. The humped-shaped pattern arises when the compensating differential D exceeds unity in value. It is not a general feature of the economies we model.

The U-shape curve pattern in Figure 4 illustrates how our framework generalizes the insights of gravity theory. First, notice that the relation between distance from the center and trade with it is positive, not negative as in the usual version of the theory. However, the notion that high-population centers trade with each other still holds. This case shows a situation in which there are various centers of gravity: the industrial center and two peripheral agricultural centers. The agricultural centers do not trade with each other (since they specialize in the same product) but each trades with the industrial center.

The pattern of trade is a consequence of specialization patterns and the population associated with the regions. In cases in which population concentrates far from the center, trade will increase with distance. The point is not taken to imply that by itself higher transportation costs tend to be beneficial to trade. But any detrimental role of transportation costs in trade can be offset by other factors, such as environmental pollution, which disperse production in favor of decentralized production centers. In the case of peripheral agricultural centers, represented by $D < 0$ in our model, distance relates positively with trade with the industrial center.

The analysis incorporates the detrimental effects of transportation costs but also alerts us to not focus exclusively on transportation costs or to associate distance with less trade. In fact, historically, distant regions trade substantially among themselves. The opposite forces for the centralization and decentralization of production must be taken into account to explain production and dispersion of production centers, and the associated trade patterns.

The theory of trade presented here differs in important respects from traditional theories that stress factor endowments and increasing returns. Factor endowment theories stress that countries differ in their endowments of labor and land. We have allowed regional labor endowments to be fully endogenous. Increasing returns models focus on trade between regions each of which is specialized in a particular product. These models, however, fail to explain why it is that all production activities fail to concentrate in the same location. In our model each country or region specializes endogenously instead of concentrating production in a single region.

What distinguishes the theory formulated here from alternative theories is that this paper has developed a theory of trade that is geographic in nature. Essentially, trade occurs as a result of the endogenous geographical dispersion of factors of production and population. A general theory of trade must explain the forces determining the geographical patterns of dispersion.

The theory of trade put forth in this paper is based two factors that motivate dispersion in the presence of a factor --land-- that is necessary to the production process. First, diminishing the marginal product of labor at a given plot of land leads to production dispersion across the whole space, and hence, of trade. Second, city congestion, modeled here in terms of pollution, leads to population dispersion in space. Thus, regional labor endowments are endogenous here.

What makes one region different from another is its location in space. The spatial relation between a point in space and other regions is determined by the location, which cannot be changed since it is a fixed factor. For instance, how far a location is from the industrial center turns out to be crucial in the model. Increasing returns is crucial in generating industrial concentration but is not the determinant of trade patterns here. What determines trade patterns is the interaction between activities that show increasing returns, which creates forces for concentration in space and for others that are decentralized or naturally dispersed.

Some activities benefit from decentralization because of the decreasing returns to concentration. Agriculture is one such activity and is exploited in our model. However, other activities can also be mentioned. For instance, recent improvements in communications have promoted the dispersion of a myriad of service activities that used to be located near a center. Sports training and health-related activities benefit from distance or by being separated from industrial pollution. As a consequence of these factors, a number of gravity centers emerge endogenously in the economy and their interactions are what determine the trade patterns.

VII. Patterns of Spatial Resource Allocation in Manufacturing and Agriculture

We are now ready to determine manufacturing employment, denoted by L^M. It is important to note, however, that the demand for manufacturing goods depends on the demand generated by agricultural workers, which in turn, depends on the size of the agricultural labor force, denoted as L^A. To determine L^M, we solve for L^A and then compute L^M from the full employment condition $L^M = \bar{L} - L^A$.

Total sales of a firm located at x_c are jthe sum of total sales to manufacturing workers at x_c, plus the integral sum of sales to agricultural workers over the interval [0,1]. In order to obtain manufacturing employment for the good in question, the labor input requirement condition for N firms which in equilibrium yields $L^M = N(\alpha + \beta q)$, ($\alpha$ and β positive) is used, where q represents total quantity sold by a single firm. Then, L^M is eliminated from the full employment condition $L^M = \bar{L} - L^A$ to obtain $q = (\bar{L} - L^A)/\beta N - \alpha/\beta$, which must equal the demand as determined above:

$$q = \frac{1}{\beta}\frac{(\bar{L}-L^A)}{N} - \frac{\alpha}{\beta} =$$

$$\left(\frac{\mu_M}{\mu_M+\mu_A}\right) \frac{p_{x_c}^{1-\sigma}}{\sum_{i=1}^{N} p_{x_c}^{1-\sigma}} \frac{\sigma-1}{\sigma\beta}\left[\bar{L} - L^A + \left(\frac{w_{x_c}}{p^A}\right)^{-\frac{1}{\rho}} \int_0^1 e^{[D(1-\frac{1}{\rho})-\tau]\|x-x_c\|} dx\right] \quad (12)$$

This is the sum of our previous total sales expressions after collecting common terms. In symmetric equilibrium, the above corresponds to:

$$q=\frac{1}{\beta}\frac{(\bar{L}-L^A)}{N} - \frac{\alpha}{\beta} =$$

$$\left(\frac{\mu_M}{\mu_M+\mu_A}\right) \frac{(\sigma-1)}{\sigma\beta}\frac{(\bar{L}-L^A)}{N} + \left(\frac{w_{x_c}}{p^A}\right)^{-\frac{1}{\rho}} \left(\frac{\mu_M}{\mu_M+\mu_A}\right)\frac{(\sigma-1)}{N\sigma\beta}\int_0^1 e^{[D(1-\frac{1}{\rho})-\tau]\|x-x_c\|} dx \quad (13)$$

Since all manufacturing goods enter symmetrically in demand, have the same cost function, and are produced at the same location, the previous equation applies equally to all of them.

Substituting the previous equation into the full employment condition, we can obtain a closed form solution for L^M:

$$L^M = \frac{\bar{L}\frac{\Psi}{\Lambda} + \frac{N\alpha\sigma(\mu_M+\mu_A)}{\mu_M(\sigma-1)}}{\frac{\sigma(\mu_M+\mu_A)}{(\sigma-1)\mu_M} - 1 + \frac{\Psi}{\Lambda}}, \quad (14)$$

where,

$$\Psi(D,\rho,\tau) = \int_0^1 e^{[D(1-\frac{1}{\rho})-\tau]\|x-x_c\|} dx, \quad (15)$$

and,

$$\Lambda(D,\rho) = \int_0^1 e^{-\frac{D}{\rho}\|x-x_c\|} dx, \tag{16}$$

and where Ψ/Λ corresponds to the average per capita sales ratio between the countryside and the industrial center.

Imposing full employment $L^M + L^A = \bar{L}$ and a zero profit industry equilibrium, we obtain the solution for the number of manufacturing goods N:

$$N = \frac{\frac{\bar{L}}{\alpha\sigma}\frac{\Psi}{\Lambda}}{\frac{(\mu_M+\mu_A)}{\mu_M} - 1 + \frac{\Psi}{\Lambda}}, \tag{17}$$

with $\Psi(D,\tau,\rho)$ and $\Lambda(D,\rho)$ as defined in the expression for L^A above.

VIII. Technological Change, Transportation Efficiency, and Externalities

Recent work on growth has stressed the wisdom of looking beyond the numbers at the national level toward the need to examine specific industries (Harberger (1993), Young (1993a, 1993b)). Aggregate data frequently hides industrial developments that constitute the sources of technological change. As Harberger (1993) observes concerning total factor productivity (TFP) growth:

> "TFP growth tends to be highly concentrated, to pop up in the most unlikely places, and then to move to other arenas. If we think of successive great technical advances--in automobile making, in rubber tires, in refrigerators, in television sets, in plastics, in petrochemicals generally, in telecommunications and most recently, of course, in the computing 'industry'-- we see advances concentrated in relatively short time spans (like decades) for each industry group, and advances concentrated in specific industry groups in any particular decade."

There are three basic sources of technological change in our highly aggregated model. These are innovation in manufacturing, improvements in agricultural technology, and reductions in transportation costs. The feedback from transportation efficiency to industrial variety shows how innovation can move from one industry to another. An examination of these three sources also suggests a series of caveats concerning the interpretation of data on technological change and industrial growth.

1. Searching for the sources of technological change

Manufacturing innovation is represented as a process of technological change in the form of a reduction in the marginal labor requirement β and as an increase in the number of manufacturing products N. The reduction in the marginal labor requirement β does not affect the resource allocation, L^M, L^A, or agricultural labor at any location. Since manufacturing efficiency increases, manufacturing output goes up and utility levels increase for all workers. In equilibrium, manufacturing output per man hour increases and agricultural output per man hour remains constant.

One way to expand the range of industrial products is through a reduction in the fixed cost coefficient α. Equation (17) shows that the consequence of a reduction in the fixed cost in manufacturing is to increase the range of available industrial goods. In this case, manufacturing employment expands and agricultural employment falls. Output per manhour increases in both sectors, as do real wages. Also, the utilities of both the urban and rural population are enhanced.

In the previous exercises, the output per manhour effects vary according to the source of the technological improvement. In the first example, there is no reallocation of resources. In the second example, there is an enhanced productivity in both sectors. It would be difficult to identify the source of the technological change either by looking at the sectoral productivity change or by examining which sector expands the most.

These considerations have a bearing on recent controversies concerning the relation between structural and technological change in Korea and other so-called Asian Tigers (Alwyn Young (1993a, 1993b)). The previous results are, of course, a consequence of the model's specifications. They should, however, alert us of the difficulty in identifying sources of technological change on the basis of market data that reflects an economy's equilibrium response. Similar caveats follow from a consideration of the effects of technological change originating in agriculture (for further discussion see Asilis and Rivera-Batiz (1993b,c)).

2. The feedback from transportation to industrial technologies

Improvements in transportation efficiency emerge as a force in innovation that is not always realized. Figure 3 shows the relation between transport costs τ and the number N of manufacturing goods. A reduction in transportation costs τ exert a secondary technological improvement in manufacturing through increased demand for manufacturing products. Because the gains from creating new goods are related to their market size, lower transportation costs will lead to innovation in the form of more manufacturing goods in equilibrium.

This effect helps to explain how innovation feeds upon itself and how historical declines in transport costs have led to a second round of related innovation. But it would be difficult to infer sources of technological effects from the data on wages or on equilibrium resource allocations.

Interestingly, the resource allocation effects of the reduction in transportation costs entail two opposite effects. Ceteris paribus, the increase in the number of manufacturing goods means that manufacturing grows at the expense of agriculture. But, recall that the transportation cost reduction itself leads to an increase in the size of the agricultural sector. Hence, the transportation cost driven innovation does not unambiguously alter the sectoral allocation of resources.

There is a feedback between reductions in transportation costs and industrial variety. Specifically, when transportation costs decrease the number of industrial products goes up and so do manufacturing employment and concentration around the industrial center. However, for the case in which pollution is increasing in the number of industrial polluters, there is a negative externality on consumers. In general, the benefits from greater industrial variety must be balanced against the negative consumption externalities created thereby. Notice that the pollution externality is partly internalized by firms through the higher wages they must pay to workers residing in the industrial center. Interestingly, increases in industrial variety lower the degree of internalization of the externality. To see this, consider the case of a symmetric two-firm industry. The marginal production of pollution affects each firm through the higher wages it must pay to its manufacturing workers. As industry size increases the impact of an increase in pollution on a firm's wages becomes smaller (see Asilis and Rivera-Batiz(1993a)).

IX. Industrial Policy and the Theory of Central Location

The model above analyzed the interregional equilibrium in an economy that produces manufacturing and agricultural goods. The model has two special traits which will be considered in this section. The first concerns the central location x_c, which was given at the outset and held constant throughout the analysis. The second is the pollution diseconomy that was not a function either of the number of plants in the city or of the levels of production realized by those plants. Therefore, this section will analyze the determinants of the central location and the case in which the number of plants in the city positively affects the health factor associated with being located away from the industrial center.

Residential location assigns an increasing utility value to the declining impact of pollution as work-living locations move farther and farther away from the industrial center. This utility value is an increasing function of the number of firms N producing manufacturing goods in the industrial center. The residential health factor can be formalized in terms of a location utility factor of the form:

$$R_x = R_{x_c}\, e^{\gamma N \ln(1+|x - x_c|)}, \tag{18}$$

where γ represents the positive health parameter associated with less incidence of pollution toward the countryside.

A greater value of the factor γN represents a superior quality of the environment stemming from a lower incidence of pollution in the countryside. The health factor $\gamma N \ln(1+|x-x_c|)$ also embodies the condition that housing services are superior the farther away one is from the polluting source (the industrial center x_c). The solution of the model in the case where health is a function of the number of firms in the industrial center is detailed in Asilis and Rivera-Batiz (1993a).

We find that there are multiple single-city equilibria in the determination of location. The reason for this is that increasing returns tend to pull firms to wherever other firms are located and generates a band of potential equilibria. We also find that a single-city equilibrium cannot be sustained under certain parameter values. In this instance, even in the presence of increasing returns two-city equilibria emerge endogenously .

The possibility of multiple single-city equilibria raises the issue of whether there is a role for industrial policy. We examine the utility level associated with each single-city equilibrium. This utility level is unique among the population because all individuals have the same preferences and there is perfect labor mobility which, as explained before, equalizes full real wages.

The utility map associated with an alternative location for the city center, for the case of positive compensating differential $D>0$ (this is the arguably more realistic case; for a discussion of optimal industrial policy for the case of negative compensating differential $D<0$ see Asilis and Rivera-Batiz(1993c)), is given by Figure 5. In this model, there is a unique location that maximizes the utility level of the representative individual. The striking result is that the optimum location is the central location $x_c = 0.5$, that is, the central location maximizes welfare. This result confirms, in a very different model that explicitly considers environmental externalities, the results obtained by Quinzii and Thisse in their paper on "The Optimality of Central Places". In this paper the central location theory was based on minimization of transportation costs where transportation costs play a role but so does environmental pollution. The optimal polluting focus, if we are allowed to speak in those terms, is also at the center. The reason for this result is that the distortions caused by a non-central polluting center to economic allocation reduce the agents' utility.

The previous considerations suggest that a natural role for industrial policy emerges in terms of choosing the city center. However, the opportunity to exercise that choice is limited. After a city center has been established, the costs of moving the center might be too high. The analysis suggests that city and regional planners should be quite careful in the choice of the regional infrastructure spending. Once a city center is established the incentives are drastically changed and the first best optimum might be unattainable.

The inclusion of environmental costs that are positively associated to the number of plants in the city introduces a number of changes in the analysis of the relation between transportation costs and the creation of technology. Figure 6 shows that the relation between these values ceases to be monotone after environmental externalities are incorporated. At high levels of industrial transportation cost, a reduction in these costs will lead to a reduction in the number of industrial goods produced in the economy. This occurs mainly as a result of the interplay between two forces when the marginal productivity parameter in agriculture is high (low ρ). Specifically, increases in transportation costs lead to greater concentration of population around the industrial center, which increases demand for the manufacturing goods; however, increases in transportation costs also tend to reduce the quantity demanded of such goods. When the marginal productivity parameter in agriculture is high, the productivity effects of greater concentration are small enough so that the effect of increased demand for manufacturing goods dominates the negative transportation effect on demand.

X. Concluding Remarks

This paper has presented a fully-specified model of an interregional equilibrium allocation of resources. As a by-product of the analysis, a geographic theory of trade and trade patterns emerges. The theory turns out to be a generalization of the so-called "gravity theory" of trade patterns that has been widely applied by trade practitioners.

A number of extensions can be accomplished with the previous framework. First, the role of growth needs to be incorporated in the analysis. Second, a characterization of the multiple-city case would be of interest in understanding the factors in favor of or against integrationist policies between trading partners and trading blocs (Asilis and Rivera-Batiz (1993b) formulate the multiple city case and provide an algorithm to be used in its computation).

At least since the classic writings of Heckshei and Ohlin, economists have dealt with models of national trade and exchange. The straightjacket of national borders and of immobile factors have been the bread and butter of trade theories. As the linkages between countries and regions strengthen and the world globalizes, the traditional paradigms will have to be modified to accommodate the new realities. In this context, the usefulness of thinking in regional terms cannot be overemphasized. The economics of location and distance are not everything in today's global setting, but it might be useful to examine the perspectives offered by well-defined general equilibrium models of interregional market behavior.

Figure 1

Agriculture Population Distribution; D>0

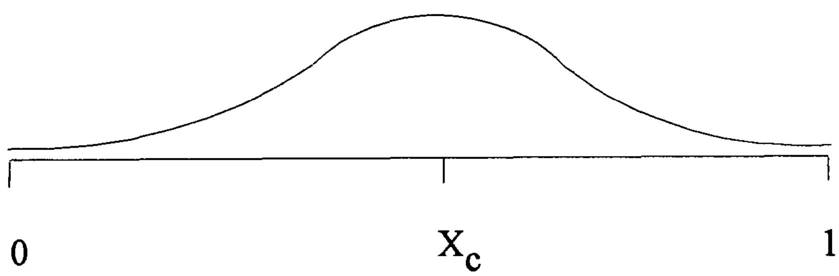


Figure 2

Agriculture Population Distribution; D<0

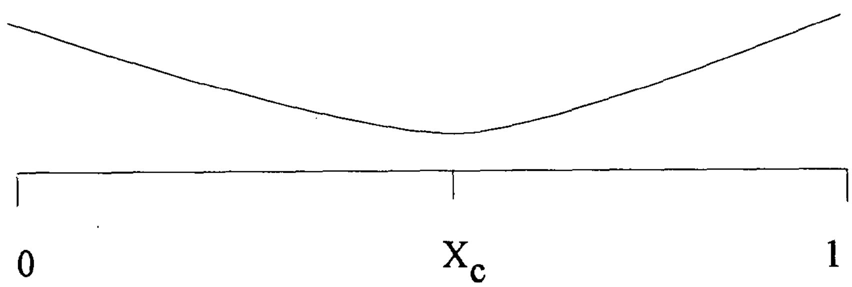


Figure 3

Exports to Production Ratio; D>0

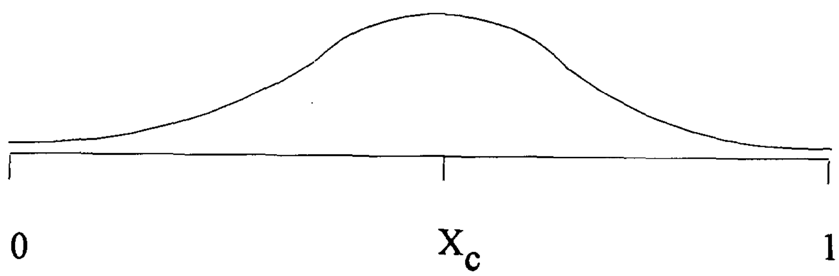


Figure 4

Exports to Production Ratio; D<0

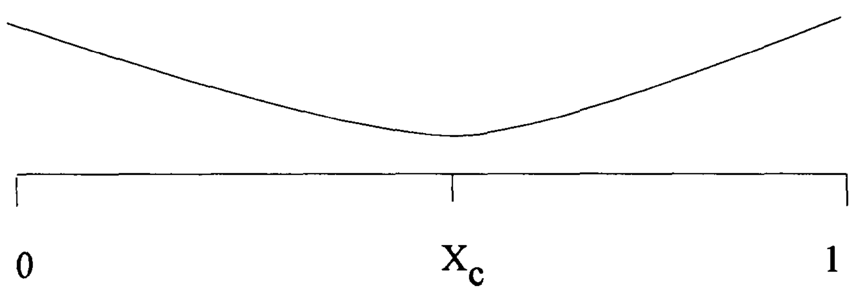


Figure 5

Pareto Optimality of Central Location in a $(\underline{x},\bar{x})$ Single-City Equilibrium Space; D>0

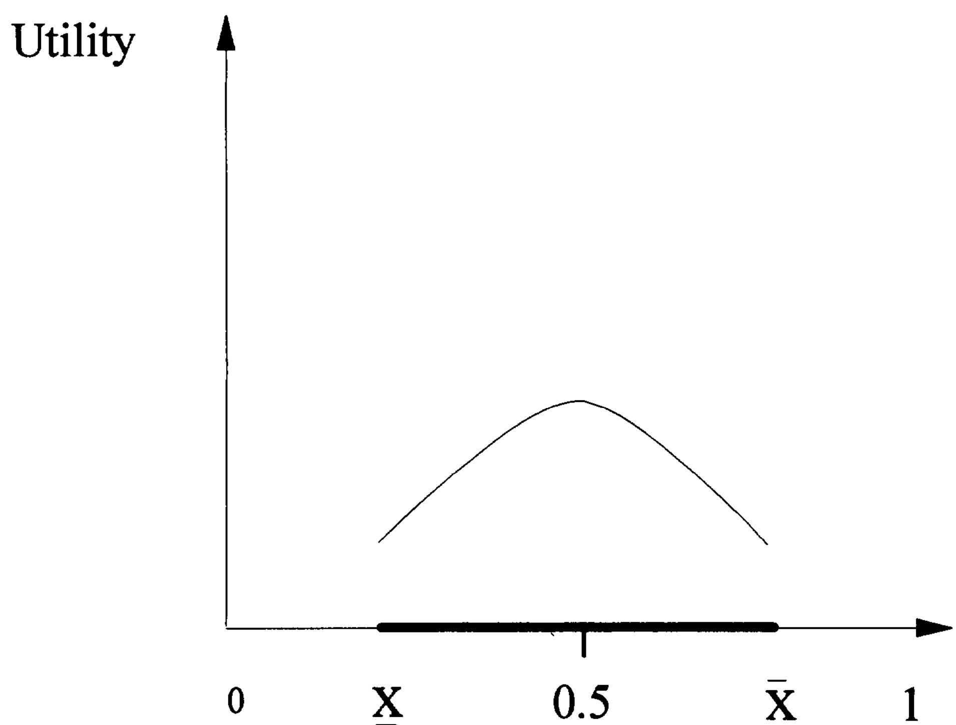
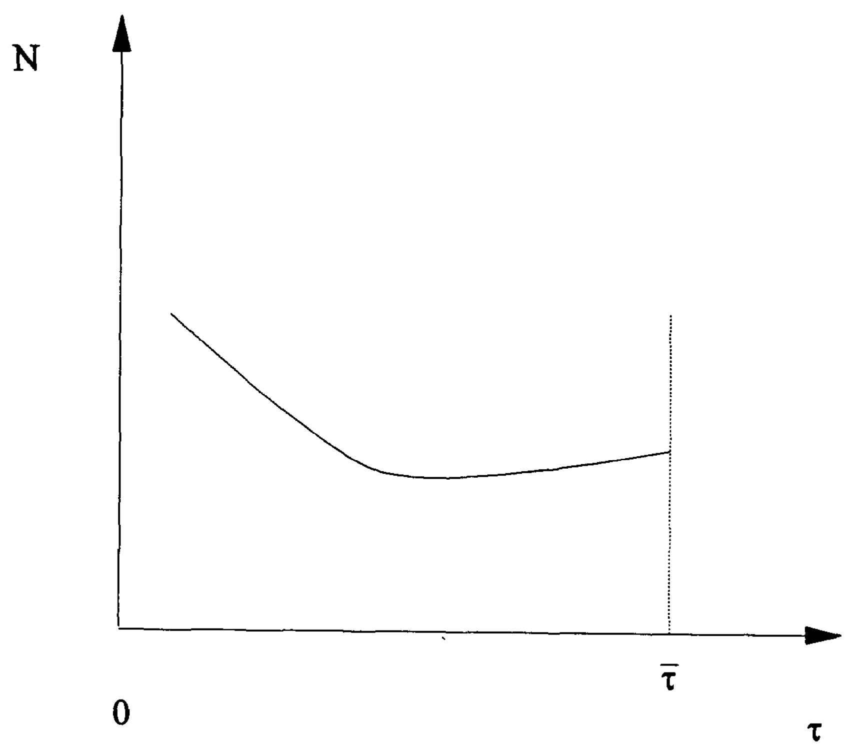


Figure 6

Industrial Variety and Transportation Costs:
Low ρ



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