TRANSPORT COSTS AND RURAL DEVELOPMENT*

Maureen Kilkenny
Department of Economics, 565 Heady Hall, Iowa State University, Ames, Iowa 50011, USA. E-mail: kilkenny@iastate.edu

ABSTRACT. Innovations that reduce costs of transport from rural locations may also reduce transport costs to rural areas. As transport costs fall, producers can afford to concentrate and achieve economies of scale. This paper explains an initially negative, but ultimately positive, relationship between reductions in transport costs and rural development. A two-region general equilibrium model with firm and worker spatial mobility highlights the firm and household location implications of costly transport-service use by both industry and agriculture in the context of scale economies and product differentiation. The computable general equilibrium model is initialized and verified with a bi-regional social accounting matrix and then used for simulations. Changes in relative transport costs are shown to affect relative regional wage rates, thus also determining the location of “production-cost-oriented” firms.

1. INTRODUCTION

Rural areas are by definition remote, sparsely populated, and often dependent on natural-resource-based industry. Distance from the center of markets makes rural areas less attractive to people and to industry that is not materials-oriented. Transportation improvements in general, and communication innovations in particular, may help overcome rural remoteness (Salomon, 1996). But many innovations that reduce transport costs from rural locations also reduce the transport costs to rural areas. They allow businesses to concentrate in cities to achieve economies of scale. Thus, the relationship between transport costs and rural development may be both negative and positive.

By rural development we mean economic diversification as well as increases in population and welfare. Three tools, classic location theory, modern industrial organization theory, and a computable general equilibrium model are needed to investigate whether transportation cost reductions promote or hinder rural development. Classic location theory tells us that as transport costs diminish in importance, fixed-facility-cost minimization drives location strategies. But classic

*Thanks to Jacques Thisse, Marie-Françoise Calmette, Richard Sexton, Jim Hite, Robert Evenson, and an anonymous referee for comments on earlier versions of this paper. Journal Paper No. J-17784 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa and supported by Hatch Act and state of Iowa funds, as well as a USDA National Research Institute Grant “Rural Development Implications of Employment Location.”

Received September 1995; revised June 1996 and January 1997; accepted March 1997.

Blackwell Publishers, 350 Main Street, Malden, MA 02148, USA and 108 Cowley Road, Oxford, OX4 1JF, UK.
location theory also suggests there will be no more than one firm of each type in each region due to the economies of scale. We need modern industrial organization theories of imperfect competition to rationalize an equilibrium multiplicity of firms, with scale economies, in one place. Product differentiation, for example, provides a qualitative distance that allows firms to profitably agglomerate in space (de Palma, et al., 1985). These theories explain why more and more firms locate in cities as transport costs fall relative to fixed costs.

What about household location? A large number and variety of firms in one place provides a broad and flexible labor market that is attractive to workers as well as firms (for more on Marshallian agglomeration externalities, see Henderson, 1994). Furthermore, people prefer to reside where a wide range of goods and services are available, that is, in central places (for more on Christaller's Central Place Theory, see Mulligan, 1984). Because people follow jobs and jobs follow people there is positive general equilibrium feedback between industrial and residential location through labor and product markets. In sum, these four forces: (1) lower transport costs to market, (2) economies of scale, (3) product differentiation, and (4) positive general equilibrium feedback, all appear to work against the development of remote and sparsely populated rural areas.

The role of declining transport costs in promoting the growth of cities at the expense of the countryside has been shown by Nerlove and Sadka (1991), Krugman (1991, 1993), Walz (1996), Calmette and Le Pottier (1995), among others. With a general equilibrium model in the von Thünen tradition, Nerlove and Sadka showed that as the cost of transporting agricultural goods falls relative to the cost of transporting manufactured goods, it becomes economically feasible to cultivate land farther and farther from the city. This encourages less labor use per acre, lowers agriculture’s terms of trade, reduces and disperses the rural population, and increases the proportion of the labor force working in town. Welfare in both the city and the countryside, however, rises unambiguously. Nonfarm business location is exogenous, however, in the von Thünen tradition. In this paper I show how a similar result obtains even when firm location is endogenous.

In Krugman’s first two-sector, two-region model, the transport cost for the ubiquitously produced agricultural goods were assumed to be zero. He obtained implications similar to Nerlove and Sadka’s about the concentration of population, employment, and industry in cities as transport costs for manufactured goods fall. With a two-region growth model, Walz (1996) also showed that investment in infrastructure that reduces transport costs between regions encourages concentration. Calmette and Le Pottier (1995) presented a variant of the Krugman model that explicitly considered agricultural transport costs. They also found that concentration is encouraged unless nonagricultural transport costs fall almost to zero, and they echoed the old suggestion that a way to reverse the decline of rural hinterlands is to tax the transport of rural products. The work of Calmette and Le Pottier (as well as Nerlove and Sadka) has shown
that relative delivery transport costs matter. Using taxes to counteract market forces, however, reduces overall welfare.

The ratio of primary (rural) to industrial (urban) delivery transport costs also rises when technological innovations specifically reduce industrial transport costs, while overall welfare increases. For example, electronic communications technologies reduce the costs of transporting certain services, which reduce average nonfarm product transport costs (Salomon, 1996; Capello and Nijkamp, 1996). Empirical surveys have found that telecommunication-intensive firms have been profitably locating in rural areas (Peitchinis, 1992; Salant and Marx, 1995). Also, telecommunications technologies may be associated with firm pricing behavior as well as location choice. Telemarkets and mail-order catalogs offer uniform delivered prices (same delivered price regardless of customer location) rather than spatially differentiated delivered prices.

In this paper I demonstrate theoretically how decreasing relative average industrial transport costs can favor rural development even in the presence of the four above-named forces favoring urban concentration. The general equilibrium approach I apply also shows how all firms can be sensitive to transport costs of unrelated products through wages. Higher urban wages compensate workers for higher rents and costs of imported items. The textbook wisdom is that transport costs are relevant to only two of three types of firms. Firms are classified as “materials-oriented” when input transport costs per unit output are relatively more significant, and “market-oriented” if transport to final consumers is relatively more costly (Mills and Hamilton 1994). “Production-cost-oriented” firms are more sensitive to wage bills and rents, which may vary across locations.

Solutions to partial equilibrium firm-location problems à la Weber suggest that the optimal location for transport-sensitive firms depends on their orientation and relative transport costs, which play no role in the location of footloose production-cost-oriented firms. This conventional partial equilibrium framework may be useful for analyzing the location problem of primary-processing firms (e.g., Parr, 1993); but not for analyzing why a firm specializing in electronically-transportable services oriented towards urban consumers would ever choose a rural location since such firms do not require rural products as inputs. Their only link to rural transport costs is through relative wages or rents.

To demonstrate how transport-cost reductions affect rural economic diversity and population, I present a rural–urban model characterized by (1) costly industrial and agricultural transport; (2) technological and pecuniary economies of scale; (3) product differentiation and uniform delivered pricing; in (4) general equilibrium with both firm and worker mobility.¹ I explain why and how this model is made computable, and present the biregional social accounting matrix.

¹In contrast, previous analyses take firm or worker locations as given and solve for an implicit profit or real-wage differential.

(SAM) to verify that the model satisfies spatial and market equilibrium. I then apply the model to test Krugman’s hypotheses by simulating the effects of symmetric transport cost reductions. Nerlove and Sadka’s findings about the effects of changing relative transport costs are also verified, but in the context of mobile firms as well as workers. Finally, I demonstrate the initially negative, but ultimately positive, relationship between reductions in industrial transport costs and rural development.

2. THE GENERAL EQUILIBRIUM MODEL

Consider an economy with two regions, called Urban and Rural. Superscripts on variables denote the region: \( r = U, R \). The Rural region has the larger proportion \( \phi \) of farm land \((0.5 < \phi \leq 1)\), whereas Urban has the proportion \((1-\phi)\). There are two types of households distinguished by occupation in each region: farm proprietors, and industrial workers. Farmers produce a homogeneous agricultural good \((Q_{A})\) and industrial workers produce varieties of manufactures \((Q_{Mi})\). Farmers are immobile (i.e., tied to their land), whereas workers are mobile across regions. But neither farmers nor workers are occupationally mobile. All manufacturing firms (and all worker households) are located in the Urban region in the benchmark scenario. In the simulations, firms choose locations where profits are higher, and workers migrate to locations where real wages are higher.

The technologies of production are modeled as simply as possible. Farmers produce one unit of output of the agricultural good per farmer. Each industrial firm, indexed by \((i = 1, \ldots, n)\), employs \( L_{i} \) workers to produce current output \((Q_{Mi})\) and reproduce fixed capital \((K)\):

\[
L_{i} = Q_{Mi} + K
\]

implying a production function: \( Q_{Mi} = L_{i} - K \). At local wage rates \((W)\), the total cost of industrial production is \( W(L_{i}) + K \). Note that average costs of production fall as quantity produced increases (increasing returns to scale) and that the marginal cost of production is the local wage rate.

The presence of increasing returns to scale in manufacturing implies an explicitly noncompetitive market structure. Marginal-cost pricing is incompatible with long-run equilibrium, since a price equal to marginal cost would cover average costs only at zero output. I follow the tradition from Lösch to Krugman in assuming monopolistic competition. Each firm produces a differentiated product (monopoly), and each consumer demands a positive quantity of every variety. Firms do not need to disperse across space to serve the same markets profitably, but they do incur delivery costs to serve consumers in other regions. In the Dixit–Stiglitz version used here, the degree of product differentiation is represented by the parametric elasticity of substitution \((\sigma)\) characterizing consumer preferences.

Each household consumes some agricultural product, $C_A$, and a bundle of manufactures, $C_M$, given income constraints and delivered prices, to maximize satisfaction according to a Cobb–Douglas utility function:

$$ U = C_M^\mu C_A^{1-\mu} $$

The manufactures $C_M$ are a constant-elasticity-of-substitution (CES) aggregate of varieties demanded ($D_{Mi}$):

$$ C_M = \left( \sum D_{Mi} \right)^{1/\rho} $$

where the CES exponent $\rho = 1-(1/\sigma)$.

Both farm and industrial goods are costly to transport across regions (but not within regions) at rates $\alpha$ and $t$, respectively. These parameters represent the amounts of own resources used up to provide transport, comparable to input–output or commodity-by-industry coefficients. The amount of product consumed is output net of transport costs for each unit shipped across regions:

$$ D_{Mi} = Q_{Mi} (1-t) $$
$$ D_A = Q_A (1-\alpha) $$

As a historical illustration, draft animals plus the feed they consumed were required per quantities of grain and livestock transported; equipment and labor were required per unit of manufactures shipped.

The delivered price exceeds the mill price by the amount of transport costs:

$$ D_{Mi} = P_{Mi} / (1-t) $$
$$ D_A = P_A / (1-\alpha) $$

where $P$ denotes mill price and $DP$ denotes delivered price (with location superscripts dropped for ease of presentation). Note, however, that for within-region deliveries, $DP = P$ for both types of goods.

Farmers face competitor’s prices (regardless of region) parametrically. To maximize profit, they produce the quantities at which the unit price received just covers marginal cost. Rural agriculture is the numeraire, establishing $P^R_A$ at 1.0, and $DP^R_A = 1/ (1-\alpha)$, according to Equation (5). Urban and Rural farm products are equally preferred (perfect substitutes), implying that both regional farm outputs are consumed in one region only as long as respective delivered

---

2The assumption of constant linear transport cost is made for simplicity, but any continuous and non-decreasing function of distance will provide qualitatively the same implications.

prices are also equal.\(^3\) Thus, mill and delivered prices of Urban farm produce (supplied to Urban consumers at zero transport costs) equal the delivered Rural price:

\[
P^U_P = D^U_P = D^R_P = 1 / (1 - \alpha)
\]

As long as there is excess Urban demand for agricultural products, the Urban region will import agriculture, and Urban farmers will earn higher nominal incomes than Rural farmers. It is shown below that agricultural transport costs protect Urban farmers and put pressure on the wages needed to survive in the Urban area; just as import tariffs protect domestic producers but hurt consumers.

In a fully-employed, budget-constrained, general equilibrium, the parameter \(\mu\) represents both the budget share spent on manufactures and the proportion of the total national population \(N\) in workforce. This full-employment constraint for the mobile workforce is

\[
\sum \sum \phi = \mu N
\]

The proportion of expenditure and employment related to farming (including farm transport) is \((1 - \mu)\). With each farmer producing one unit of farm output, nationwide agricultural output when farmers are fully employed is given by the sum of the Rural plus the Urban farm population

\[
Q = (1 - \mu)N = \phi(1 - \mu)N + (1 - \phi)(1 - \mu)N
\]

Farmers consume their desired share of agricultural output, then market the rest. Urban farm output available for workers is Urban farm production net of farmers’ own consumption

\[
(1 - \phi)(1 - \mu)N - (1 - \mu)(1 - \phi)(1 - \mu)N = \mu(1 - \phi)(1 - \mu)N
\]

Similarly, the available Rural agricultural output is:

\[
\phi(1 - \mu)N - (1 - \mu)\phi(1 - \mu)N = \mu \phi(1 - \mu)N
\]

The sum of regional net agricultural outputs gives the amount of farm product available for worker consumption, gross of product transport.

Workers spend the share \((1 - \mu)\) of their income \(W^U\mu N\) on agricultural goods. In general equilibrium, nominal worker wages must be sufficient to purchase the net farm product (plus pay for its transport). Under the benchmark assumption that all workers are concentrated in Urban, the agricultural market-clearing condition equates the sum of available output \((8) + (9)\) at Urban delivered prices \((5)\), to Urban-worker expenditure on agriculture:

\(^3\)When all consumers choose the mix of local and imported agricultural products that maximize satisfaction at the minimum expenditure, cross-hauling will not occur. In particular, Rural consumers would not simultaneously export and import, since this would waste expenditures to cover redundant transport costs.

After simplification, this condition shows how Urban-worker wage rates exceed unity as well as reflect agricultural transport costs

\( W^U = (1 - \phi \alpha) / (1 - \alpha) \)

In comparison, Rural farmers (who each produce one unit of the numeraire good) earn only a wage of unity; and Urban farmers earn the highest wage of \(1 / (1 - \alpha)\). Through the wages to workers, agricultural transport costs \(\alpha\) raise average, fixed, and variable costs of industrial production even though, in this model, agriculture is not an industrial input.

Analysis of the consumer expenditure minimization problem concerning manufactures consumption reveals that \(\sigma\) is the price elasticity of demand. Facing this elasticity of demand, industrial firms maximize profits by equating marginal revenue to marginal cost

\( DP[1 - (1 / \sigma)] = W \)

(11)

(10) \[
(1 / 1 - \alpha)(\mu(1 - \phi)(1 - \mu)N + (1 - \alpha)\mu\phi(1 - \mu)N] = (1 - \mu)W^U \mu N
\]

Thus, within each region, each industrial firm charges the same delivered price to local residents. The optimal delivered price would be lower the more substitutable products are (the larger is \(\rho\), and \(\sigma\)), and the higher are local wages.

Instead of assuming that regional markets are completely segmented, I assume that firms charge the same delivered price to each consumer regardless of where they reside. Old mail-order as well as modern telemarketing firms, for example, practice uniform delivered pricing. The uniform delivered price that would maximize profits over both markets is \(W / \rho + t / \rho(2 - t)\). This is higher than the delivered price, Equation (11), which maximizes profits in the local market alone. It can also be shown that the profit-maximizing mill prices for products destined for either market, assuming a spatially discriminatory pricing policy, is the same as the single price under a mill-pricing policy (given the particular assumptions of this model). In continuous space, the pricing policy determines market size, and thus is significant in firm location choice (Beckmann and Thisse, 1986). In this model, however, the market size is not a function of distance. Firm profits under either mill or discriminatory pricing are independent of the spatial distribution of workers and households. Profits depend on the spatial distribution of workers only under a uniform-delivered-pricing policy. Finally, any delivered price that covers transport costs may be assumed without qualitatively altering the simulation results.

Given Equation (10), which defines wages in terms of transport and other parameters, and the assumption of uniform delivered pricing at the optimal
discriminatory price on the local market, the uniform delivered price to either location of any variety of Urban manufactures is

\[ DP_{Mi}^{Ur} = (1 - \phi \alpha) / \rho (1 - \alpha) \]  

Net revenue on transported sales is lower than net revenue on local sales by the cost of transport. Accordingly, each firm’s mill price for transported sales is

\[ P_{Mi}^{UR} = (1 - t) W^U / \rho \]

The lower are \( t \) or \( \rho (\sigma) \), the higher the price is relative to marginal cost. The larger the markup, the higher the profits, the more firms are supported in the industry. Thus, the smaller is \( \sigma \), the larger the scale of the industry. More firms means more varieties and higher consumer utility (or welfare), and higher real wages (without affecting nominal wages or production costs paid by firms). Higher real wages induces worker in-migration and expands local employment. The size of the local industry increases. This kind of positive feedback and agglomeration is monotonically welfare-increasing.

By the same token that nominal Urban-worker wages must be high enough to cover agricultural transport costs, Rural wages must cover manufactures’ transport costs. Furthermore, unless real Rural wages \((RW_R)\) also are at least equal to real Urban wages \((RW_U)\), workers will not migrate to the Rural region. The worker migration-choice equation allows for ‘corner’ solutions:

\[ L_{r}^{UR} (RW_R - RW_U) \geq 0 \]

In conjunction with nonnegativity constraints on the numbers of workers in any location, this condition says workers choose to locate in the Rural region as long as real Rural wages are at least as high as real Urban wages.

Real wages in each region are nominal wages divided by the regional price index or cost of living \((COL_r)\). When all manufacturing is concentrated in the Urban region (and manufactures sell at uniform delivered prices), local price indices are the expenditure share-weighted sums of the delivered Urban manufactured-goods price and the local delivered agricultural price:

\[ COL_U = \mu (1 - \phi \alpha) / \rho (1 - \alpha) + (1 - \mu) / (1 - \alpha) \]

Similarly, the Rural price index (or cost of living) is

\[ COL_R = \mu (1 - \phi \alpha) / \rho (1 - \alpha) + (1 - \mu) \]

The Rural cost of living is strictly lower as long as agricultural products are not imported. The nominal Rural wage that would satisfy interregional real wage equality, given \( W_U \) by Equation (10), and the \( COL_r \) by Equations (14) and (15), is:

\[ W^R = \frac{(1 - \phi \alpha) \mu (1 - \phi \alpha) / \rho (1 - \alpha) + (1 - \mu)}{\mu (1 - \phi \alpha) / \rho + (1 - \mu)} \]

Because the Rural cost of living is lower than the Urban one, the nominal Rural wage is less than the nominal Urban wage even though real wages (and thus welfare) are equivalent. This is a point well-remembered by regional-development specialists.

If some manufacturing firms locate in the Rural region, there is no closed-form expression for nominal Rural wages satisfying real-wage equality. Price indices would have to reflect the delivered prices of both Rural and Urban varieties of manufactures. Also, when workers and firms join the indigenous farmers in the Rural region, less Rural farm output is available for export to the Urban region. This would be reflected in lower Urban wages (and welfare). In other words, wages, delivered prices, and price indices all depend on the spatial allocation of workers, which depends on wages, delivered prices, and price indices. There is no closed-form solution. The general case is a system of simultaneous equations defining a fixed-point problem. An explicit computable general equilibrium simulation model will be required to conduct comparative static analyses.

The optimal output level \( Q^U_M \) maximizes firm profit (total revenues over total costs). The simplest way to express total revenues while highlighting transport costs is at delivered prices. Total production costs are given by the wage bill. For example, the \( i \)th Urban manufacturing firm’s profits are the sum of revenues earned from Urban sales plus revenues earned from Rural sales less total costs:

\[
\text{Profit}^U_{Mi} = DP^U_{Mi} Q^U_{Mi} + DP^U_{Mi} (1-t) Q^{UR}_{Mi} - W^U (Q^U_{Mi} + K)
\]

where material balance is guaranteed by \( \Sigma_i Q^U_{Mi} = Q^U_{Mi} \).

Free entry of firms will drive excess profits to zero, so Equation (17) is the long-run equilibrium condition establishing the optimal size of firms \( (Q^U_{Mi}) \) in each region. Solving Equation (17) for \( Q^U_{Mi} \) highlights that per-firm activity levels in free-entry long-run equilibrium is a function of the population and income distribution, scale, and taste parameters:

\[
Q^U_{Mi} = \frac{K \rho}{(1 - \rho - t \gamma)}
\]

where \( \gamma = Q^{UR}_{Mi} / \Sigma_i Q^{UR}_{Mi} \) denotes the portion of an Urban firm’s product destined for the Rural market. The assumptions imply that each firm in the same region will be the same size, and that firm size is increasing in \( K, t, \) and \( \rho \) (or \( \sigma \)). Under the uniform-delivered-pricing assumption, firm size (not profitability) is positively related to transport costs and product homogeneity. Readers familiar with Krugman-style models will recall a simpler condition:

\[
Q = \frac{K \rho}{(1 - \rho)} = K(\sigma - 1).
\]

This simple condition follows from Krugman’s assumption of a mill-pricing policy, which, given the CES functions, renders profit independent of the spatial distribution of demand.

In contrast, under uniform delivered pricing, profits vary across locations explicitly according to \( \gamma \), the share of output destined for the Rural market. Urban-firm production costs are also positively related to agricultural transport.
costs through Urban-worker wages. Finally, since net revenues are a negative function of industrial transport costs, both types of transport costs affect profits by location. The more profitable is a region, the more firms it will have. On the other hand, the larger is the share of the national or farm population in the Rural region, the larger in size, the less profitable, and the fewer in optimal number are Urban firms. In sum, product homogeneity and higher transport costs mitigate against urban concentration.

Firm location choice is expressed by a complementary slackness condition: if profits in one location are at least as high as in the other location, the fixed cost can be incurred; otherwise it should be zero:

\[ K^U (\text{Profit}^U_{Mi} - \text{Profit}^R_{Mi}) \geq 0 \]

Assuming an initial concentration of manufacturing in Urban, reductions in delivery costs \((t)\) and increasing product differentiation \((\sigma, \rho \downarrow)\), which allows firms to raise delivered prices, \(DP^U_{Mi}\) will increase the Urban profit advantage and favor continued industrial concentration. Dispersion is favored by higher delivery costs due to transport costs \((t)\) rising or because a larger share of the population resides in Rural \((\phi \uparrow \text{ and/or } \mu \downarrow)\); or by agricultural transport-cost \((\alpha)\) pressure on Urban wages.

The number of industrial firms, and thus varieties \((n^r)\) that can exist in each region is limited by the regional labor force. Equation (18) expressed in terms of \(K\). Inverting the production function (Equation 1) gives labor \((L_{Mi})\) as a function of \(K\):

\[ L^U_{Mi} = K[\rho / (1 - \rho - t\gamma)] + 1 \]

In the benchmark case when all industry is concentrated in the Urban region, the Urban labor force is \(\mu N\). Given the optimal employment per firm by Equation (20), the equilibrium number of firms and thus varieties is

\[ n^U = \mu N / K[\rho / (1 - \rho - t\gamma)] + 1 \]

The benchmark case of Urban concentration is a corner solution for both the firm’s location choice problem and the consumer’s constrained expenditure-minimization problem. In general, consumers minimizing expenditure to obtain their satisfaction-maximizing bundles of goods equate the ratio of marginal utility between varieties of manufactures to the ratio of their delivered prices. Locally produced varieties are priced the same, so equal quantities of local varieties are demanded. Each Rural compared to Urban variety should be demanded in a mix determined by preferences, given relative prices:

\[ \frac{D^R_{M_i}}{D^U_{M_i}} = \frac{(DP^U_{M_i})^\sigma}{DP^R_{M_i}} \]

Although the variety subscripts \((M_i)\) are not shown for ease of exposition, it is important to recognize that this tradeoff is made by each consumer between each individual Rural variety and each individual Urban variety. The aggregate

consumption by a customer in region \( r \) of Rural varieties is \( n_R^r D^{Rr} \) and the aggregate consumption of Urban varieties is \( n_U^r D^{Ur} \). Condition (22) differs from a condition expressed in terms of regional aggregates as long as the ratio \( n_R/n_U^r \) differs from unity.

This optimal choice condition can be rearranged to express demand by region \( r \) consumers for a Rural variety \( (D_{Mi}^{Rr}) \), with delivered prices, Equation (11), expressed in terms of wages as follows:

\[
D^{Rr} = D^{Ur} \left( \frac{W^U}{W^R} \right)^{\sigma}
\]

This initializes latent demand for lower-priced Rural varieties of manufactures in a system of simultaneous equations defined with respect to Urban concentration. Given demand for Rural manufactures, solve simultaneously for local price indices and the Rural wage that would guarantee real wage equality. Given prices and wages, Rural firm profitability would also be defined. Relative profitability drives firm location choice. Workers migrate to capitalize on the regional employment opportunities given real wage equality across regions.

Equations (1) through (22) are the basis of a system of simultaneous equations representing the production and consumption behavior of farmers tied to land; the profit-maximizing location, pricing, sales, production, and employment behavior of firms; and the utility-maximizing location and consumption behavior of mobile-worker households. In place of the objective functions, the first-order conditions for the optima with respect to each choice variable are explicit in the system of equations. By adding complementary slackness conditions (Kuhn–Tucker), the variety mix in consumption, firm-location, and worker-location decision equations also explicitly allow for corner solutions. This system can be simulated to consider how changes in transport costs may affect the spatial allocation of industry and population.

**Social Accounting Matrix**

To make the theoretical general equilibrium model “computable,” first choose values for the exogenous variables: population, land allocation, transport costs, fixed costs, and behavioral parameters. For example, consider a national population of \( N = 100 \) and assume that 60 percent of the farms are in the Rural region (\( \phi = 0.60 \)). As a benchmark, assume symmetric transport cost rates equivalent to 20% of activity per unit shipped (\( \alpha = t = 0.20 \)). Let fixed costs equal half a unit (\( K = 0.50 \)). And assume that 60 percent of income is spent on manufactures (\( \mu = 0.60 \)); which are somewhat homogeneous (\( \sigma = -2 \)). These assumptions numerically initialize wages, prices, number of firms, and quantities of products, assuming also that all manufacturing is concentrated in the Urban region.

Due to the self-reinforcing tendency of the mobile-worker population to locate where manufacturing is, we must impose a spatial diversification constraint and relax one of the initial constraints (assumptions) to initialize a
spatially diversified benchmark equilibrium starting from the spatially concentrated benchmark. For this paper, a nonnegative industrial transport-cost rate is determined endogenously so that a specified minimum share of the workforce (and industry) optimally locates in the Rural region.

To verify that the spatially diversified model economy satisfies goods-market equilibrium, factor market equilibrium, and regional payment balance, the numerical solution of the model is displayed in the form of a biregional social accounting matrix (SAM). The SAM is a set of double-entry receipt–expenditure accounts for both types of firms, goods, factor markets, and households in a single tableau. It is an ideal tableau for initializing interregional computable general equilibrium models and verifying that Walras’ Law holds (e.g., Kilkenny, 1993).

It is useful to distinguish SAM accounts for (i) decision makers with distinct objectives, instruments, or constraints; (ii) markets for different items or at different prices; and (iii) balancing budgets for different types of nominal transactions. It is also useful to aggregate accounts so that the entire SAM can be displayed on one page. The dimensions of this general equilibrium model are already the minimum so the SAM has the same number of accounts (twelve). Figure 1 presents in one tableau the full SAM with both Urban and Rural industrial accounts, Urban and Rural farm-sector accounts, the four commodity markets, and both worker and farmer labor-supplying-goods-consuming households in each region. Within-region transactions are shown in the diagonal blocks, between-region transactions are in the off-diagonal blocks.

By convention, SAM column entries show expenditures while row entries show receipts for each account. The entry in the (Urban agricultural activity, Urban agricultural commodity market) cell is the mill value of local output destined for local markets. The (Urban farmer household, Urban agricultural activity) entry is what farmers earn from production, including farm-transport activity. The (Urban-industry activity, Rural manufactures commodity market) cell shows the mill value of manufactures sold by Urban industry in Rural markets. The (Rural agricultural activity, Urban agricultural commodity market) cell shows the mill value of agricultural goods sold from the Rural region to the Urban one. The (Rural-manufactures commodity market, Rural farmer household) cell shows rural farmer expenditure on both imported and locally-produced industrial goods at their respective delivered prices.

The values in Figure 1 are the solution values of the general equilibrium model (above) assuming that at least 5 percent of the workforce is in the Rural region. The twelve accounts all balance to essential zero \((1 \times 10^{-16})\). This verifies that costs of production inclusive of transport and fixed costs equals revenues from demand at delivered prices; supplies equal demands for labor as well as both goods; and income equals expenditure. Note also that Rural “export”

---

3Walras’ Law concerns \(n\) choices subject to income = expenditure constraints. Only \(n-1\) can be chosen independently, whereas the \(n\)th is determined residually to satisfy the budget constraint with equality. A system of choice equations is exactly determined if one equation, the “\(n\)th”, not explicitly included in the system, is satisfied \(ex\, post\).

<table>
<thead>
<tr>
<th>Activity Markets</th>
<th>Households</th>
<th>Activity Markets</th>
<th>Households</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>AG</td>
<td>MNF</td>
<td>AG</td>
<td>MNF</td>
</tr>
<tr>
<td>AG</td>
<td>22</td>
<td>49</td>
<td>9</td>
<td>26</td>
</tr>
<tr>
<td>MNF</td>
<td>22</td>
<td></td>
<td>13</td>
<td>39</td>
</tr>
<tr>
<td>FARMERS</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WORKERS</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>AG</td>
<td>13</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>MNF</td>
<td>3</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>FARMERS</td>
<td>13</td>
<td></td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>WORKERS</td>
<td>3</td>
<td></td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>COLUMN TOTALS</td>
<td>22</td>
<td>65</td>
<td>35</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>65</td>
<td>22</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>5</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>5</td>
</tr>
</tbody>
</table>

earnings equal “import” expenditures. This equality is not required explicitly, but implicitly by Walras’ Law. This ex-post regional balance of payments proves that this general equilibrium model is exactly determined.

3. SIMULATIONS

Given the spatially diversified benchmark, first I verify that concentration is favored by reductions in (symmetric) transport costs. This point has been demonstrated by Krugman (1991, 1993), Calmette and Le Pottier (1995), and Walz (1996), among others. Figure 2 shows the simulated positive relationship between Rural firm numbers and higher symmetric transport costs. At lower transport costs, there are more Urban firms and fewer Rural ones. At high transport costs relative to fixed costs, more Rural locations are sustainable. This mimics the historical trends in use of space. In horse-and-buggy days, small-scale industry located even in farm towns. Population was more evenly distributed among regions. As labor was shed from an increasingly efficient agricultural sector, and faster vehicles and routes appeared, firms and people increasingly concentrated in the larger towns. Positive feedback accelerated the depopulation of the hinterlands and the growth of cities.

![Figure 2: The “Krugman” Result: The Relative Number of Rural(Urban) Firms is Positively(Negatively) Related to Symmetric Transport Costs.](image)

The model used to generate Figure 2 was reformulated to mimic Krugman’s model. In particular, manufacturers charge the same mill price regardless of destination (different delivered prices), and consumers allocate expenditures over regional good aggregates rather than choosing individual items. Otherwise, the initial parameters are the same as noted above. A diversified benchmark is simulated, then the model is used to simulate the new optimal number of firms in each region as transport costs are reduced symmetrically.

In this model, workers change residential locations only if their real wage in the new location is at least as good as in the original location. Firms open in a new location only if, given the workforce in the region and the prevailing wages, they can at least cover average costs of production. In contrast, rather than solve an explicit general equilibrium model (as is done here), in his early papers Krugman drew his conclusions from comparative static analysis of the profit potential of an inframarginal firm which relocates to the smaller region while paying a wage that provides real wage equality. To do this analytically he invoked the traditional assumption of monopolistic competition that one may ignore the inframarginal firm’s effect on regional incomes, price indices, and so forth, so that one can analyze closed-form solutions. Nevertheless, we show that Krugman’s main conclusions are valid under his assumptions. These simulations also show that symmetric reductions in transport costs favor concentration.

I also verify the implications of falling agricultural transport costs. As Nerlove and Sadka (1991) argued, this promotes movement to the city. To mimic this result I had to use the “Krugman” version of the model. Firm location is exogenous in the von Thünen tradition, the basis of Nerlove and Sadka’s paper. This exogeneity is mimicked when consumer choice is expressed over regional varieties in terms of regional aggregates. The model is initialized with respect to a mix of Rural and Urban manufactures demanded by households in each region. Given strictly convex preferences over these aggregates, even a large change in regional relative prices implies a relatively small change in the mix of regional products in demand. Thus, it is not surprising that this “Krugman” version of the model is fairly insensitive to relative transport cost changes.

Now for the new story. I applied the general equilibrium model described in Equations (1) through (22) to simulate the relationship between transport costs and rural development. I measure rural development as the share ($\delta$) of the worker population that chooses to reside in the Rural location. Workers will only choose the Rural residence if firms locate there and can afford to pay nominal wages that provide real wage equality.

Figure 3 shows that the relationship is nonmonotonic, as hypothesized. The simulation results are that when rural (agricultural) transport costs are relatively cheap ($\alpha/t < 100$ percent), decreasing industrial transport costs favor Urban concentration. When agricultural transport is relatively expensive ($\alpha/t > 100$ percent), decreasing industrial transport costs favors rural development.
Note that 44 percent (50 percent of the total population, given the Rural farm population) is the Rural region’s largest share of the industrial workforce. This fifty-fifty population split is achieved only at the highest relative costs of industrial transport. It reflects a constraint that the Rural region never imports agriculture, to reflect the definition of Rural. The rural region would import agriculture if more than half of the population and industry were Rural. But then, the Rural region could not be considered sparsely populated and dependent on farming.

Consider what happens as industrial-goods transport costs fall relative to agricultural transport costs ($\alpha/t$ rises). As long as agricultural good transport remains relatively cheap ($\alpha/t < 100$), the relationship is negative (points 1–4). This simulates the historical trend. Remnants of this history still persist today. There are factories in rural towns that have been abandoned for decades. If you look closely you can still read signs like “Acme Hosiery Company” through peeling paint on the highest walls. At high overall transport costs, rural locations used to be profitable for nonfarm industry. Those were also the days when industrial transport costs were relatively higher than agricultural transport costs. For example, shipping cut beef to urban customers was prohibitively expensive, compared to moving live cattle to the market. The shift of the

![Figure 3: The Non-Monotonic Relationship Between Relative Transport Costs ($\alpha/t$) and the Rural Share of the National Workforce.](image)

meat-packing industry from market-oriented (city locations) to materials-oriented (rural locations) as industrial transport costs fell is a textbook case.

In contrast, I simulate the locational response of nonfarm industry, industry that does not rely on agricultural intermediate goods, to relative reductions in nonfarm transport costs. Nonfarm industry could achieve economies of scale by concentrating in cities, without having to pay much of an urban wage premium, thanks to the same rail, auto, and air transport innovations that helped the meat-packing industry change orientation. As population and transport costs fell, nonfarm industry abandoned rural towns. Positive general equilibrium feedback accelerated the process.

But at a point \( \alpha/t > 100\% \), further reductions in nonfarm product transport costs reverse the negative relationship between declining relative transport costs and rural development. At relatively high agricultural transport costs, the gap between urban and rural wage rates is larger. Cheaper rural labor attracts firms. A new mail-order ladies-fashion retailer decides to occupy the old hosiery factory. Electronic communications media facilitate coordinating supplies with demands, shipping by air reduces the time premium, and there is a relatively cheaper, but just as productive, rural labor force enjoying the lower real cost of living there.

The previous work by Krugman, Nerlove and Sadka, Calmette and Le Pottier suggested that rural development could only be achieved at lower overall welfare. Higher relative agricultural or higher symmetric transport costs do appear necessary for rural locations to be competitive. Raising \( \alpha/t \) by increasing \( \alpha \), however, is not a good way to do it. Satisfaction, defined by the utility function (3), arises from consumption. The more resources required for transport, the less there is for consumption, the lower is household welfare. A change in the spatial distribution of workers is unlikely to increase welfare if it requires diverting resources from consumption to transport.

My finding is much more optimistic, as illustrated in Figure 4. There are overall positive welfare gains as relative rural transport costs increase. Of course, this is because the rise in relative transport costs is due to reductions in industrial transport costs. Lower transport costs mean more output is available for consumption. Real farmer wages are unaffected by reductions in industrial transport costs (assuming uniform delivered pricing). Nominal Urban worker wages are also constant with respect to industrial transport costs. Nominal Rural worker wages fall as delivered prices fall with transport costs, to satisfy real wage equality. But utility rises for all four types of households because there are more product varieties and consumable production net of transport.

4. CONCLUSIONS

This analysis has identified a nonlinear relationship between transport costs and rural development. When industrial-product transport is relatively costly, reductions favor concentration. At relatively low industrial transport cost rates, further reductions favor the industrial development of a natural-resource-
based economy. Rural locations can be attractive to firms when the combined costs of supporting a rural workforce and transporting output is lower than the cost of supporting an urban workforce. Surely this is no surprise to firms that have already successfully chosen nonmetropolitan locations. This research simply provides a theoretical explanation of an increasingly significant trend.

The general equilibrium approach adds to our understanding of the classic firm location problem. I show how the remoteness of rural residents from urban manufacturers, and of urban residents from rural food producers, is reflected in real wages. Transport costs are reflected in the nominal wages required to retain interregionally mobile labor. Thus, all firms are “transport cost sensitive,” even if they do not require any transportable inputs. Transport innovations can alter the “orientation” as well as optimal location of any firm. Also, this computable general equilibrium model has many features familiar to input–output modelers. It is easily replicated, altered, enriched, and can be used to simulate other abstractions.

The explicit general equilibrium modelling exercise also shows that Kaldor (1935) and others (e.g., Archibald, Eaton, and Lipsey, 1986) were justified in questioning the appropriateness of monopolistic competition assumptions for spatial models. In particular, they criticized the assumption that new firms have negligible impacts on the market facing incumbent firms. In this model, no firms are inframarginal, in contrast with models in the “Krugman” tradition. Although

FIGURE 4: Welfare Rises as Industrial Transport Costs Fall.
this means there is no closed-form analytical version of this model, it also means that the model is sensitive to any change in the spatial distribution of employment. This sensitivity is particularly critical when production is characterized by increasing returns to scale. Future work should also characterize the markets in the locations in which new firms open as oligopolistic with strategically interdependent firms.

Given the (pessimistic) implications of Krugman-style models for rural development, this paper also fills a gap in the literature. There has been a dearth of testable hypotheses concerning rural development. This paper suggests a few. First, it theoretically rationalizes the recent turnaround in rural manufacturing. Second, it clarifies the role of transport costs. Surveys of businesses, for example, have found conflicting reports about the role of transport costs in business relocation to rural areas. This investigation suggests that such confusion may be due to confounding the behavior of firms that have high relative transport costs with firms that have low ones. The hypothesis test entails estimating a random effects model in which firms of the first type (either because of location or orientation) may respond to transport-cost reductions by concentrating in cities, where firms of the second type respond by expanding to rural areas.

Another testable null hypothesis is that product differentiation has nothing to do with rural development. As Anderson, de Palma, and Thisse (1992) explain, and Equation (19) reflects, decreasing product homogeneity (just like decreasing transport costs) allows for higher profits, and more numerous firms by location. Product differentiation allows firms to concentrate in space. It may also mean, however, that rural firms producing relatively unique products can afford to charge prices that cover their transport costs. Preferences might be defined over products distinguished by place of origin, rather than over symmetric varieties. Indeed, as the labels on bottles from France remind us, rural products distinguished by their location of production can command premium prices and might support rural communities. What types of U.S. firms producing what American products might these be?

Future work that changes and expands upon the current set of assumptions will also be interesting. Rural areas could be modeled as peripheral to urban centers. In that case, all products are processed before consumption, so that rural households pay both to transport output to processors and then back again for consumption. Land could be introduced as a separate factor of production. In the current model, farm proprietors are the fixed factor of production, so urban farm proprietors claim the rents. Since land rents do not necessarily equate in real terms between regions, land rents provide an even more potent link between transport-cost innovations, profitability by location, and worker incentives to migrate. The basic general equilibrium model presented here is a good point of departure.

Finally, a policy implication from this analysis is that rural development can be encouraged by transport cost reductions. No previous analysis has identified a positive relationship between improvements in communications, in
the broadest sense, and industrial population in a natural-resource region. An abstract analysis such as this cannot rank the welfare effects of transport cost reductions relative to all possible rural development strategies. But it explains that industrial transport cost reductions, such as those made possible by electronic communications infrastructure, can enhance the attractiveness of rural locations to traditionally market-oriented firms.

REFERENCES


