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Spatial Externalities, Introduction and Position Papers

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Expert Meeting on Externalities, Introduction and Position Papers

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The concept of "externalities" in general and "spatial externalities" in particular has gained considerable recent attention in economics. Both from a theoretical perspective as well as empirically, the explicit modeling of interacting agents (e.g., strategic interaction) rather than isolated agents has come to the fore in a range of sub-fields in economics (economic geography, labor economics, public, urban and real estate economics, environmental and natural resource economics, etc.). In addition, new paradigms that emphasize increasing returns, path dependence and imperfect competition have led to a renewed interest in agglomeration economies and spatial externalities. Complementing this theoretical focus, the explosion in the availability of geo-coded economic information collected at a range of spatial scales has strengthened the need to explicitly take into account spatial effects in econometric methodology (spatial econometrics).

Our ultimate purpose is to identify the ways in which CSISS can support the development and dissemination of spatial theories and concepts, tools and techniques (such as geographic information systems), and formal analytic methods that will support research efforts.

Meeting Goals

- research questions related to externalities, where consideration of the spatial dimensions of the issues has led to, or is most likely to lead to new insights;
- emerging issues in research on externalities requiring new developments in spatial theory, methodology or technology, with an eye to developing future CSISS workshops (this would include identifying topics, target audiences, and potential workshop instructors);
- specific learning materials that could be collected, developed, and disseminated by CSISS, to support research and instruction on the spatial aspects of externalities;
- specific software tools, including methods, platforms, and implementations, that CSISS could refine or further develop to support research and instruction on externalities; and
- specific materials related to the study of externalities that could be collected as part of CSISS' virtual community.

Steering Committee

- Luc Anselin, Chair, CSISS, University of Illinois, Urbana-Champaign
- Jan Brueckner, University of Illinois, Urbana-Champaign
- Robert Deacon, University of California, Santa Barbara

Position Papers

Position papers, prepared and circulated in advance of the meeting, follow in alphabetic order by authors' names.

Audretsch
Bockstael
Brown
Brueckner
Can-Talen
Epple
Fingleton

Kelejian
McMillen
Murdoch
Nijkamp
Rosenthal
Smith
Sonstelie
Wilens

Knowledge Externalities in the Microfoundations of Growth by David B. Audretsch

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POSITION STATEMENT

An important contribution of the New Economic Growth theory has been to identify that knowledge does not solely descend like "manna from heaven", but spills over across geographic space creating endogenous growth through increasing returns. However, while the New Economic Growth theory has identified the important role that knowledge externalities play in generating endogenous growth, the actual mechanisms by which knowledge spills over to generate growth remain virtually unknown.

The starting point for most theories of innovation is the firm. In such theories the firms are exogenous and their performance in generating technological change is endogenous. For example, in the most prevalent model found in the literature of technological change, the model of the knowledge production function, firms exist exogenously and then engage in the pursuit of new economic knowledge as an input into the process of generating innovative activity. The most decisive input in the knowledge production function is new economic knowledge. Knowledge as an input in a production function is inherently different than the more traditional inputs of labor, capital and land. While the economic value of the traditional inputs is relatively certain, knowledge is intrinsically uncertain and its potential value is asymmetric across economic agents. The most important, although not the only source of new knowledge is considered to be research and development (R&D). Other key factors generating new economic knowledge include a high degree of human capital, a skilled labor force, and a high presence of scientists and engineers.

There is considerable empirical evidence supporting the model of the knowledge production function. For example, at the unit of observation of countries, the relationship between R&D and patents is very strong. Similarly, the link between R&D and innovative output, measured in terms of either patents or new product innovations is also very strong when the unit of observation is the industry. However, when the knowledge production function is tested for the unit of observation of the firm, the link between knowledge inputs and innovative output becomes either tenuous and weakly positive in some studies and even non-existent or negative in others. The model of the knowledge production function becomes particularly weak when small firms are included in the sample. This is not surprising, since formal R&D is concentrated among the largest corporations, but a series of studies has clearly documented that small firms account for a disproportional share of new product innovations given their low R&D expenditures.

The breakdown of the knowledge production function at the level of the firm raises the question, *Where do innovative firms with little or no R&D get the knowledge inputs?* This question becomes particularly relevant for small and new firms that undertake little R&D themselves, yet contribute considerable innovative

activity in newly emerging industries such as biotechnology and computer software. One answer that has recently emerged in the economics literature is from other, third-party firms or research institutions, such as universities. Economic knowledge may spill over from the firm conducting the R&D or the research laboratory of a university.

Why should knowledge spill over from the source of origin? At least two major channels or mechanisms for knowledge spillovers have been identified in the literature. Both of these spillover mechanisms revolve around the issue of appropriability of new knowledge. Firms may develop the capacity to adapt new technology and ideas developed in other firms and are therefore able to appropriate some of the returns accruing to investments in new knowledge made externally.

By contrast, there may be new insights gained from shifting the unit of observation away from exogenously assumed firms to individuals, such as scientists, engineers or other knowledge workers - agents with endowments of new economic knowledge. When the lens is shifted away from the firm to the individual as the relevant unit of observation, the appropriability issue remains, but the question becomes, *How can economic agents with a given endowment of new knowledge best appropriate the returns from that knowledge?* If the scientist or engineer can pursue the new idea within the organizational structure of the firm developing the knowledge and appropriate roughly the expected value of that knowledge, he has no reason to leave the firm. On the other hand, if he places a greater value on his ideas than do the decision-making bureaucracy of the incumbent firm, he may choose to start a new firm to appropriate the value of his knowledge. In the metaphor provided by Albert O. Hirschman, if voice proves to be ineffective within incumbent organizations, and loyalty is sufficiently weak, a knowledge worker may resort to exit the firm or university where the knowledge was created in order to form a new company. In this spillover channel the knowledge production function is actually reversed. The knowledge is exogenous and embodied in a worker. The firm is created endogenously in the worker's effort to appropriate the value of his knowledge through innovative activity.

Research on the geography of innovative activity essentially shifts the model of the knowledge production function from the unit of observation of a firm to that of a geographic unit. The consistent empirical evidence supports the notion knowledge spills over for third-party use from university research laboratories as well as industry R&D laboratories. This empirical evidence suggests that location and proximity clearly matter in exploiting knowledge spillovers.

While a new literature has emerged identifying the important that knowledge spillovers within a given geographic location play in stimulating innovative activity, there is little consensus as to how and why this occurs. The contribution of the new wave of studies described in the previous section was simply to shift the unit of observation away from firms to a geographic region. But does it make a difference how economic activity spills over within the black box of geographic space?

Penetrating the black box, not of the firm, but of the knowledge spillover process would provide a strong analytical and empirical basis for the microfoundations of economic growth. Recent work has identified a number of key processes serving as the foundations for the microeconomics of growth. Innovative activity, one of the central manifestations of change, is at the heart of much of this work. Entry, growth, survival, and the way firms and entire industries change over time are linked to innovation. The dynamic performance of regions and even entire economies is linked to how well the potential from innovation is tapped. While a rich literature has emerged in recent years identifying the links between innovation, entry, growth, survival and industry evolution, the geographic component is generally lacking.

Very little has been done to measure and track knowledge externalities. Paul Krugman has argued that knowledge spillovers are impossible to measure because "knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked." However, there may be an opportunity for the CSISS to be a leader in measuring the spatial dimension of knowledge externalities. Part of this challenge involves the measurement and the geographic linkages of various types of knowledge, such as R&D, patents, new innovations introduced into the market, publications, and citations. A different aspect involves identifying the geographic linkages between the various measures of knowledge and the geographic locus of their commercialization, which can involve the startup of new firms, growth of existing enterprises, and the survival and growth of all firms. Other types of measures focus on the interactions and mobility of scientists, engineers and knowledge workers, in order to identify where and under what conditions is new knowledge produced, and where does it become commercialized and impact economic performance measures, such as growth.

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Spatial Externalities in the Context of Land Use Change by Nancy Bockstael

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POSITION STATEMENT

Spatial externalities arise in a number of interesting contexts, but land use is the most obvious one - and arguably the most pressing one from a policy perspective. Environmental externalities tend to be spatial in nature, but these are only one category of a broader class of spatial spillovers that cause land use/land cover of one parcel to affect the values in differing land uses of neighboring parcels. Since the value of land in alternative uses governs the process of land conversion, spatial spillovers between land parcels can lead to a complex, path dependent process of land use change. This path dependence is only exacerbated by the irreversibility of many types of land conversions.

Local governments in many parts of the U.S. are keenly interested in the underlying causes of land use change, as they struggle with the public finance implications of increasing low density, fragmented exurban sprawl. The amount and spatial pattern of land use is also critical to environmental scientists, because of the implications for bio-complexity, non-point source air and water pollution, and global climate change. Digitized maps of land use pattern serve as the basis for landscape ecology, hydrological engineering, and atmospheric deposition models. The focus of much of my research is the development of methods to predict the spatial pattern of land use change under alternative regulatory and growth scenarios, for use by these "audiences".

Space poses a challenge for economists in a fundamental way. The land use change problem is frequently one in which we are interested in understanding how the location specific decisions of individual economic agents aggregate up to a spatial pattern that is changing over time. Economists are familiar with the concept of aggregating up from an individual to a collective outcome, in the sense that a large number of individual agents making utility or profit maximizing decisions constitutes a market. In understanding how these individual actions aggregate up into market outcomes, the defining factor for economists is the distinction between what is endogenous and what is exogenous at each scale. Our usual way of crossing from one scale to the next is aspatial, though, and understanding spatially distributed aggregate outcomes, especially when spatial externalities exist, is not straightforward.

By far the best known example of an economic spatial model that links individual decisions with a description of aggregate land use pattern is the bid-rent model (or monocentric city model) of urban economics. What was once a robust but parsimonious description of urban spatial structure comes up short when trying to capture the observed complexities in pattern that are currently of chief concern. More complicated versions of the basic model have been developed, but the model's success as a predictor of observed urban land use pattern at a spatially disaggregate scale is limited. This is primarily due to the model's inability to explain the formation and location of urban centers, its reduction of space to a one-dimensional measure of distance from city centers, and its inability to accommodate the types of spatial heterogeneity that are central to the science questions.

The spatial distribution and pattern of land use change is so important to

ecologists and other environmental scientists that they have often assumed the role of land use change modelers to meet the pressing need for forecasting tools. Most represent the landscape in terms of pixels or cells, and many model land use change with Markovian or semi-Markovian constructs where the transition probabilities can be made functions of earlier states, sojourn times, and interaction effects among neighboring cells. While complex with respect to the ecology of transition, these models are simplistic with regard to human-induced change - which in many parts of the world is the dominant form. Some landscape ecology models simply extrapolate from past land use change; others include "socio-economic drivers," but the validity of the underlying variable choice and exogeneity assumptions is questionable. More sophisticated state transition models, developed by geographers and spatial statisticians, draw on parallels with thermodynamic systems or use cellular automata models to simulate the complex processes by which global patterns are generated from rules about cell interactions. But again the underlying economic processes are ignored.

Although they are yet to be put to the empirical test, exceptions include the economic agent-based models of interaction that adopt modeling techniques from interacting particle systems. Fujita, Krugman, and Venables (1999) and Anas, Arnott, and Small (1998) review this literature. The common theme of this work is that the pattern of developed land uses is driven by interactions among spatially distributed agents, although the source and specification of these interactions varies. They may arise from transportation costs and pecuniary externalities or directly through agents' preferences over the spatial distribution of other agents through social interactions, knowledge spillovers, or negative externalities. Because these interactions both influence future location decisions and are a function of past location decisions, the spatial distribution of agents across the landscape is endogenously determined. Add to this the durability of most urban development and the result is the evolution of a complex urban spatial structure that is characterized by multiple equilibria and path dependence.

These agent-based models are of importance because they provide a means of deriving aggregate spatial patterns from the microeconomic behavior of atomistic, but interdependent, agents. However, these models have tended to be abstract, ignoring the many heterogeneous features of the landscape that are likely to influence location decisions (e.g. roads, zoning, environmental amenities/disamenities). This simplification allows for tractable analytical models that demonstrate the *potential* role of interactions, but has inhibited empirical research. Empirical applications of these models require not only spatially explicit data but the resolution of serious identification problems. The effects of endogenous interactions are difficult to separate from spatially correlated exogenous landscape features, which may evoke land use patterns that are observationally equivalent. Similar challenges have been outlined in a separate literature on empirical models of social interactions, most notably by Manski (1995, 2000).

Because it is difficult to measure such interactions, separating these effects from unobserved exogenous heterogeneity is possible only for limited cases. One such case arose in the context of work by Irwin (1998) and Irwin and Bockstael (2000). Drawing upon the agent-based interaction models discussed earlier, we developed a model in which exogenous features create attracting effects (e.g. central city, road, public services) among developed land parcels and interactions among land use agents create net repelling effects. Empirical evidence of a negative interaction effect among land parcels in a residential use was econometrically identified. This model offers an explanation of the fragmented residential development pattern found in urban fringe areas. One of the more interesting questions that arises from this type of work is the conceptual connection between Manski's identification problem, set in a spatial context, and the difficulty of distinguishing between spatial autocorrelation and spatially dependent variables in spatial econometrics.

This discussion has assumed a modeling strategy based entirely on micro-level agents making interrelated economic decisions on individual land parcels. The strategy provokes two types of challenges. First, are parcel-level data on economic variables sufficiently prevalent as to make estimation of such models possible? Such data are available in Maryland where the Maryland Office of Planning has, since 1996, digitized the centroids of all land parcels in the tax assessment data base. Similar digitization programs are only beginning elsewhere, and only in some of the more affluent states. Even for Maryland, however, sufficient historical data to estimate cross-section time-series models are difficult to obtain, and in states where these activities are only beginning it may be many years before enough "history" has been compiled. Together with remote sensing researchers, we are investigating to what extent Landsat data can supplement or be substituted for parcel level data, given that Landsat data are broadly available for the US for the last 15 to 20 years but represent the landscape as a mosaic of cells rather than parcels. The second challenge is more fundamental: are agent-based, parcel-level models the right modeling strategy? Alternatives exist that, although based on theories of individual behavior require data on at a more aggregate level. These include, but may not be limited to, large-scale urban simulation models based on transportation zones (e.g. Anas and Kim, 1996) and locational-equilibrium sorting models (Epple and Sieg, 1999).

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Spatial Considerations in Natural Resource Economics By Gardner Brown

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POSITION STATEMENT

Over the past decades economists have developed intertemporal models to the point where it is standard material in core graduate programs. The discipline also has made some progress toward a better understanding of uncertainty. However, research on the spatial dimension of economic phenomena is virtually non-existent. Whether this is because until recently increasing returns and market structure were uncomfortable features for our models to neatly integrate, as Krugman [1995] argues, or the gap is due to other reasons is not particularly important. The workshop is recognition that the spatial considerations are too important to continue to neglect.

In natural resources economics the need to treat space explicitly is urgent. In the next decade and more, I believe substantial intellectual energy will be devoted to building ecological economics. By this I mean integrating an ecological model of some biota with a model which captures economic behavior.¹ Before the interdisciplinary effort can proceed very far, economists will have to come to grips with space since it plays such a fundamental role in the ecological scheme of things. It is easiest to build on first steps.

About the simplest way to characterize how biological populations diffuse through space is to make the rate of diffusion proportional to the gradient of its density (u). Clark (1990) considers a fishery in which growth, $F(x,u)$, depends on distance from shore (X) and density. Fish density is then a parabolic non-linear partial differential equation,

$$\frac{\partial U}{\partial t} = \sigma^2 u_{xx} + F(X, u), \text{ where } \sigma^2 \text{ is the "diffusion" coefficient. Then some}$$

objective is maximized through the choice of effort to harvest $u(x)$. Real animals are not so linear and their diffusion must be characterized in two dimensional space. See Huffaker, et al. (1992), Huffaker and Cooper (1995), and Bhat, et al, (1993).

Building on an earlier model with patchy and heterogeneous distributions of fish and an open access fishery, Sanchirico and Wilen (1999) study the effect of creating marine reserves.

Many valuable coastal marine populations are characterized by an adult phase of the life cycle when there are spatially separated populations connected through a common

¹ Public policy will drive this marriage just as public policy has been a major force in shaping resource economics in the past.

larvae pool in an earlier stage of the life cycle. In such a model, Brown and Roughgarden (1997) found that it was optimal to harvest all the adults from all sites but the one most efficient at producing larvae. The surprising answer is produced by unbounded increasing returns in the population dynamics.

Ecologists know and their models are beginning to capture the fact that both shape and location of habitat are critical determinants in a species viability or in a wetlands assimilative capacity (Bockstael, 1996). Bockstael (1996) captures both the spatial dimension and fragmentation in an hedonic model using shares of contiguous land in forests, crops or pasture and the length of conflicting edges between rival land uses.

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Strategic Interaction and Spatial Econometrics

by

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Analysis of strategic interaction among decision makers has recently become a major focus of economists and other social scientists. An example of such interaction includes interdependent choices of policy instruments by local or state governments. In this case, the optimal level of a jurisdiction's policy instrument depends on the levels chosen by other (perhaps neighboring) jurisdictions. Another example of strategic interaction might include fashion decisions. One individual's preferred choice of clothing style might depend on what other people are wearing. In both cases, an agent's optimal choice depends on the choices of others. The equilibrium set of decisions in such a setting must be mutually consistent, with all agents making choices that are optimal given what others are doing.

Spatial econometrics provides an ideal tool kit for empirical analysis of strategic interaction. The "spatial lag" model in particular closely captures the behavior described above, where different, spatially distinct agents make interdependent decisions. The model allows the analyst to test for the presence of strategic interaction and, if present, to determine its nature. The purpose of the ensuing discussion is to sketch a general theoretical model for the analysis of strategic interaction, and to discuss the use of the spatial lag framework in estimating its parameters.

In the economics literature, two principal types of strategic-interaction models can be identified. Despite their differences, these models ultimately lead to the same empirical specification, which can be estimated with spatial lag methodology. The first approach can be referred to as the "spillover" model. In this framework, each agent chooses the level of a decision variable, or "instrument," with t_i denoting the level of agent i 's instrument. In addition to being affected by the level of his own instrument, agent i is affected by the instrument levels of other agents as well. Thus, i 's objective function is written

$$U(t_i, t_{-i}, X_i), \tag{1}$$

where t_{-i} denotes the vector of instrument levels for agents other than i , and X_i is a vector of characteristics of agent i . In addition to representing variables that help determine preferences, these characteristics might include measures of the "relevance" to i of each of the other agents. In a spatial context, this relevance might be measured by the "distances" between i and other agents, where distance is measured by some appropriate metric.

An example of the spillover model is provided by Case, Rosen and Hines (1993). In their model, residents of a given U.S. state are assumed to benefit from public expenditure in other states, as well as from their own state's spending. Residents of California, for example, might benefit from spending on roads in Arizona, which could affect the pleasantness of a vacation in that state. In a different context, the spillover model could apply to fashion choices. An individual's benefit from spending on a particular type of garment might depend on whether his or her peers are also buying it.

Agent i chooses t_i to maximize (1), setting $\partial U/\partial t_i = 0$, and the solution depends both on the agent's own characteristics and on the choices of other agents. The optimal choice can then be written

$$t_i = F(t_{-i}, X_i) \quad (2)$$

The function F represents a *reaction function*, which gives agent i 's best response to the choices of other agents. Analysis of the above optimization problem shows that an increase in t for some other agent can cause t_i either to rise or fall, depending on the particular features of the objective function U . Therefore, the direction of the interaction between agents is ambiguous. However, if other agents' choices matter in U , the derivatives of F with respect to the elements of t_{-i} will generally be nonzero.

A second type of strategic-interaction framework can be referred to as a "resource-flow" model. In this model, an agent does not care directly about the instrument levels of other agents. But the agent does care about the amount of a particular "resource" that he enjoys. Because the distribution of this resource among the agents is affected by the instrument choices of all, each agent is indirectly affected by t_{-i} . In this model, agent i 's objective function is

$$V(t_i, R_i, X_i), \quad (3)$$

where R_i is the resource level enjoyed by i . The distribution of resources depends on the entire vector of instrument levels as well as on agent i 's characteristics. Thus, the resources available to agent i are given by

$$R_i = H(t_i, t_{-i}, X_i). \quad (4)$$

Note that the appearance of X_i in (4) might capture the effect of i 's location relative to the other agents in determining R_i , conditional on the vector of instruments. Other characteristics of i , measured relative to other agents, might matter as well.

An example of a resource-flow model is the tax-competition framework of Brueckner and Saavedra (1997), where agents are local governments. In the model, the instrument is a tax rate on business investment, and the resource represents the level of such investment. The allocation of investment across communities depends on the vector of tax rates, and this allocation determines community tax revenues (i.e., the tax rate times investment), and consequently the levels of public spending. Another example is the welfare-competition analysis of Saavedra (2000), where the agents are state governments. In this case, the instruments are welfare benefit levels, and the "resource" is the number of welfare recipients, who are assumed to migrate across states in response to benefit differentials. In contrast to the business investment model, the resource in this case is a "bad" rather than a good.

To derive the reduced form of the resource-flow model, (4) is substituted into (3), yielding $V(t_i, H(t_i, t_{-i}, X_i), X_i)$. This objective function, however, can be rewritten as

$$\tilde{V}(t_i, t_{-i}, X_i). \quad (5)$$

Thus, even though the underlying model is different, this objective function has the same form as (1). As a result, maximizing (5) by choice of t_i yields a reaction function like (2).

Both the spillover and resource-flow models of strategic interaction thus lead to the same empirical framework, which calls for estimation of a reaction function relating each agent's instrument choice to the choices of other agents. An estimating equation based on (2) can be written

$$t_i = \beta \sum_{j \neq i} \omega_{ij} t_j + Z_i \theta + \epsilon_i, \quad (6)$$

where β and θ are parameters (the latter a vector), Z_i is a vector of i 's characteristics, and ϵ_i is a well-behaved error term. The ω_{ij} represent weights that depend on the relevance to i of other jurisdictions j in the process of interaction. Such weights, which might capture the location of j relative to i , can be viewed as part of i 's characteristic vector X_i , which also includes Z_i . While the weights (properly normalized) are specified exogenously based on prior judgement about the pattern of interaction, the parameter β , which reflects the strength of interaction among the agents, is estimated from the data.

The specification in (6) is known as a spatial lag model, and rewriting the equation in matrix form yields

$$t = \beta W t + Z \theta + \epsilon, \quad (7)$$

where t is the vector of the t_i 's, Z is the characteristics matrix, and W is the weight matrix, with representative element ω_{ij} . With interdependence among all the instrument choices, only one collection of levels is mutually consistent, and it is given by solving (7) for the t vector. This yields the solution

$$t = (I - \beta W)^{-1} Z \theta + (I - \beta W)^{-1} \epsilon. \quad (8)$$

The parameters of the model can be recovered by maximum likelihood estimation of (8), with a significance test on the estimated β indicating whether the data are consistent with a model of strategic interaction. As explained above, both positive and negative β 's are admissible under the model.

Several econometric pitfalls might cause this procedure to give faulty conclusions regarding interaction among agents. First, the error vector ϵ might exhibit positive spatial autocorrelation, indicating, for example, that unobserved characteristics take similar values for agents with nearby locations. In this situation, the estimated β may give the appearance of positive interaction among agents located near one another when this outcome simply reflects similarity of unobserved characteristics. The literature offers several remedies for this problem.

A second potential problem is a feedback effect between instrument choices and agent characteristics. For example, in the tax-competition context, communities with high business taxes may attract residents who value public spending. As a result, elements of the Z_i vector may be endogenous, leading to a potential bias in the estimate of β . While this problem could be corrected by abandoning maximum likelihood and using an instrumental-variables approach, finding suitable instruments may be difficult. In any event, it could be argued that the feedback effect may be relatively unimportant.

This discussion shows that strategic interaction may occur in many contexts in the social sciences, and that spatial econometrics provides a convenient tool for studying this phenomenon. Researchers, however, must have a clear conceptual foundation in order to successfully apply these methods to the study of decision making in a spatial setting.

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Measurement of Spatial Spillovers in Urban Housing Prices

The importance of neighborhood is inherent in most business practices and policy decisions concerning housing markets. Realtors know that “location, location, location” determines the premium that households are willing to pay for comparable properties. Appraisers take into account neighborhood factors and recent sales in assessing the market value of properties. Mortgage lenders and insurers know that the location of the property that secures a loan is a major determinant of their credit risk exposure. Neighborhood is also of prime concern to housing policy makers and regulators. Steering low-income households to neighborhoods where their housing investment is most likely to lead to increased wealth is an important policy consideration. Laws such as Home Mortgage Disclosure Act (HMDA) and Community Reinvestment Act (CRA) are designed to ensure that there is sufficient housing investment in low-income and minority neighborhoods.

Modeling and quantification of neighborhood effects on the economic value of housing prices is an important empirical question that can greatly benefit from the application of spatial analytical methods and GIS. Neighborhood effects are spatial externalities that are associated with the geographic location of a house – both its absolute location (“site”) and the neighborhood in which it is located (“situation”). Can (1992) distinguished between two types of spatial externalities. First is neighborhood effects i.e., the impact of shared neighborhood characteristics (public schools, crime, accessibility, etc.) on house prices. Second are *adjacency effects*, which are spillovers associated with the neighboring structures. The physical quality as well as the uses associated with the immediate neighboring structures is expected to exert externalities that will ultimately be capitalized into the prices of nearby houses.

Although neighborhood effects are well recognized in the mainstream literature, adjacency effects are largely ignored. Can and Megbolugbe (1997) introduced a spatial hedonic model that closely resembles the practice of “comparable sales” approach in residential real estate appraisals. Comparable sales method is based on the notion that the economic value of a given house will be greatly influenced by the price history of neighboring structures. Typically the prices of recently sold comparable properties in the immediate neighborhood are used in estimating the market value of a property controlling for differences in their structural attributes. Conceptually this is analogous to the consideration of spatial spillovers in spatial econometric context. Can and Megbolugbe (1997) introduced a spatial lag operator, which is a spatially weighted average price of recently sold nearby properties into a hedonic approach as follows:

$$P_{it} = \alpha + \rho \sum_j w_{ij} P_{j,t-m} + \sum_k \beta_k S_{ik} + \sum_l \gamma_l N_{il} + \varepsilon_{it}, \quad m = 1, 2, \dots; j \neq i$$

where P_{it} is the transaction price of a given house i at time t and $P_{j,t-m}$ is the transaction price of a nearby sale j that occurred during $t-m$, where m is the number of months. w_{ij} is the weight that denotes the extent of influence prior sale $P_{j,t-m}$ has on P_{it} and ρ is a measure of overall level of spatial dependence among $\{P_i P_{j,t-m}\}$ pairs for which $w_{ij} > 0$. S is a vector of structural attributes containing variables such as the age and size of the house and N is a vector of neighborhood characteristics. β and γ are the parameter vectors corresponding to S and N , respectively; and ε is a vector of error terms. Once this equation is estimated, the coefficient of ρ will give us a measure of the overall spatial spillover effects on present sales of prior transactions.

While this spatial model conceptually captures more closely the actual house price determination process in urban markets than the traditional hedonic model, the incorporation of the spatial lag operator poses several challenges in empirical applications. It will be important to address these in order to promote the use of spatial regression models in housing research. These are summarized below.

- *Spatial scale of spillovers.* The most critical element in this specification is the definition of w_{ij} as its value will determine which j 's are considered "neighbors" in time and space as well as the extent of their influence on the transaction price for i . Currently one has to specify these weights in an a priori fashion using a distance-based measure. As there is no theoretical guidance, there is a need to determine spatial weights from the data. While there exists several spatial exploratory tools such as the G_i^* statistic (Getis and Ord, 1992) and Moran scatterplot (Anselin 1995), there is a need for more flexible tools in the context of spatial econometric estimation to aid with the determination of spatial scale at which spatial externalities operate. GIS-based tools can be useful in this regard.
- *Spatially lagged dependent variable and spatial error autocorrelation.* Even when a spatially lagged variable is included, there is still the possibility of error autocorrelation that might result from model misspecification or omitted variables. While there are some diagnostic tests offered in Anselin et al 1995, the estimation of spatial models with both types of spatial operators is quite operationally difficult when one is dealing with very large data sets.
- *Modeling of spatial and temporal effects in housing price models.* The consideration of spatial effects in conjunction with temporal effects is an area of research where there is very limited work. A recent study by Quercia et al is an effort in this area. In this study a repeat-sales model is employed to investigate housing price appreciation (depreciation) trends in low-income and high-minority neighborhoods. A spatial lag operator is introduced into a seemingly unrelated regression (SUR) model with two equations. While the error structures of the two equations are linked through simultaneous estimation, there is no accounting for spatial autocorrelation in estimation. This is an area for further research.
- *Operational issues.* There is still limited awareness of the availability of spatial analytical methods and tools in the housing research community. The lack of software tools, limited availability of accurate and comprehensive information on neighborhoods, and lack of research computing environments to facilitate the geoprocessing needs of spatial data also continue to hinder the use of spatial models in housing research and policy analysis.

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POSITION STATEMENT

Sorting of households by income and demographic characteristics is commonplace--across neighborhoods, primary and secondary schools, municipalities, colleges and universities. If peer effects and neighborhood effects are present, sorting can have consequences for individual behavior, educational attainment, career choices, and other private and social outcomes (Benabou, 1996; Durlauf, 1996; Epple and Romano, 1998).

Models of individual choice frequently imply sorting. If high-income households are willing to pay a higher housing price premium than poor households to obtain access to neighborhoods that are of higher quality, then sorting will emerge (Ellickson, 1973). Moreover, the sorting will be such that the ordering of incomes and housing prices across neighborhoods will follow the same order as neighborhood qualities. If qualities are endogenous and determined by collective choice of local public expenditures within municipalities, then the allocation of population across locations determines and is determined by expenditure on local public services (Westhoff, 1977; Epple, Filimon, and Romer, 1984; Epple and Romer, 1991; Fernandez and Rogerson, 1996; Nechyba, 2000).

Peer and neighborhood effects provide powerful forces for sorting (Benabou, 1993). This is the case even if neighborhoods are physically identical and expenditures on local public services do not vary. For example, suppose that high-income households are willing to pay a higher housing price premium than the poor to obtain access to high quality schools. This creates a force for sorting, with higher income households choosing neighborhoods with higher housing prices and higher quality schools. School quality differentials will sustain and be sustained by such sorting if parental involvement in schools and children's peer "qualities" (motivation to do homework, refrain from disruptive behavior, etc.) tend to increase with income (Epple and Romano, 2000). Of course, income is only one of many characteristics that affect household's willingness to pay for education, local public services and neighborhood quality (Epple and Platt, 1993). Similarly, when peer and neighborhood effects are present, many characteristics of a household may be associated with their actual or perceived desirability as neighbors or school peers.

In considering the allocation of households across neighborhoods and communities in a metropolitan area, spatial proximity can be characterized in at least three ways. Geographic proximity is the most obvious, and it is particularly relevant if there are spillovers across locations. Proximity of communities may also be characterized by the extent to which their bundles of services, amenities, and peer qualities are similar. Finally, proximity of communities may be characterized by the similarity of the characteristics of their residents. The second and third types of proximity are illustrated by the example above in which school quality is determined by student peer quality. Equilibrium has the property that ordering of communities by student peer quality is the same as the ordering by household income. Thus, two communities that are adjacent in peer quality are also adjacent in income, even though they need not be physically adjacent. These three ways of thinking about proximity of communities can also be relevant in thinking about proximity of schools or of colleges and universities (Epple,

Romano and Sieg, 1999).

From an empirical perspective, equilibrium models of community choice impose consistency requirements between individual choices and the aggregate distribution of households across communities and schools, or of students across colleges and universities. These consistency requirements provide a valuable mechanism for assessing the extent to which a particular model of individual choice predicts allocations of households across locations that are consistent with the observed distribution of household types across locations (Epple and Sieg, 1999; Epple, Romano and Sieg, 1999; Epple, Romer and Sieg, forthcoming). An empirical analysis can simultaneously investigate aspects of individual choice as well as aggregate outcomes. For example, micro data can be used to study the college attended by an individual with a given income and SAT score and the financial aid awarded by the institution that admits and attracts the student. Aggregate data can be used to investigate consistency of the model of individual choice and college admission policy with aggregate outcomes, such as the distribution of SAT scores in each college and the distribution of SAT scores across colleges.

Developing equilibrium models of population sorting and developing and implementing methods of estimating those models is a promising approach for improving understanding of the stratification of population across communities, schools, and colleges and universities. Such models also have the potential to enhance understanding of peer and neighborhood effects, and the quality of education and local public services received by households as a function of their incomes and demographic characteristics. These models can also serve as a mechanism to provide a comprehensive evaluation of policy changes (Sieg, Smith, Bahzaf, Walsh, 2000).

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POSITION STATEMENT

There has been a valuable reinvigoration and exciting new impetus produced by developments in new economic geography theory (Fujita, Krugman and Venables, *The Spatial Economy : Cities, Regions and International Trade*, MIT Press 1999), although I think it is important to now give emphasis to models designed for empirical as well as theoretical consistency, in order to develop a truly scientific approach in which theory is confronted by data and new, more realistic, and ultimately more useful, theory is the outcome. With this as a motivating force, I model productivity and GDP per capita growth, mainly for regions of the European Union, using my models to monitor across-time changes in the strength of spillover and increasing returns, and to simulate regional dynamics and equilibria. Recent publications illustrating this are Fingleton B (2000) 'Spatial econometrics, economic geography, dynamics and equilibrium : a third way?' *Environment & Planning A*, 1481-1498 and Fingleton B (2001) 'Equilibrium and economic growth : spatial econometric models and simulations' forthcoming in *Journal of Regional Science*, Feb (a recent *.pdf version is available at <http://www.landecon.cam.ac.uk/>) and Fingleton B (2001) 'Theoretical economic geography and spatial econometrics : dynamic perspectives' forthcoming in *Journal of Economic Geography*, Feb.

This empirical work can be shown to be consistent with Chamberlinian monopolistic competition theory developed by Spence (1976) and Dixit and Stiglitz (1977), involving explicit micro-level market structure assumptions typical of new economic geography theory. Assuming a constant elasticity of substitution production function for intermediate immobile non-traded services, we see increasing returns and greater intermediate variety in denser areas. The (increasing returns) intermediate services combines with labor in a Cobb-Douglas production function (degree one) as the final manufactured good technology. The preferred underlying theory also assumes diseconomies due to congestion effects, following Ciccone and Hall, 'Productivity and the density of Economic Activity', *American Economic Review*, 1996, although reduced form parameter estimates indicate that the net outcome is increasing returns.

The foregoing theory represents an advance on our modeling of pecuniary externalities since it precisely and explicitly shows the origins of agglomeration economies, but it has nothing to say about technological externalities (previously described by Marshall). One way forward, allowing a more comprehensive suite of (spatial) externalities, is via spatially varying technical progress rates. In this vein, I model the rate of technical progress as a function of across-region knowledge spillovers plus the local rate of innovation creation and adoption determined by schooling/human capital and the initial technology level. Low initial technology regions benefit more from technology diffusion and thus achieves faster technical progress (the existence of a significant positive 'catch-up' effect has the important consequence that dynamics converge to a steady state). Fast productivity growth in 'neighboring' regions boosts technical progress locally as knowledge spills across region boundaries, and gives an explicit spatial econometric orientation to my empirical analysis. Spatial spillover implies that

productivity growth is an endogenous variable, with productivity growth in an area partly determined by, and partly determining, productivity growth in 'neighboring' areas.

Consequently, a reduced form I and others have used to try to capture spatial externalities/spillovers is the space lag model familiar to spatial econometricians, involving an endogenous dependent variable (in my case productivity growth) requiring maximum likelihood or instrumental variables estimation. Various single equation specifications with these general characteristics have been estimated using SPACESTAT, with diagnostics indicating the necessity of the lag. Faute de mieux, I write my own programs in the GENSTAT programming language (occasionally going down to FORTRAN) to support the SPACESTAT results and to take the analysis further. Generally, I find GENSTAT useful for data manipulation, simulation and graphics, and other types of modeling (eg generalized linear modeling) not available in SPACESTAT. For the purpose of monitoring across time the varying effects of externalities and increasing returns, I fit spatial seemingly unrelated regressions, as set out in Luc Anselin's 'Spatial Econometrics', 1988. Estimation for these multi-equation models is usually via LIMDEP and PcFIML. I also use ARCVIEW to visualize and organize my data, and to link to SPACESTAT. This overall combination is messy and time consuming, and it would be an excellent development if a more completely integrated platform for spatial modeling combining these various elements could be developed under the aegis of CSISS.

This raises issues regarding the data and tools available facilitating complementary and alternative approaches to modeling spatial externalities. I feel that more emphasis should be given to generalized linear modeling approaches to spatial interaction analysis to model for example knowledge externalities created by labor migration between firms.

There are numerous other questions generated by our consideration of spatial externalities, for instance what is the empirical basis of our assumptions about the spatial reach of externalities and how can this be enhanced? Can progress be made modeling knowledge spillovers due to the cooperative and competitive interaction of firms? How do we introduce into our modeling overarching exogenous developments in communications technology and economic integration, which change the scale and scope of spatial interaction? What is the relationship between sectoral structure and spatial externality effects? Are regions with more small firms more likely to produce more externalities and what are the consequences for regional development?

Also, dynamics are very important. We need to keep in mind the paths implied by cross-sectional models, whether they lead to deepening core-periphery patterns and stronger clustering or the ultimate dominance of centrifugal forces, and the role played by spatial externalities in this. My preferred approach is probably close to what Fujita, Krugman and Venables call 'quantification', meaning theory consistent models whose parameters are 'based on some mix of data and assumptions, so that realistic simulation exercises can be carried out'. Thus my simulations are driven by estimated parameters and assumptions about the values of variables in empirical spatial econometric models. This focus on empirical and theoretical consistency differs from simulation exercises currently typifying new economic geography, which purposefully abstract from the real world to illustrate particular theoretical outcomes, but is seen as 'the way forward'.

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Research Suggestions Relating to Spatial Models

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Spatial econometric models are especially well suited to study economic, political, sociological, and psychological relationships which involve interactions between decision making units of various sorts. These interactions could be due to copy-cat policies, externalities, systems feedbacks, and competitive pressures, among other things. The decision making units could relate to micro analytic units, such as a firm, a family, a legislator, etc. or macro units, such as a city, a state, a country, etc.

Although there have been an increasing number of studies dealing in one way or another with spatial issues in recent years, the scope and extent of applications have not been commensurate with the potential of spatial models. One reason for this is that most spatial models rest on reasonably strong assumptions. Therefore, research is needed to weaken the assumptions underlying these models. Research is also needed to extend the scope of spatial models.

Below are some suggestions for such future research.

² By far the most frequently considered spatial model is a variant of the one considered by Cliff and Ord. The specification of this model involves a weighting matrix which is typically specified in an ad-hoc manner and assumed to be known. This restricts the scope of applications of the model. An obvious suggestion for future research is to parameterize this matrix in such a way that distance measures between units can depend upon more than one variable. A major difficulty concerning the determination of the large sample properties of various estimators of the model's parameters is that the dimension of the weighting matrix increases with the sample size, and the dependent variable of the model is a triangular array; therefore, evident continuous mapping results can not be applied.

² In the Cliff and Ord model the innovation error is typically assumed to be i.i.d: $(0, \sigma^2)$, or parameterized in a user friendly way so that estimation is evident. Since the dependent variable in spatial models typically relates to units which differ in magnitude in various ways, a heteroskedastic specification is more reasonable and, following research in related areas in

econometrics, this specification should be non-parametric. At present, there are no formal results relating to the estimation of such spatial models which contain spatially lagged dependent variables.

- ² The determination of formal large sample results relating to, perhaps, an error component panel data extension of spatial models containing spatially lagged dependent variables would also be a fruitful avenue for further research. An evident reason for this is that the availability of panel data sets is increasing.
- ² As in many other scenarios, spatial relationships often take place in a multi-equation systems framework. These equations will often be simultaneous, and involve spatially lagged dependent variables. Thus far, there are no formal large sample results relating to the estimation of such systems. The availability of such results should increase the scope of application enormously.
- ² Finally, in most cases spatial models which contain spatially lagged dependent and independent variables, and a spatially correlated error term are specified in terms of the same known weighting matrix. Typically, our theoretical modeling relates to the dependent and independent variables involved. Spatial correlation is something we wish to account for. Therefore my suggestion is that the spatially correlated error term should be specified non-parametrically, and hence future research should focus on estimation problems relating to the resulting variance-covariance matrix of the estimators involved.

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POSITION STATEMENT

As an urban economist and applied econometrician, nearly all of my research has a spatial dimension. One focus of my research is the effect of zoning on the spatial pattern of land values. Another focus is the effect of employment subcenters on the spatial patterns of population and employment densities in polycentric cities. In a recent project, I analyze how housing prices changed when a copper smelter closed and later when it was designated as a superfund site. My research has also been focused on analytical tools for spatial models, including parametric approaches to discrete choice spatial models and applications of nonparametric approaches to the analysis of spatial data.

Taking space into account is critical when analyzing externalities. For example, in our analysis of zoning in suburban Chicago, John McDonald and I found that areas were more likely to be zoned for manufacturing use at the borders between suburbs (*Journal of Urban Economics*, 1991). Some of the pollution, noise, and traffic generated by manufacturing plants can be pawned off on a suburb's neighbors. We have found that highly disaggregated data are desirable when analyzing zoning. Many studies fail to distinguish between areas within a suburb by treating the municipality as the unit of analysis. In fact, some sites within suburbs are best suited for a particular use, and we have found that these sites are likely to be zoned for the use that produces the highest land value.

My work with Paul Thorsnes is another example of the importance of taking space into account when modeling the effects of externalities (*Advances in Econometrics*, 2000). In a recent manuscript, we find that the spatial pattern of housing prices in Tacoma, Washington were affected significantly by distance from a copper smelter. The smelter spread arsenic over nearby ground and the emissions reeked. We find a positive gradient for distance from the smelter up to the closing of the smelter, after which the gradient falls to insignificance. Superfund site designation and the start of cleanup operations had no effect on the gradient.

These two examples are representative of the situations where spatial modeling adds important insight to an analysis of externalities. Externalities nearly always have a spatial dimension. Local public goods such as parks, schools, neighborhood pools, snow removal, public hospitals, mosquito abatement, and municipal golf courses all generate benefits that decline with distance. Similarly, the negative externalities associated with crime, pollution, and traffic congestion are geographically concentrated. Both positive and negative externalities affect the behavior of local government, firms, and individuals.

Though significant advances have been made in approaches to spatial data analysis, important problems remain. First, work still remains in developing models and estimation procedures that are appropriate for large data sets. Current spatial approaches generally involve ad hoc specifications developed to analyze small data sets, and often are quite cumbersome when applied to large data sets. This feature of current models is ironic because the most common approaches use maximum likelihood techniques to replace simple ordinary least squares estimation, and these techniques are grounded in asymptotic theory.

A second problem is the difficulty in distinguishing between common spatial models and general model misspecification. Spatial autocorrelation may well be the result of a misspecified functional form. Explanatory variables in spatial models are typically highly correlated across space, making results very sensitive to model specification. As an example, consider the excellent study by Brueckner (*Journal of Urban Economics*, 1998), who analyzes strategic interactions between neighboring municipalities in the adoption of growth controls. Many variables may explain the stringency of growth controls, only some of which are available to the researcher. Missing variables are likely to be correlated across space. Is an indication of strategic interaction real or merely the result of missing variables or functional form misspecification?

Nonparametric procedures are currently underdeveloped in spatial analysis. These procedures impose less structure than common spatial models and are fairly easy to apply to large data sets. Nonparametric statistics is still largely theoretical and difficult for the average practitioner to read. Suitable software is not publicly available. CSISS could play a pivotal role in making nonparametric procedures accessible to applied researchers through dissemination of lecture notes, working papers, and computer code. A similar role would be helpful in making other approaches - such as GMM estimation - accessible to applied researchers. In general, spatial analysis is hampered by the lack of suitable computer code. SpaceStat is an excellent program, but many researchers prefer to use one computer program for all applications. It would be helpful for CSISS to serve as a warehouse for computer code for implementing common spatial procedures.

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POSITION STATEMENT

One area that I have done some work in and one where the explicit consideration of the spatial dimension of externalities has led to new insights is in the provision of public goods. When the geography is defined by political boundaries, like school districts, cities, states, and nations, many spending and taxing decisions by one political entity cause "spillovers" that impose costs or benefits in other entities. Failure to enforce environmental controls, the provision of goods with public characteristics (environmental quality, parks, golf courses, traffic flow), and the setting of tax rates are some of the obvious examples. Within this context, we wish to study the type of behavior exhibited by the political entities vis-à-vis one another; i.e., the collective action. Various economic models (Nash-type, collusive, cooperative, Stackelberg) generate simultaneous empirical models that are essentially spatial econometric models. Distinguishing between the models is quite interesting in a policy context (e.g., "race to the bottom" or Lindahl solutions).

Based on my experiences with these problems, I have a couple of general observations. First, the dependent variable is often a limited (participate or not in the provision), suggesting the need for estimators (and software) for limited dependent variable models with spatial dependence. Second, these problems frequently give insights into the nature of the dependence and, therefore, how to construct the spatial weight matrix. For example, determining the spillins of sulfur emissions to one European country from other nations requires calculation of their location relative to prevailing winds as well as distance. In the context of local communities, modeling the provision of (say) parks and recreation requires some consideration of accessibility (perhaps travel time) rather than just distance. In "traditional" spatial econometric models, the weights are formulated with geographic concepts like contiguity, relative distance, and nearness, and then calculated using GIS tools. A common example would be the use of *pointdistance* in Arc/Info to generate a distance matrix that could be used to make various spatial weight matrices. The examples above, however, suggest that some weight matrices may be based on the geographic data or features (points, lines, polygons) and some of the attributes of that data. Hence, construction of the matrices may require more interaction with a GIS than the standard problems.

More specifically, I have found that in estimating such models, relative to "regular" data analysis and econometric estimation (using a package like SAS or STATA, for example), the integration of GIS technologies (spatial data analysis) and spatial econometric estimation is somewhat lacking in a couple ways. First, in an ordinary problem, missing values can be handled almost seamlessly. In spatial problems, however, the simple introduction of a new attribute with missing values results in quite a bit of work to re-create just the spatial weight matrix. Additionally, there may be conceptual problems with missing values as they generate a "hole" in the space under consideration. A similar situation exists with

respect to sampling. Regular econometric packages make sampling quite painless. Sampling in a spatial context, in my experience, is a different matter. Not only do I often not know how to sample (theoretically) but even when I do know, it seems difficult to implement the plan.

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**A Framework for Modelling Interaction
Between Ecological and Economic Systems (the Abstract)
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POSITION STATEMENT

**A Framework for Modelling Interaction Between Ecological
and Economic Systems (the Abstract)**

Transboundary environmental issues, like climate change, have in recent years received much attention from the side of political scientists and economists. Within the economics discipline, we witness sometimes differences between ecologically-oriented and mainstream economists, which may form a barrier for proposing clear policy recommendations on external effects in open and interacting spatial systems. This unfortunate situation may be due to lack of an integrated analytical framework as well as to the multi-disciplinarity of the problem at hand. The present paper aims to identify some relevant aspects for a methodological synthesis for analysing sustainable development issues in open economic systems with a view to the development of an integrative framework through which a great many ecological-economic studies can be investigated. We focus on conceptual issues centring around the integration on interacting economic and ecological subsystems, inter alia in relation to spatial externalities and ecological footprints. Our discussion enables us to build a framework for a systematic categorisation of various types of models for economic-ecological interaction. The paper concludes with some reflections on the way forward.

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POSITION STATEMENT

In recent years I have worked on several different topics in which spatial dimensions affect the degree and nature of externalities. The most recent portion of this work is joint with Will Strange (University of British Columbia) and focuses on agglomerative externalities arising from spatial concentrations of firms. I will focus my comments on that research.

The central purpose of the research program with Will Strange has been to shed light on three critical questions: why do cities exist? What makes them grow? What role will they play in the future? Since concentrating people and capital is costly, there must be some benefit that encourages profit maximizing firms to incur the costs of city building. These benefits are referred to as agglomeration economies. Broadly defined, agglomeration economies arise when spatial concentration of industry and employment provides firms with improved access to valuable human and non-human capital. The research program with Strange adds to the growing literature on urban development by incorporating detailed geographic information into a series of analyses designed to evaluate the determinants and geographic scope of agglomeration. As a result, our research focuses on several questions that have explicitly spatial dimensions including the following.

1. What is the geographic scope of agglomerative externalities? Although the theoretical literature argues that interaction between establishments declines with distance, most previous empirical studies have implicitly assumed that all activity in a rather large area such as a state, city, or county affects everyone in the area symmetrically.
2. What are the principal determinants of agglomeration? Although this issue has been examined at the state and county levels by Audretsch and Feldman (1996) and Dumais, Ellison, and Glaeser (1997), it has not been considered at a refined level of geography.
3. What are the implications of the information and telecommunications (IT/T) revolution for the future growth of cities, and more generally, for the mix of industries doing business in urban and non-urban areas? The IT/T revolution has greatly increased our ability to access valuable resources from remote locations. Access to human and physical capital, however, is the main reason firms choose to cluster in cities despite the high overhead costs of such locations. Thus, it certainly makes sense to consider the future of cities in this light. Gaspar and Glaeser (1998) provide a nice way of thinking about this issue, and also provide some suggestive evidence. However, they do not consider the relationship between IT/T and location directly.

To address these and other questions we have been working with data from the Dun and Bradstreet Marketplace file in conjunction with various MapInfo mapping

software products. The D&B data provide establishment-level information on over twelve million establishments in the United States. These data include information on establishment location down to the 5-digit zip code level, SIC codes to the 8-digit level, number of employees at the site and at the parent firm, sales, ownership status (e.g. corporate, subsidiary, public, etc.), age, various measures of IT/T use, and much more. With mapping software, we have geocoded the data and computed the spatial distribution of different types of employment and establishment attributes across the United States. For example, in a couple of our projects, we calculate a set of concentric ring variables that measure the levels own-industry and other-industry employment at a given distance from an establishment's own zip code, such as less than 1 mile, 1 to 2 miles, and on out to k miles.

Our first effort examined the geographic scope of agglomerative externalities. This was accomplished by modeling the number births of new establishments and related employment in a given zip code as a function of concentric rings of own- and other-industry employment associated with that location at the time the location decision was made. Results suggest that entrepreneurs in the six manufacturing industries studied care much more about the level of own-industry employment within a few miles than just 5 or 10 miles away. From this and related results we conclude that agglomeration economies attenuate rapidly at first, but then level off and attenuate much more slowly beyond 5 miles. For many applications, therefore, agglomerative externalities should ideally be studied at a relatively refined geographic level.

In a related project, Strange and I examine the microfoundations of agglomeration economies for 3- and 4-digit manufacturing industries in the United States. We regress the Ellison-Glaeser (1997) measure of spatial concentration for each industry on industry characteristics that proxy for the presence of knowledge spillovers, labor market pooling, shared intermediate inputs, and natural advantages. The analysis is conducted separately at the zip code, county, and state levels, and for both old and newly established enterprises. Results indicate that input sharing and labor market pooling are both associated with increases in agglomeration. In addition, there is suggestive evidence that knowledge spillovers further contribute to agglomeration, with the greatest effect stemming from innovation at small firms. Furthermore, there is evidence once again that agglomerative externalities attenuate geographically, especially among industries where input sharing and labor market pooling are important.

In work in progress, Strange and I are examining the impact of technological changes in information technology and communications on urbanization. Since these changes permit access to valuable resources from remote locations, they may impact the benefits from agglomeration. Ultimately, this means that they may change the role of the city in the economy, and the mix of industries and establishment-types choosing to locate in urban versus non-urban areas. For example, one question we are actively studying concerns the impact of IT/T on the industrial organization and size distribution of establishments in and outside of urban areas. In cities, firms can make use of a broad and deep network of outside suppliers, allowing for both a good match between a firm's needs and supplier competency, and for competition among suppliers. As noted in Vernon (1962, 1972) and Holmes (1999), this means that more vertically integrated establishments tend to locate outside the central city while less vertically integrated establishments tend to locate in downtown areas, *ceteris paribus*. As noted in Holmes and Stevens (2000), it is not necessarily true that the centrally located firms are smaller, however. With improvements in IT/T, distant firms are more accessible, so it may be possible to avoid the costs of vertical integration in industries able to take advantage of IT/T. That in turn has implications for the mix of industries and size distribution of establishments in and outside of urban areas.

With these thoughts as a backdrop, I would recommend that the CSISS consider offering a future workshop on the potential role of IT/T on spatial patterns of economic activity. In addition, further advertisement of underutilized data sources such as the Dun and Bradstreet MarketPlace file would be valuable. Training seminars on mapping software and related products - skills that are relatively uncommon among economists - would also be of considerable value.

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Externalities and Spatial Analysis V. Kerry Smith

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POSITION STATEMENT

There are few fields in economics where a recognition of the spatial dimensions of the analysis is more important than in environmental economics. As a result, there are a number of areas in environmental economics where more explicit integration of spatial analysis seems likely to lead to new insights. I selected four themes. Two of these relate to areas of established and continuing research and two are relatively new. All could benefit from the insights of those familiar with formal methods of spatial analysis.

1. Transport Modeling and Externalities

A major pre-occupation of environmental economists interested in externalities has been in specifying exactly how the activities of one (or more) agent(s) have negative (or positive) effects on others. For the case of air and water pollution from point sources, these inter-connections are often described with what are labeled transport models or, in simple cases, coefficients linking sources of the externalities and receptors of their effects. These models are an integral part of the definitions for the policies required to promote an efficient allocation of resources in the presence of externalities. Early examples of their role in: defining effluent charges can be found in Kneese and Bower [1979]; designing marketable permits systems in Tietenberg [1985]; and comparing the net benefits of command and control versus incentive based policies in Oates, Portney, and McGartland [1989]. With mobile and non-point sources of externalities, the spatial distribution of activities over an area influences the character of externalities. At the scale most commonly used to define environmental policy, time and spatially time delineated integrals of activity are often required to define the externalities that arise from mobile and non point sources. The economic models familiar to me are ill-equipped to deal with these issues in a way that has any hope of informing policy choices.

While most environmental economists recognize the importance of the technical relationships for point source questions, there are only a few examples of situations where the ways we treat them empirically have been explicitly evaluated. For example, in measuring the cost savings of an incentive based approach to controlling point and non-point sources how much does spatial delineation of differences in soil characteristics that affect surface and sub-surface loss of fertilizer and pesticides influence the conclusions? How does the modeling of the transport processes of streams and a river within a watershed influence the design of incentive based responses to TMDL (total maximum daily load) policies?

My own work and that of a former student, Kurt Schwabe (currently on the faculty of the University of California, Riverside) have attempted to address some of these questions for a watershed in North Carolina (see Smith et al. [1999], Schwabe and Smith [1999], and Schwabe [1996]).

Future research questions that are likely to be especially important in this area involve: (a) the use of statistical (as opposed to hydrological) models to describe

how emissions from one location are linked to ambient concentrations in other locations and to judgments about the implementation plans for TMDL in watersheds; (b) are simplified rules defining the spatial rates of exchange in emission credits (or marketable pollution permits), such as what is used for RECLAIM, "good enough" to realize the efficiency gains from these policies? and (c) what is the relevant spatial unit of analysis for environmental externalities? Available political boundaries rarely overlap with the units describing these environmental interactions.

II. Spatial Delineation and Non-Market Valuation

As in the case of externalities, recognition of opportunities to use spatial differences in environmental conditions have been important to the measurement of people's values for changes in environmental resources. The two most common revealed preference approaches that rely on spatial differences in access to resources or in the available amenities are: the travel cost recreation demand and hedonic property value models.

In the first the spatial distribution of consumers around recreation sites defines implicit prices for using these areas for recreation. For hedonic models the spatial locations of homes "delivers" environmental amenities and disamenities. The process of defining what these might be in empirical studies has often been arbitrary and, as a result, rarely subjected to spatial analysis. Actually these types of questions are relevant to both methods. Some examples help to illustrate how explicit spatial analysis can play a role.

In the case of travel cost models the analysis often seeks to describe how consumers' decisions to use a site are influenced by its quality attributes. These choices are assumed to reveal consumers' preferences for these quality attributes. Meeting this goal requires linking measures of quality characteristics to each recreation site. To illustrate the spatial questions in resolving these issues consider the case of water quality indexes. The water quality measures are usually developed for one set of objectives (e.g., monitoring the sources of pollution) and now must be used for another -- assessing ambient quality that is perceived by users. In the first case the task for the measure involves judging whether an emission rate exceeds a standard. In the other it is to evaluate quality at the locations of a water based recreation site that people use.

How should these interconnections be made and are the processes used important to conclusions derived about recreation site choice and the valuation of amenities? There has been limited research on the importance of such questions in recreation models (see von Haefen [1999] and Smith et al. [1993]).

Hedonic property value models require a parallel question to be addressed in linking measures of ambient concentrations of pollution to home sites -- nearest neighbor, kriging, and other techniques are available. However, few have been evaluated in a comparative framework assessing their impact on the results derived from hedonic models. In unpublished research, I participated in an evaluation of their influence on the estimates from hedonic models but know of few comprehensive evaluations of their importance to the models' results (see Sieg et al. [1999],[2000a],[2000b]).

An important issue that arises in using these models has recently been raised by Irwin and Bockstael [2000]. Their concern parallels issues raised in assessing social interactions (Manski [1993]). More specifically, the parallel arises when the marginal effect of a spatially delineated amenity on property values is affected by the average of amenity values in areas around that location. Open space is the example used by these authors, but any site specific attribute whose impact depends on adjoining values would raise the same issue. The value of a wooded lot depends on the neighborhood, a restored historic home on homes around it,

the impact of an undesirable land use on other adjoining land uses, etc.

III. Locational Equilibrium Models

Recently Epple and Sieg [1999] have developed a minimum distance estimator, using the conditions for a locational equilibrium of heterogeneous households selecting residential locations among communities differentiated by local public goods and housing prices. Locational equilibrium models predict a stratification of households by income among communities differentiated by public goods.

These models offer a potentially attractive way of introducing spatial delineation into economic models of markets. They do not require one measure to distinguish location, as in the case of monocentric city models. Instead, a vector of attributes of each community can be used to define the features of locations important to economic agents. Unobserved heterogeneity in households' taste for these features, together with the conditions for an equilibrium, provide predictions about the distributions of households that should be observed. With sufficient restrictions on preferences, it is possible to recover estimates of the preference parameters.

These models appear attractive to spatial applications because they avoid using political or distance related distinctions to include spatial features (through the attribute vectors) into a market model. My recent work with Sieg and graduate students has applied the framework to air pollution problems in Southern California (Sieg et al. [1999],[2000a]) and open space in North Carolina (Walsh [2000]).

A number of research questions have emerged from this activity that require more extensive use of spatial methods. A few examples include: (a) the definition of the spatial unit that defines the community or area that serves as a "commodity" that the models assume is selected for exclusive consumption by each household; (b) the impact of spillovers between communities for the equilibrium; (c) the endogeneity of the public goods sought in locational choice; (d) the modeling of land supply (or housing supply) within locational equilibrium framework; and (e) the linking of these economic location models to spatially delineated ecological models of the impact of land use on the functioning of ecosystems.

IV. Spatial Delineation and Experiments

Recently economists have used the spatial attributes of locational choices of households or firms to estimate the effects of rules delineated in space as a result of political decisions. Holmes [1998] used this logic to evaluate differences in right-to-work laws on firms' location choices and Black [1999] to evaluate whether school quality matters to parents.

In the environmental context, hedonic analyses of locally undesirable land uses perform comparable implicit experiments whenever a measure and a sample of housing sales are selected to evaluate the effect of the use (see Farber [1998] for a review of these studies). When these studies are expressed as spatially delineated experiments it seems natural to ask what do we expect of the spatially matched controls to test the hypothesis involved or recover the valuation estimates? I am currently involved in research that uses a new loop road as the source of an "experiment" changing local lands uses, availability of open space amenities, and the choice set available to households for residential decisions. A spatially defined repeat sales framework is what we plan to use to attempt to evaluate how households evaluate these choices (see Smith et al. [2000]).

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POSITION STATEMENT

The description of our meeting identifies three issues. The first is externalities, the second is increasing returns, and the third is spatial econometrics. For my contribution to our conference preparation, I'd like to call attention to a topic that involves all three issues.

The topic is the spatial concentration of crime, which Scott Freeman, Jeff Grogger and I wrote about in a paper in the JUE. In that paper, we argue that crime involves a spatial externality that leads to increasing returns to criminal activity, and thus to the agglomeration of that activity. Though this is not part of the paper, I also think the model leads to some difficult issues in spatial econometrics.

Here's the model. Crime is an economic activity. Individuals compare the expected return in that activity with the return in legal activities. They choose the activity with the highest expected return. The return to crime is determined by the rewards from a successful crime (the take) and also by the probability of being arrested. The higher is the probability of being arrested, the lower is the expected return. The probability of being arrested is determined by the police force in an area, but it is also determined by the number of other criminals. The larger is the number of criminals, the smaller is the probability that any one will be arrested. In that sense, any one criminal creates a positive externality for other potential criminals, an externality which causes increasing returns to scale.

In the paper, we thought about this externality operating on a neighborhood level. Because of the increasing returns, there can be two types of border equilibria for a neighborhood. It can be crime-free, a situation in which the very fact that there are few criminals means that the probability of arrest is very high and thus that the return to crime is very low. It can also be crime-ridden, a situation in which there are many criminals and the probability of arrest is very low. If the take from a crime were exogenous, this equilibrium would have everyone involved in crime. We ruled this out by assuming that the take was decreasing in the number of criminals. Regardless of that little fudge, the basic idea is that increasing returns creates two possible equilibrium, both extremes.

Also, in this model, crime increases in a city because more neighborhoods turn from crime-ridden to crime-free, not because crime increases in every neighborhood. And, large interventions could tip a neighborhood from one equilibrium to another. For example, a massive increase in the police force might tip the scale from crime-ridden to crime-free. Or a big increase in the juvenile population in a neighborhood might have the opposite effect.

The model is extreme, but I think it does capture an essence of reality. The question is whether it stands up to empirical scrutiny. Here's where the econometrics comes in. Suppose one had data on crime rates across neighborhoods at two point of time. If we were to time-difference the data, we would expect to see a tri-modal distribution. Many neighborhoods would remain the same. Some would go from very low crime rates to very high crime rates, and

some would go in the opposite direction. The question is how does one distinguish that pattern from, say, a normal distribution. One possibility is some kind of mixture of normals.

That's one problem. The other is the definition of neighborhood. On what spatial scale is this externality operating? Conceptually, we might think of the problem this way. Start with neighborhoods defined on a very small scale. It seems to me that, at a small scale, you would be most likely to pick up the tri-modal pattern if it exists. But, you'd also get a lot of noise, making it difficult to pick up anything. As you increase the scale of neighborhoods, you reduce the noise, but you are also more likely to average over the two types of neighborhoods. Is there a way that the data itself could be used to resolve this issue?

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POSITION STATEMENT

At UC Davis, I have been working over the past several years at incorporating more realistic and explicit notions of space into my research and graduate teaching. On the teaching front, in addition to incorporating new spatial material into my lectures in graduate natural resource economics, I have also organized and conducted formal seminar courses for graduate students focused on spatial econometric methods. These seminars were oriented around Anselin's books and economic journal articles by researchers including Ann Case and Nancy Bockstael. On the research front, I have supervised three major Ph.D. thesis efforts to completion recently (with two more in progress), all aimed at exploring the spatial behavior of resource users, principally in fisheries. These projects have been motivated by new questions that are fundamentally spatial in nature, and not informed by conventional non-spatial conceptual and empirical methods.

My motivations for moving in spatial directions are several. First, newly available information derived from remote sensing and GIS technologies presents opportunities to do empirical work with data sets that may contain unexploited sources of variation associated with spatial heterogeneity. This is important because good empirical economics relies on "natural experiments" to identify behavioral parameters of interest. For the most part, economists have had to find natural experiments in time series data, and time series data present their own difficulties that inhibit unbiased and efficient parameter identification. Economic decision makers surely make decisions that depend upon space as well as time. Ignoring the spatial dimension eliminates the opportunity to exploit additional natural experiments that are spatial as well as temporal. At minimum, ignoring spatial heterogeneity foregoes statistical efficiency gains, and it may also wash out important processes by aggregating behavior that is fundamentally spatial. A second reason for studying spatial economic processes is that, for the most part, economics is essentially a non-spatial discipline. While some subdisciplines have had to incorporate spatial dimensions into their conceptual foundations, most of the core of economics has not done so. This may be because adding the spatial dimension complicates deductive theorizing exponentially rather than proportionately. But the difficulties of exploring alternative spatial theories are rapidly diminishing as computational power increases. Even simple computational methods allow numerical exploration of decision making in experimental environments that incorporate spatial interaction and spatial externalities, different degrees of spatial coordination and myopia, and different kinds of spatial equilibration processes. Full exploitation of these new tools will probably require that economists overcome their reverence for "pure" deductive model-based thinking and come to appreciate the essential usefulness of computational methods for generating and testing behavioral hypotheses in more complex settings. In addition, we will probably have to develop new intuition about spatial processes, by learning how computational methods complement rather than substitute for analytical deductive modeling.

As a natural resource economist, I see particularly exciting new conceptual and empirical opportunities associated with spatial modeling. In many ways, the need

to address spatial dimensions of resource utilization problems is perhaps more pressing than in some of the other subdisciplines in economics. Natural resource economics has always been a field that is closely tied to supporting science disciplines, including biology and ecology, soil science, hydrology, etc. While most of these hard science disciplines have begun to transform themselves in ways that explicitly incorporate space, natural resource economics itself seems stuck in a paradigm that focuses on time in a mostly spatially heterogeneous setting. Thus continued multidisciplinary collaboration calls for an upgrading of the foundation of the field, in ways that parallel developments in supporting disciplines. In addition, there are some interesting natural resource policy options that are beginning to come under consideration that require an explicitly spatial framework. For example, many terrestrial mammals are managed with zoned policy instruments that take into account (generally in an ad hoc manner) the fact that the resource is migratory. What is often ignored is that resource users in this setting are also acting strategically to account for the fugitive nature of the resource. Thus managers are bound to be surprised unless they are able to forecast the spatial behavioral implications of policies. This is probably best done with integrated bioeconomic models that not only account for fundamental dynamics of resource and resource user behavior, but also fundamental spatial processes of both components. Another important example of a new resource management policy that requires spatial analysis in order to understand the potential implications is marine reserves. Understanding the implications of marine reserves requires, at minimum, a biological modeling approach that accounts for the important spatial processes at work, but also an understanding of the spatial behavior of resource users.

I see the study of spatial processes in resource economics as a "new frontier" of sorts, and one that will transform the field in a way similar to the manner in which Pontryagin's optimal control theory ushered in the "dynamics revolution" of the 1970s. There are several ways in which an institution like CSISS might accelerate progress. The first is to continue to promote, offer, and even subsidize exposure of students and faculty to spatial data handling methods, spatial statistics, and spatial modeling procedures. There is a considerable demonstration effect achieved by sprinkling students who have had some exposure to these workshops around the country in various programs. A second need is for sponsorship of additional workshops, proceedings, and special sections at ASSA, AEA, and AAEA meetings to promote spatial analysis. Most important is the need to demonstrate how spatial analysis matters. That is, what kinds of issues absolutely require spatial conceptual and empirical methods? What kinds of circumstances give rise to tangible payoffs to the investments necessary to master spatial methods? What happens when you ignore spatial heterogeneity and spatial processes? When are big mistakes in understanding most likely?

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