United States
Department of
Agriculture

Economic
Research
Service

Resources and Technology Division

SEPT, 1987

Land Use in Economic Theory

Principles and Prospects

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LAND USE IN ECONOMIC THEORY: PRINCIPLES AND PROSPECTS. By Douglas H. Brooks, Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. ERS Staff Report No. AGE870806.

ABSTRACT

Profit-maximizing behavior determines the rents that will be bid for a piece of land in an agricultural or urban context, and competition among potential users determines the resulting use of that land. Techniques recently developed in urban land use theory are shown to apply to agricultural land use as well, and can be particularly useful in studying land use change at the urban fringe. This report highlights the economic principles governing land use and ways in which they can be applied in current and future land use research.

ACKNOWLEDGMENTS

Thanks to Ralph Heimlich, James Horsfield, Paul Wilson, W.D. Anderson, and Robert Boxley for their review and comments, and Martin Beckmann for the inspiration.

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September 1987

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SUMMARY

Agricultural and urban land use theories can be combined in a general study of land use patterns and dynamics. The traditional, agricultural approach has been to see which industry (crop) will bid the most for land with particular characteristics such as fertility and distance from market. The urban economics approach has been from the firm's viewpoint, selecting among site characteristics or locations. Both approaches view transport costs for overcoming distance as a key determinant of land use patterns. This common thread of analysis allows these symmetric approaches to be reconciled and combined in a general theory of land use and land use dynamics.

Traditional land use theory focuses on trade-offs between transportation costs to market (distance) and rents land can command. Competition among potential users of the land as a productive input ensures that it will be occupied by the use yielding greatest net returns. The pattern of rents bid and the resulting pattern of land uses can be affected by variations in fertility, physical characteristics of the land, population, income, preferences, and technology.

Location theory examines the location decisions of firms and industries and has laid the groundwork for modern urban economics. Economies of agglomeration draw some economic activities together, creating cities and concentrated markets, while congestion costs and the need for land as a productive input in other activities limit city size. Transportation costs balance these opposing forces in an equilibrium land use pattern, with competition again determining land rents.

The new urban economics combines land use decision processes with dynamic optimization techniques and produces an array of new discrete and continuous choice models, one of which is outlined here. Profit- and utility-maximizing behavior determines the maximum rents competing uses will bid for land with particular characteristics. Competition among the bids determines the use of the land. By examining the resulting uses of land with observed characteristics, it is possible to estimate the effects on land use patterns of changes in the land's and economic agents' characteristics.

Changes in relative prices, income, preferences, technology, comparative advantage, and adjustment costs influence land use dynamics. A study of land use dynamics must account for these factors in a multidimensional, international framework, and can best be guided by established economic principles of land use theory.

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INTRODUCTION

Land has occupied a unique place in economic theory as an essential factor of production, fixed in quantity and location. Frictions of distance help explain the existence and growth of urban areas and interregional and international trade patterns. Because of the costs of overcoming distance, constant returns to scale in production can be consistent with optimal plant scale, and increasing returns to scale can be consistent with competitive equilibrium. Spatial differences in fertility and climate can account for agricultural variations and the ability of agriculture to compete with other land uses.

Actual land use patterns result from the uneven distribution of natural resources, transportation routes, climate, and historical settlement patterns. Changes in land use patterns may result from changes in consumer preferences, income, technology, and international comparative advantage. Past and present public policies also help determine land use patterns and dynamics. Economies of agglomeration draw some activities together, while resource variations and the demand for land as an input encourage spatial dispersion. Transportation costs balance these two opposing forces. A better understanding of the economic principles guiding land use decisions and the assumptions made in theoretical presentations of those principles can better our understanding of observed land use patterns and dynamics, guide current research efforts, and show areas for further research.

This report presents the basic economic principles of land use theory and illustrates important similarities and differences between traditional location theory, modern urban economics, and trade theory. This report also indicates areas for research efforts, particularly in the Economic Research Service's Dynamics of Land Use project and simultaneous equations modeling of major land use patterns.

TRADITIONAL LAND USE THEORY

Modern economic theory usually traces its roots to Adam Smith. Land use theory can be traced to Smith's recognition that rent varies with fertility and location, or traced back earlier to Sir James Steuart's rings of agricultural activities surrounding a city serving as center of demand and source of transportation infrastructure (5).[1] However, it was David

[1] Underscored numbers in parentheses refer to literature cited in the References section.

Ricardo's treatment of agricultural rent and Johann Heinrich von Thünen's modeling of the spatial organization of agricultural activities that laid a solid foundation for later land use theory (27, 30).

Ricardo and von Thünen: The Foundations and Rent Gradients

Ricardo noted that although transport cost advantages of proximity to a market will accrue to landlords, fertility differentials are the primary source of agricultural rents. Competition among farmers in the form of rents bid for land ensures that the full advantage of more productive land goes to the landlord through the rent received.

Von Thünen's early theory of location differential rent, based on transportation savings and competition among land uses, was a more complete economic analysis set in mathematical form. Written in his native German, his work was not immediately appreciated by English-speaking economists but came to be the basis for later geography and location theory. Samuelson (29) has recently revived interest in and acclamation for von Thünen's pathbreaking efforts, crediting him with creating marginalism and managerial economics while developing one of the first general equilibrium models in terms of realistic econometric parameters. Samuelson hailed von Thünen as "one of the great microeconomists of all time." Von Thünen analyzed a simple situation concerning land use, based on the following image (4):

> Consider a very large town in the center of a fertile plain which does not contain any navigable rivers or canals. The soil of the plain is assumed to be of uniform fertility which allows cultivation everywhere. At a great distance the plain ends in an uncultivated wilderness, by which this state is absolutely cut off from the rest of the world.
>
> This plain is assumed to contain no other cities but the central town and in this all manufacturing products must be produced; the city depends entirely on the surrounding country for its supply of agricultural products. All mines and mineral deposits are assumed to be located right next to the central town.
>
> The question now is: How under these circumstances will agriculture be developed and how will the distance from the city affect agricultural methods when these are chosen in the optimal manner?

These assumptions about an isolated state with a fixed demand structure and transportation costs as a function of distance, together with a technology of fixed coefficients, allow a clear analysis of how land can be efficiently allocated by competition among alternative uses. Much of the later work in land use theory has involved relaxing these assumptions.

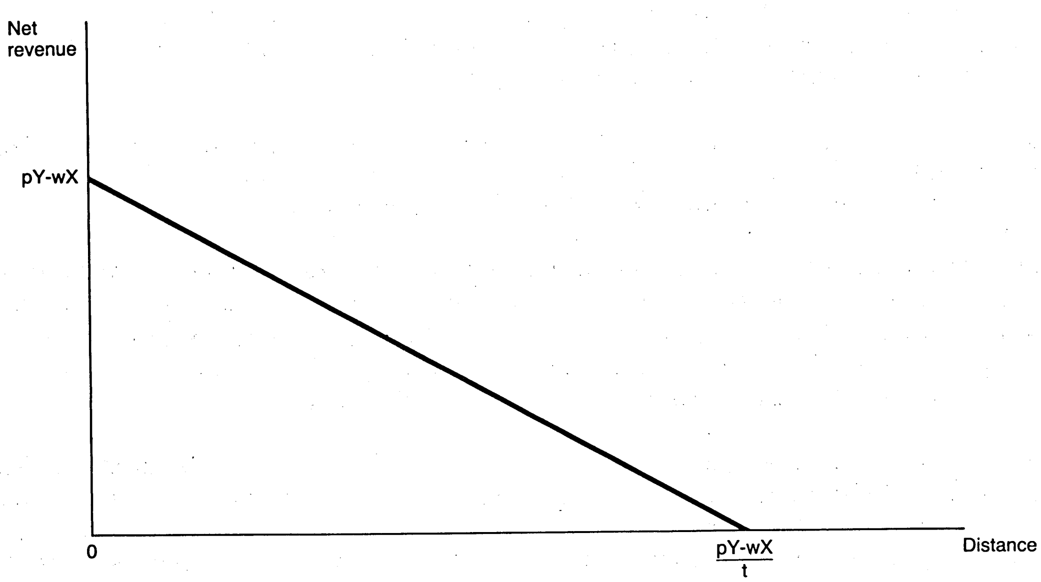
In von Thünen's model, each crop (land use) can bid a rent per unit of land at each location (distance from market), equal to the value of the product minus production costs and transport costs to the market. The maximum rent offered for any location by producers of a particular crop depends solely on distance from the market (through transport costs) when nonland production costs are assumed everywhere equal for each crop. Competition among farmers assures that the actual rent offered will be the maximum. Potential net revenue (bid rent) for any product decreases with distance from the city at a rate per unit distance equal to the transportation cost of an acre's product.

In mathematical form, let R(d) be the net revenue per unit of land at radial distance d from the market, or the bid rent for that land. Let Y be the yield and X a vector of inputs for production per unit of land with p the output price and w the vector of input prices. The variable t measures the transportation cost (assumed constant) of moving a unit of land's output one unit of distance. Then in simplest form, $R(d) = pY - wX - td$. The bid rent (net revenue) curve for this crop appears in figure 1. Note that an increase in the market price (p), increase in productivity (Y), decrease in input price (w), or decrease in unit transport cost (t) could extend the maximum distance.

Differences in market prices, production technologies, and transportation costs (due to size, weight, and deterioration variations) yield different bid rent functions for each crop. The crop offering the highest rent at a location will outbid the others, and the land will be allocated to that use. Variations in transportation costs across crops and in net revenue for the product at the market mean that different crops dominate at different distances from the city (fig. 2). For example, with crops indexed by their net revenues at the market, 0, crop A will be produced closest to the market, crop B next, and crop D farthest out. The upper contour of bid rent functions forms the rent gradient for land in the State. Crop C will not be produced even though its market price is higher than crop D's and its unit transport cost is lower than B's since other uses outbid that activity at all economically feasible locations. We then view the resulting spatial arrangement from above. The appropriate market price for each product is determined simultaneously (or iteratively) so that the equilibrium quantity of land (to equate supply with demand of the product) is established and so the supply as well as spatial orientation of any agricultural industry depends not only on its own price but on prices for all others as well.[2]

Figure 1

Bid rent function



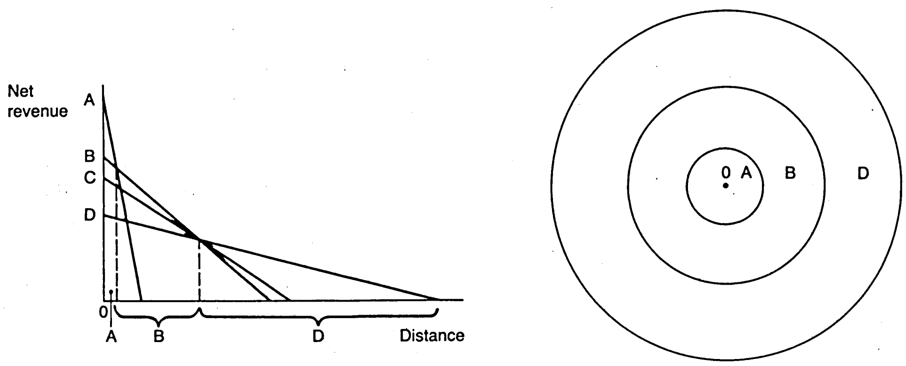
2 Von Thünen further assumed that transportation was by horse-drawn vehicles that also carried the horses' feed, placing an additional limit on the city's supply area and size.

Rent per acre decreases with distance from market at a constant rate within each resulting concentric ring of agricultural production. Rent per acre decreases from ring to ring until production reaches its limit where the combination of production and transport costs exhausts market value for all crops and the bid rent is zero. This explains the observed decrease in rent with distance from market and agricultural specialization in areas of uniform fertility and climate.

Dunn showed that complementarity in agriculture at the individual firm level depends on the full use of the farmer's time and equipment (8). Complementarity can result in the cultivation of a combination of crops in each ring and the same crop appearing in several successive rings. Relaxing the uniformity and centralized demand assumptions and introducing topographical features and transportation systems allows the basic principles to explain a large range of observed land use patterns. For example, a radial road system could easily convert the concentric circles in figure 2 to the star pattern in figure 3. Tord Palander has analyzed the effects of these spatial isocurves in greater detail (26).

Figure 2

Spatial pattern determined by bid rent functions

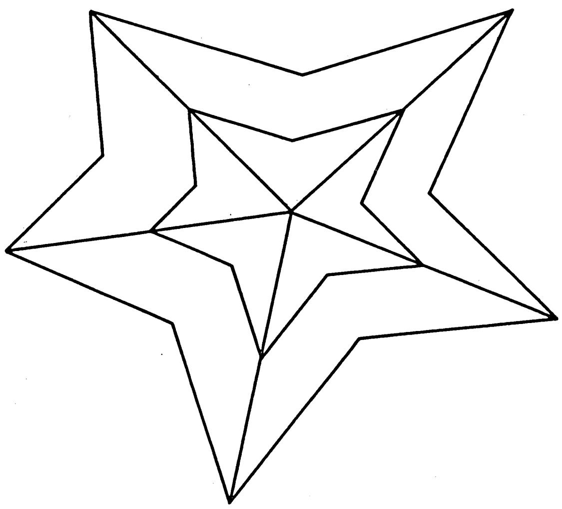


Competition among land uses

Aerial view of resulting pattern

Figure 3

Spatial pattern with radial transportation system



Weber and the Firm's Approach

In the von Thünen framework, a farmer any distance from the city is guided by the goal of profit maximization to produce the product or combination of products yielding greatest net revenue (net of nonland input and transportation costs) at that distance. Thus, the location serves to choose the optimal activity. An alternative approach to the location of economic activities is from the viewpoint of an activity choosing among locations. While von Thünen sought to determine location for all producers of a particular product (an agricultural industry), Alfred Weber investigated where a particular manufacturing firm or plant should locate amid given conditions (32). While von Thünen dealt in the homogeneous space most amenable to more challenging theoretical issues, Weber tackled the more practical questions dealing with heterogeneous space.

Considering the fixed locations of many natural resources and markets, Weber noted that transportation costs for inputs and outputs affect manufacturing activities, and so they may be either input- or market-oriented. Activities whose transportation costs of labor and other inputs exceed those of the products are drawn toward resource locations. This can help to explain zones of mixed manufacturing and residences, as well as mining towns. Activities whose final product is less transportable (heavier, bulkier, more fragile, or more perishable) than the inputs are pulled toward their markets, including toward transportation terminals for products exported from the area. Production activities not tied to a raw material or consumption location may be transport-oriented.

Transport, resource, and labor cost differentials interact to determine the broad regional distribution of industry. Within a region, agglomeration economies and diseconomies concentrate or disperse industries. Given the assumption of a fixed-coefficient technology that eliminates the influences of firm-level scale economies and input substitution, the location with the lowest total costs for assembling enough raw materials to produce and market a unit of output is the optimum. Over time, technical change tends to reduce the weight or amount of inputs while increasing the weight or bulk of outputs. This change reduces the transportation costs of inputs relative to outputs, reduces the attraction of resource locations, and increases the attraction of urban areas. However, changes in transportation technology over time generally reduce transport costs, which may partially offset this effect.

Agglomeration effects can operate at three levels: (1) scale economies in a firm, dependent on the level of production at one location (plant); (2) localization economies for all firms in an industry at a location (urban area), dependent on production or employment levels in each firm and the number of firms; and (3) urbanization economies for firms in different industries in an urban area, dependent on general levels of economic activity (production, employment, and income). Each of these is a reason for the clustering of population. In modeling these agglomeration effects, the production function is usually specified as including (1) firm labor and capital, (2) industry employment or number of firms in addition to firm labor and capital, and (3) urban area employment in addition to firm labor and capital. Then the market size and demand level become endogenous in the system. Land use influences travel demand, production, employment levels, and income, all of which affect the transportation system and product demand patterns, which in turn determine the changing pattern of land uses.

Increasing returns to scale are one explanation for the existence of urban areas, with diseconomies in production and disamenities in consumption (such as congestion, pollution, and crime) limiting city size. Urban activities are not spaceless, as treated in the von Thünen model, but are allocated to land according to the same principles as for agriculture. Alfred Marshall stated "in the urban as in the agricultural case, potential users of land make bids for various sites based on their respective location advantages, and the highest bidder captures the land in each case." According to Marshall, the site size is important because "industries are willing to pay a high value for additional land in order to avoid the inconveniences and expense of crowding their work onto a narrow site ... if land is cheap he will take much of it; if it is dear he will take less and build high" (20).

The static theories of land use reflect the differences in the relative land and labor (or other resource) intensities between agricultural and manufacturing or service activities. Agricultural land use theory emphasizes the complete immobility of land and relative immobility of labor, and determines profitability (rent) for the landowner by examining product transportation. Urban land use theory emphasizes an existing agglomeration of population or production and then examines the influences of consumers' and workers' transportation costs (including time and (dis)utility). Urban land use theory examines how agglomeration economies influence profitability of different activities in different locations. Bid rent functions then determine residential sites, with potential residents maximizing (indirect) utility rather than profit; land is therefore a consumption good.

Agricultural and Urban Land Use

While based on the same principles, rural and urban land use theories were usually developed separately because of differing physical and economic characteristics. Rural, or agricultural, land use theory considers land an essential input for production, with the physical characteristics of the land often determining the land use. Rural economic activities account for most land area. These activities locate in rural areas due to relatively high land-capital and land-labor ratios. Urban economic activities tend to use less land but generate higher output (and land) value. Urban economic activities generally have lower land-capital and land-labor ratios, but emphasize location due to economies of agglomeration.

For agricultural and urban approaches to land use theory, competition among bidders determines land use, economic frictions implied by physical space limit competition, and principles of monopolistic competition can connect von Thünen's industry-level analysis to Weber's firm-level study. Chamberlin's classic work on monopolistic competition treats spatial location as one form of product differentiation (7). Lösch examined a simple static model of a homogeneous-space economy with free entry and determined a longrun equilibrium pattern of hexagonal market areas, with each firm having a degree of monopoly power in its own market area (19). This pattern completely covers any area while minimizing the transport costs of supplying a given demand.

A general equilibrium system that evolves over time can be analyzed once it is recognized that the theoretical land and other resource use patterns in agriculture can be functions of the size and spatial organization of urban populations and activities. By treating transportation as an input in the transformation function and acknowledging the importance of existing resource endowments, Walter Isard synthesized the von Thünen, Weber, and Lösch frameworks. This synthesis combined modern production theory with location theory to extend urban-type externalities to the agricultural sector. Transport inputs to production (and marketing) measure factor services required "to overcome resistance encountered in movement through space where friction is present. In a space-economy, we obviously wish to minimize these, ceteris paribus" (16, p.79).

Topography, transportation systems, and congestion can make effective economic distance different from mileage. Neighboring uses or other activities in the metropolitan area may affect the potential rent of land at any effective distance. Thus, externalities play an important role in land use theory, particularly in urban activities. Changes in demand or supply lead to an evolving structure in the general equilibrium system, with technological advances, transportation costs, and the mobility or pace of depreciation in capital stock influencing the rate of structural change. Changes in demand or supply of land may also result from changes in environmental features such as soil erosion, climatic changes, silt accumulation, or catastrophes such as floods and fire. Fales and Moses present one of the rare empirical studies that avoids the fixed investment effects and analyzes urban land use in the context of theoretical principles (10). Fales and Moses combined von Thünen and Weberian analyses to explain the distribution of residential and industrial land use in Chicago following the great fire of 1871.

While most earlier writers focused on the fixed locational aspect of land use, William Alonso combined location and quantity in land use decisions and extended the use of bid rent functions from agricultural to urban land use theory (1). Equilibrium in the land market involves one price (that of land) but two aspects (lot size and distance). Then "every user of land, whether a resident, an urban firm, or a farmer, determines his location by the point of tangency of the lowest of his bid price curves to come in contact with the price structure," and "the market will be in equilibrium when (1) no user of land can increase his profits or satisfaction by moving to some other location or by buying more or less land and (2) no landlord can increase his revenue by changing the price of his land." (1, pp.76-77). Site and quantity decisions must be based on substituting land for transportation costs and other inputs. Hedonic pricing best separates the relative values of different aspects of land (distance from market, fertility, soil type, slope, and others). Hedonic pricing, originally formulated in agricultural economics, was developed primarily in urban economics where it is commonly applied to the housing market.

RECENT TRENDS IN LAND USE THEORY

Since Beckmann's (2) and Alonso's (1) work, the new urban economics has rapidly developed, making use of optimal control theory to examine and compare equilibrium and optimal patterns of land use and economic activities (14, 15, 23, 24, 25). The new urban economics has focused primarily on residential land (which accounts for most privately developed land in American cities) but applied microeconomic theory to a wide range of urban topics (pollution control, zoning, suburbanization, discrimination, local government finances, and community development), using sophisticated mathematics to ground the resulting economic relations on individual behavior.

This new urban economics endogenizes transportation systems' capacities and costs, particularly congestion costs. It is assumed that relative prices determine and reflect rational behavior, and that institutional structures are more determined by than determining of economic behavior. Rent gradients continue to absorb differences in utility or profitability, determine the location of industries and residences, and determine the intensity of land use in each activity. Making full transportation costs (including congestion and pollution) endogenous in the equilibrium analysis focuses on information inherent in prices, with less explicit emphasis on distance than in more traditional land use theory.

Two opposing forces influence the amount of land devoted to roads. In a monocentric city, the number of commuters increases nearer to the city center, thereby increasing travel time through congestion and suggesting the amount of land allocated to transportation should be increased. However, the opportunity cost of land also rises nearer to the central business district, increasing the marginal costs of investing in roads. Improved transportation lowers the effective distance to farther sites, and possibly expands the residential area, thereby **raising** the number of commuters. Policymakers must weigh the rising marginal costs of investment and central city pollution against the rising marginal benefits of additional travelers and potential relief from congestion.

Using (assumed) efficient prices to transcend the spatial aspects of traditional location theory has led to new approaches in modeling and estimating determinants of land use. Techniques for studying transportation modal choice and residential location, which base decisions firmly on individual maximization behavior, have been extended to industrial location. With production related to location decisions, the location question can be approached from von Thünen's view (which use will bid the most for a given piece of land) or Weber's view (which site will yield greatest profit for a given firm). Starting with a form for the profit function or bid rent function, the maximization process leads to the multinomial logit model, which allows estimation of parameters affecting land use and production decisions. So far, however, empirical applications of these methods have not explicitly considered distance or transportation costs. Brooks reviews these methods and derives an alternate technique of evaluating policies for influencing industrial location choices among alternate urban areas, including localization effects and entrepreneurs' residential preferences (6).

When more than one urban area is considered, the models and techniques become more complicated, but the principles affecting land use remain the same. Variations in the effect of localization economies, urbanization economies, and resource endowments on economic activities lead cities to specialize in the production of different traded goods; and a hierarchy of cities develops. Zipf (33) and Beckmann (3) documented the relation between a city's rank in the hierarchy and its size. Henderson showed how city size and growth in a system of cities can be determined from the investment behavior of capital owners, migration decisions of laborers, entrepreneurial actions of land developers, and policies of city governments (15).

A Discrete Choice Model of Land Uses

The rapid development of the new urban economics helps put land use theory for the urban and agricultural sectors more firmly in its microeconomic foundations. Where most previous empirical studies of land use patterns estimated linear equations postulated *ad hoc*, it should now be possible to derive and estimate economic relations more firmly based on individual maximization behavior.

In the notation of Lee's (17) work on intraurban employment location, let $Y=f(L,X;Z)$ be a firm's production function where: Y is output, L is lot size, X is a vector of other inputs including labor, and Z a vector of site characteristics or local public goods. If some input is limited in quantity (such as entrepreneurship), there will be diminishing marginal productivity for other inputs in production. Therefore, a restricted profit function of input prices, output prices, and site characteristics can be specified as producers respond to input price and site characteristic differentials in choosing optimal input combinations.

The firm's profit equation can be written as $\pi = pf(L,X;Z)-RL-wX$, where: π is profit, R a measure of land rent per acre, and w a vector of other input prices. Profit maximization requires that the first-order conditions $\partial\pi/\partial L = R/p$ and $\partial\pi/\partial X = w/p$ be satisfied, yielding the optimal levels L^* and X^*. Then the profit function $\pi^* = pf(L^*,X^*;Z)-RL^*-wX^* = \pi^*(p,R,w;Z)$ can be normalized using p as numeraire to form the normalized profit function $\pi^* = g(R,w;Z)$.

In locational equilibrium, profit will be constant across firms for a given Z and no firm has an incentive to relocate so a bid rent function can be derived (suppressing the constant π^*), $R(Z)=h(w;Z)$, where: w is now a vector of normalized prices and $R(\cdot)$ is increasing in Z.

Use of the bid rent function allows analysis in terms of indifference curves defined in urban space (bid rent curves). This expands on the concept of an indirect utility function leading to indifference curves in commodity space introduced into urban land use theory by Solow (30). Bid rent curves have the additional advantage of being expressed in real terms, so they are comparable across economic agents.

Assuming all firms in a particular land use category have the same bid rent functional form, for a site with characteristics $(w;Z)$, the n^{th} firm of type (land use category) t will have the stochastic bid rent $R_{tn}=h_{tn}(w;Z)+e_{tn}$, where: e_{tn} is a random disturbance term reflecting unaccounted variations of firm-type t characteristics. The maximum rent bid by any firm from land use type t for a site with input prices w and characteristics vector Z is, therefore, $R_t^{max}=\max(R_{tn})=h_t(w;Z)+e_t$ where: $e_t=\max(e_{tn})$, that is, e_t for the highest bidding firm in the highest bidding technology in land use category t. Note that a given site is occupied by a firm with the highest bid. Therefore, the probability of observing a particular land use at that site depends on the maximum bid by firms from that land use category. For residential use, the consumer's utility replaces profit as the maximization objective, but the bid rent similarly follows through and competes with industrial bids.

Assuming the e_t are independently and identically distributed according to the Weibull distribution (for example, the maximum values of independently and identically distributed normal, log normal, or logistic variables are distributed Weibull), the specification of a multinomial logit model (21, 22) follows.[3] The probability that a site with characteristics (w;Z) will be occupied by land use category t is:

$$\text{Prob}(t|w;Z) = [\exp(h_t(w;Z))]/[\sum \exp(h_s(w;Z))], \; s \neq t.$$

With a specified functional form for $h_t(\cdot)$, coefficients can then be estimated (relative to a base category). The estimated coefficients will indicate which prices or site characteristics have the strongest effects on rents bid by different economic activities and will indicate how changes in these variables may influence changes in the observed land use pattern. This form of the theory is capable of testing a wide variety of propositions with appropriate data. Transportation systems, proximity to markets, employment and income levels, foreign trade, and agglomeration potentials may have important effects on current land use patterns and probable changes, and should be included as exogenous variables in the bid rent functions. A related research project would involve examining the changes in land use patterns in areas with rapid population growth.

Land Use Dynamics

The dynamics of production, population, and income in urban agglomerations, along with labor-saving technical change in agriculture, influence the pattern and extent of agricultural land use, particularly for land nearest urban centers. The substitution principle in partial equilibrium land use theory assumes that distance inputs (and hence location and land use) satisfy the familiar marginal conditions of profit maximization. The marginal rate of substitution between any two distance inputs (such as for coal and iron ore in steel production) at the point of minimum transport cost must equal the inverse of the ratio of their transport costs. Changes in demand or supply affecting relative prices and quantities will thus affect the pattern of land use in the long run.

Returning briefly to the isolated state, consider the effects of a growing population. Agricultural technology has been modified as population density has increased. The low income elasticity for agricultural goods and increased labor productivity from industrialization, urbanization, and further labor specialization have made industrial centers less bound to agriculture and agriculture more dependent on manufactured inputs.

Greater intensity of land use in urban activities allows rents bid for urban uses to dominate those of agriculture. Increasing demand for land raises the rent gradient for urban and residential uses, leading the city to expand into what was its agricultural fringe. At the same time, increasing demand for agricultural goods can offset the increasing cost of transporting them greater distances, so the city's supply area also expands. Rising demand and rising transportation costs from more distant production areas may produce higher food prices. Housing costs also rise as competition intensifies for land near the central business district. Incomes grow more slowly without capital accumulation or technical change, due to the diminishing returns to land, so a new equilibrium will be reached. Without externalities and

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[3] A random variable is Weibull distributed if $\text{Prob}[Y<y]=\exp[-e^{-y}]$ (22).

uncertainties, land will be allocated efficiently when the marginal products of land at the borders of competing uses are equalized (fig. 2).

Economies of scale and transportation costs vary across industries, causing variations in size among the the optimal input and output supply areas for each industry, thus allowing smaller agglomerations to exist within the extended market area of the larger central place. Cities of different sizes specialize in the production of different traded goods. Population growth changes demand and supply areas, number of cities, trade flows, economic character of smaller cities, and land use patterns.

Economic growth, through economies of scale and technical change, tends to lower transport costs relative to other prices, flattening rent gradients and extending market areas for low-cost suppliers at the expense of high-cost suppliers. Decreased time and cost of commuting, with rising income from increased labor productivity, has led to decentralized or suburbanized urban areas. The attraction of suburbs for higher income people may be explained by a high income elasticity of demand for residential land, the desire of higher income people to have newer homes or more pastoral settings, Federal tax incentives for homeowners in a (nominally) progressive income tax system, and the desire for fiscal separation in relatively homogeneous communities. This desire for fiscal separation to form a community with public service levels based on more evenly distributed incomes is one explanation for the spatially discontinuous expansion of urban areas. Lack of continuity in expansion may be an efficient land development process in a growing city, and efficiency may even require a sprawl-type pattern of development (11).

The spotty nature of suburban developments on formerly agricultural land at the urban fringe has changed the structure of American cities by creating new, smaller markets and employment centers in the extended range of influence of larger central cities. The monocentric configuration of urban land uses in most theoretical models is becoming increasingly difficult to justify on empirical grounds. Many expanding urban areas run into each other, creating supercities, continuously built-up urban areas populated with at least 1 million (18) in a process sometimes referred to as "Los Angelization." As market areas overlap, formerly isolated areas begin to compete and trade with each other, and further specialization takes place. Although small in scope at the national level, the effects on agriculture of this new form of urban sprawl can be significant at the local or regional level (12).

Durability and adjustment costs of urban infrastructure must be considered in a dynamic framework combining capital theory with urban land use theory to explain spatial phenomena such as urban sprawl, urban decay, and urban renewal. Durability and adjustment costs also affect agricultural land use decisions, particularly in the face of uncertainties concerning land development and land prices at the urban fringe (where most land use change takes place). In dynamic land use models, large adjustment costs for changing to or among urban uses hinder clearly defining land rent. Therefore, bid land prices play the allocative role, where the bid price is the present value of the expected stream of net revenues from a unit of land. Dynamic models must, therefore, include assumptions about discount rates, time horizons, and expectation formations or uncertainty, since expectations about the future influence present decisions.

Aside from agricultural use, the rental market for land is not well-defined, and future users may not be in today's market. Therefore, land developers typically are the leading agents in dynamic models, anticipating future demand, determining bid land prices, and making any necessary conversions to future uses (15, 11). For example, a developer's bid price for a piece of land of size s at location d (at time 0) could be expressed as

$$P(s,d|t) = E[\int_0^t e^{-rv}R_A(s,d,v)dv + \int_t^{\infty} e^{-rv}R_B(s,d,v)dv - e^{-rt}C(s,t)],$$

where: $P(s,d)$ is the bid price, t is the time at which the land will be converted from agricultural to business (or residential) use, E is the expectations operator, r is the discount rate (usually assumed equal to the interest rate), $R_A(s,d,v)$ and $R_B(s,d,v)$ are the agricultural and business or residential rents, or pre- and post-development rents, respectively, and $C(s,t)$ is the cost of developing the land at time t.

Community development and urban spatial dynamics are areas of urban economics that still need substantial analysis. These are also areas that significantly affect agriculture. A theoretical and empirical analysis of the effects of urbanization and urban sprawl on agricultural land use, using techniques recently developed in urban economic theory but with agricultural emphasis, could greatly improve our understanding of some important factors affecting agriculture. Incorporating changing transportation costs with urban residents' preferences for fresher produce and more rural neighborhoods could help explain the concentration of farms producing high-value crops in metropolitan areas (13) and interregional shifts in production patterns.

Land Use and Trade Theory

Distance and factor immobility form the basis of trade theory. Under free trade, the same principles explain trade between nations as trade between a city and its surrounding agricultural area. Accounting for spatial aspects of pricing, Bertil Ohlin attempted to demonstrate that international trade theory is only part of a generalized location theory, with local differences in factor endowments and transportation costs (26). However, Ohlin does not explain the international distribution of transport-oriented industries seeking minimum transport cost for obtaining fuel, input supplies, and marketing output. Since empirical studies point to the importance of distance frictions in interregional and international trade, it is necessary to incorporate transport orientation in trade theory. As Isard noted, "one can view trade theory and the general theory of location and space-economy as synonymous. For (1) location cannot be explained unless at the same time trade is accounted for and (2) trade cannot be explained without the simultaneous determination of locations" (16, p.53).

A nation's comparative advantage in trade depends on opportunity costs of producing alternative goods. The transport cost advantage of one location over another will depend on the opportunity cost (in terms of a commodity produced at both sites) of shipping raw materials or finished products. Then, "a transport-oriented industry must be defined as one in which the differential advantage of the optimal transport point completely offsets the net differential advantage of any other site **where costs are expressed in terms of a commodity produced in common by two or more nations.**" A labor-oriented industry is one in which "the differential advantage of a cheap labor point completely offsets the net differential advantage of any other site, **again where costs are expressed in terms of a commodity produced in**

common" (16, p.217, Isard's emphasis). Differences in relative prices may then vary the cost orientation of industries across countries. The pattern of land use in each country is, therefore, related to the composition of trade and exchange rates. Changes in preferences and incomes, capital accumulation, population growth, and technological change can alter these patterns.

CONCLUSIONS AND AREAS FOR FURTHER STUDY

In land use theory, transportation costs link centripetal forces of increasing returns to scale in certain industries with the use of land or resource deposits as inputs to the production process in other industries (including the consumption value of residential land). Variations in land qualities (such as fertility, climate, slope, and distance to population centers or transportation nodes) influence the amount of rent different users of the land are willing to pay. Revenue net of the costs of assembling raw materials and transporting the finished product produced on a unit of land to market will be the maximum rent bid by a producer. Commuting costs, expectations of price changes, and amenity value determine residential bid rents. Competition among potential users in bidding for a particular piece of land ensures that the landowner will receive the maximum rent.

Changes in population, income, preferences, or technology affect revenues or costs and influence the pattern of land uses. Equilibrium patterns of land use may not be optimal when externalities are present, and institutional constraints influence and are influenced by individual profit and utility maximization. While the relationship between optimal and equilibrium patterns and policy's role in influencing the two have recently been subject to some theoretical analysis, there is still need for further research.

Von Thünen's isolated state helped demonstrate the relationships between transportation costs, land rents, and land uses, but we do not live in such an isolated state. Rising incomes, population, production, and transportation possibilities have increased the number of goods facing regional and national markets. It may be necessary to make prices endogenous in a national model, possibly in a computable general equilibrium (CGE) framework linking agriculture and forestry to the industrial and service sectors. Such a model would also be useful for exploring macroeconomic influences on land use.

Even a national economic model may be too simple to accurately explain land use patterns. Agriculture, the major land use in the United States, has become increasingly subject to variations in government policies and international trade. While the duality of trade and location theories has been demonstrated, there has been little theoretical or empirical work to explain or document these effects, the results of trade restrictions, or national economies of scale. This may be the area most in need of research. Urban economists generally focus on the level of an individual urban area where international trade plays a smaller role, so trade effects on land use are generally not analyzed. Urban economists view agriculture as a single industry--a residual land use. It is up to agricultural and regional economists to explore this area more fully. The multinomial logit model described above presents one framework for incorporating these influences.

Urban land uses strongly affect agriculture, particularly as urban areas expand. Yet, the dynamics of land use change, especially in the urban fringe, are still poorly understood. While occupying a small percentage of total acreage, urban land uses have economic influences extending far beyond their borders. Changes in production and communication technologies, income, and residential preferences are altering current land use patterns with (so far) unpredictable results and require further analysis. Empirical studies relying on Markov processes only project past trends and do not identify separate influences as well as do modern regression techniques. Input/output models also restrict analysis to a static and fixed coefficients framework. USDA's Economic Research Service is analyzing data from aerial photography of counties with rapid population growth to improve understanding of the dynamics of land use changes. Previous contributions to land use theory can best guide such attempts at empirically accounting for various influences to identify current and future trends in land use patterns.

Theory shows that technological and relative price changes in different economic sectors (especially in transportation) influence land use patterns. Changes in localization economies and urbanization economies affect land use dynamics through industrial and commercial demands for land, while changing demographic, income, and preference structures alter demand for residential land. Competition with other land uses and changes in agricultural technology will determine the amount of agricultural land available and the forms of agriculture that develop. Since production serves as the primary link between international trade and natural resources (such as land), it may be necessary to include effects of changing export demands on agriculture's ability to bid competitively for land. A model must also incorporate government policies affecting land use decisions. Developing new statistical techniques that extend the multinomial logit methods to analyze panel data (time series of cross-sectional data) may aid in studies of the dynamics of land use.

Studying land use in a static, isolated society laid the groundwork for a better understanding of land economics. That basis has been extended, particularly in urban economics and the analysis of transport systems. However, much work remains in formulating a dynamic, empirically verifiable model of land use incorporating effects of expectations, international trade, and technical change. That work will be easier if it builds on established theoretical foundations.

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*U.S. GOVERNMENT PRINTING OFFICE:1987-180-916:60133/ERS