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Identifying the driving forces of rural economic growth: the impact of intellectual spillovers, technology, and amenities on employment growth in the US Midwest

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Identifying the driving forces of rural economic growth - the impact of intellectual spillovers, technology, and amenities on employment growth in the US Midwest

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ABSTRACT

This dissertation examines a number of issues related to economic growth in rural regions. The major themes explored are the roles of spatial technological externalities in the creation of new knowledge, the impacts of technology and technology spillovers on non-farm employment growth, and the role of amenities influencing non-farm employment growth. The theoretical model examines the interaction between rural and urban areas in an overlapping generations model allowing migration of high skill workers. The major theoretical conclusions reached suggests: 1) if technology spillovers exist in the urban market then high skill individuals will seek employment in the urban area where they earn an income superior to that in the rural area; and 2) the usefulness of rural amenities as a means to attract individuals is not unambiguous since the trade-off between higher urban wages and rural amenities will depend to a large extent on what type of equilibrium, i.e. high vs. low steady state equilibrium, the economy is in currently. In the empirical applications spatial econometric methods are employed to control for and examine the effect of economic activity in surrounding counties. In chapter two are identified the variables which have significant impacts on new knowledge and technology creation as measured by patents and finds impressive evidence of spatial knowledge spillins. That is, the patenting behavior in close, neighboring proximity tends to have a positive impact on patenting activity in the home county. Chapter three examines the role of local technology and knowledge creation embodied in patents on employment growth in the US Midwest over the period 1969-2000. The results from the empirical analysis overwhelmingly suggest that when patent counts within the county are used as an indicator for new knowledge and technology, then this variable has a strong positive impact on non-farm employment growth within the county. The final chapter exploits the tradeoff relationship between wages and non-monetary amenity benefits. The research indicates amenities in the home county as well as amenities in surrounding counties have an important influence on non-farm employment growth.

GENERAL INTRODUCTION

Introduction

Rural areas have traditionally been focused on production and distribution of agricultural products. However, with the development of labor saving technologies, labor once employed in primary agriculture has moved away from these rural areas to larger urban centers offering a wide spectrum of employment opportunities. For those continuing to remain in rural areas employment opportunities were generally quite limited. The realization that primary agriculture is no longer a driving force in many rural economies has prompted consideration of the factors influencing economic growth in rural areas. If proper rural policy is to be prescribed it is important to have both an appropriate theoretical model and realistic empirical framework that in essence captures the interaction of economic agents in a rural-urban dichotomy.

It is generally understood that the fundamental building block of economic growth is technological growth and new knowledge. Innovation and technical change take place at the local level but may have far reaching impacts. While the large scale, ie nationwide and global, impacts have been studied and documented in a much more macro framework, little has been done to examine the local impacts of such innovation. These local impacts may have important consequences for local economic growth even if the bulk of the benefits occur elsewhere. Unfortunately little research has focused on the impact of new knowledge created in small localized areas. If locally generated technology has a role to play in regional economic growth this is clearly a topic that warrants further consideration. The literature has been quite clear regarding the overall importance of innovation and technical change but has little to say about the actual growth process of new technology especially in smaller less populous regions dubbed rural.

Much of the growth literature comparing rural and urban regions and counties tends to focus on what urban regions have which rural areas have not. These factors may include developed communication networks, market access, market diversity, and entertainment and cultural opportunities. Unfortunately this view does not take into consideration the comparative advantages inherent in many rural areas. While rural regions have scare human resources by definition, they generally tend to have greater access to large uninhibited or sparsely populated areas that are or can be developed to provide amenity value. The realization rural areas tend to have higher capacity to develop and maintain natural and recreational amenities within the county has prompted a growing discussion on how to best design policies to add amenity value thereby attracting additional economic activity. As a policy variable, natural and recreational amenities as a development tool on their own or as part of a broader development strategy are receiving more and more attention.

Natural amenities, while obviously immobile themselves, can generally be enjoyed by any individual who takes the time to go and see or experience them. In this way the amenity benefits are essentially unimpeded by county boundaries. Likewise, technology and new ideas can cross from one county into another as simply as business dinner between colleagues or a social event with friends. When examining a map of counties in the continental US it is apparent that county boundaries are somewhat arbitrary and are unlikely to impede economic behavior in any meaningful manner. A quick look at commuting patterns throughout the US makes this apparent as thousands upon thousands of individuals cross county borders on a daily basis. When conducting empirical analysis involving rural counties one aspect often overlooked is the spatial relationship between counties. Many individuals cross county borders, often on a daily basis, when commuting to work and conducting business activity or taking a weekend trip to the lake or a park. In such a situation the classical assumption of independence among observations is clearly violated. Thus to obtain more reliable econometric estimates for our various models this spatial interaction should be taken into consideration explicitly in any estimation. While the use of spatial statistics is somewhat well developed, the development and application of spatial econometrics has been limited until recently. The last decade especially has experienced a marked increase in work applying spatial methods to economic problems to greatly increase the understanding of how economic agents interact in physical space. These tools can be effectively applied to economic empirical analysis where spatial relationships and externalities are believed to be present.

This dissertation examines a number of issues related to economic growth in rural regions. The major themes explored are the role of spatial technology externalities in the creation of new knowledge, the impacts of technology and technology spillovers on non-farm employment growth, and the role of amenities as factors influencing non-farm employment growth. While analyzing these issues both analytically and empirically attention is given to explicitly capture the spatial interaction that occurs between rural counties. The theoretical model examines the interaction between rural and urban counties in an overlapping generations model that allows for highly skilled or educated individuals to move between urban and rural counties. In the empirical applications spatial econometric methods are employed to control for and examine the effect of economic activity in surrounding counties. The forces underlying new knowledge and technology are modeled in a spatial framework to identify spatial innovative externalities and identify other factors contributing to the creation of knowledge as measured by patents. This spatial framework is also applied to empirical sections where are considered separately the role of technology and knowledge spillovers and the impact of amenities on employment growth in US Midwestern States.

Organization and Progression of Dissertation

This dissertation is organized into two major sections. The first section is conceptual in construct, while the second is primarily empirical. In the first section an overlapping generations growth model is developed with a rural and an urban region. The second section contains chapters two, three, and four and employs a number of spatial econometric methods. While these three chapters may each be considered separately on their own they are each linked by the underlying theme of rural economic growth and development and are further related by the type of methods used to derive empirical estimates. Chapter two examines factors influencing the creation of new knowledge and technology. The chapter three uses spatial econometric methods to examine employment growth in the US Midwest while capturing spatial externalities and patenting activity. The final chapter discusses what impact recreational amenities have had on employment growth.

The theoretical section develops a two-period, two-region overlapping generation model with which to examine some key rural-urban linkages and motivates much of the empirical research in the second section. In this framework the two regions are a rural and urban region with distinct but linked local economies. Only the highly skilled or highly educated individuals are permitted to move between regions in response to wage and market signals. Within the framework of this model, technology or knowledge spillovers enter the model in the form of a production spillover which impacts labor migration behavior. The second modification of the model introduces an amenity benefit to a rural region and attempts to show how amenities attract high skilled workers back to rural areas.

The analysis progresses in the second section to identifying the underlying forces influencing non-farm employment growth and creation of new knowledge. As all analysis in this section is concerned with data from counties, spatial econometric models are primarily used to compute numerical estimates. In chapter two the relationship between neighboring inventors and inventors in the home county is examined in greater detail and is then tested econometrically. Non-farm employment growth is modeled in a simple two period framework and the tested in a spatial model where new patents filed over the period are used as an explanatory variable in the third chapter. In the fourth and final chapter, a conceptual model, similar to the one used in chapter two but with a key modification to incorporate the value of amenities, is used to explain non-farm employment growth. In this chapter the role of amenities comes not only from amenities in the surrounding county but also from neighboring counties as well. A final section with general results and overall implications drawn from the analysis concludes the dissertation.

PART I. THEORETICAL FRAMEWORK OF THE IMPACT OF TECHNOLOGY SPILLOVERS AND AMENITIES ON RURAL-URBAN MIGRATION BEHAVIOR

CHAPTER 1 – THE IMPACT OF TECHNOLOGY SPILLOVERS AND AMENITIES ON RURAL-URBAN MIGRATION BEHAVIOR

Introduction

Rural economic growth, while a common topic of policy analysis and discussion, has generally not been afforded the same rigorous theoretical attention as countries and cities. Most rural counties in the US share a common theme in their general dependence on markets outside the county itself whether it is agriculture, manufacturing, tourism, or any number of other industries. In contrast, larger urban and metro centers often tend to be somewhat self- sufficient and have in the past been able to drive their economic growth from within. Applying existing macro economic growth models to rural economic behavior tends to omit some of the key factors which designate a region or area as rural. In general rural areas tend to be dependant on these larger urban centers for markets of both inputs and outputs. It is this key linkage between rural and urban areas that needs to be better understood if we are able to better understand the forces underlying rural economic activity and assess different policies for development.

One popular area of concern with rural areas has been the so called brain drain effect whereby the educated and intelligent of the rural population have moved from rural areas to larger cities with more opportunities and higher returns to skill. The migration of such individuals has had a two fold impact on rural counties. The first is the reduction in the number of people living in rural areas and contributing to the overall problems associated with maintaining an adequate tax base to provide essential services and maintain infrastructure. In many areas this has led to an increased dependence on federal and state transfer payments to local governments. The second problem deals with the type of people leaving rural areas. This brain drain problem is in specific reference to the loss of well educated or highly skilled individuals, and since these people tend to have higher incomes this can appear to further exacerbate the problems of both reduced total county income and a reduction in county income per capita. This apparent exodus away from rural areas by high skill individuals may be partly due the lack of networking, formal or informal, found in urban areas where individuals are much more often in contact with one another. This interaction has the potential to benefit from positive knowledge, technology, production, and other such beneficial economic externalities. While the relocation of skilled and educated individuals from rural to urban areas brings about obvious concerns regarding provision of local services and the political view of maintaining a viable rural economy, there may be a positive side which is much less frequently addressed. If there is a positive correlation between rural and urban incomes then the low skill workers in rural areas may actually gain from this brain drain effect. If high skilled and highly educated workers are able to attain a higher overall level productivity in urban areas through the realization of production externalities, thus attaining a higher level of income, then low skill workers may better off due to a high correlation between rural and urban market activity.

Another area receiving much attention in rural America is the use of existing natural and recreational amenities and/or development of additional natural and recreational amenities in rural areas to attract economic activity. Such development programs are obviously aimed at making rural regions more attractive to both people and potential employers. Many have maintained one reason residents in rural areas have consistently received lower overall incomes compared to their urban counterparts is related to the idea there are positive quality of life attributes and rural amenities that provide a non-monetary benefit equal to or in excess of the difference in incomes. In a static setting it would thus appear an increase in the amenities associated with rural areas will indeed attract more individuals and increase the viability of the rural counties which adopt such programs. However, in a dynamic model the outcome of such a result is not obvious. If there is a strong relationship between the wages in urban areas and rural areas, an increase in the amenity benefits will result in higher non-monetary benefits to rural residents and workers and there will be a resulting incentive for rural employers to pay lower wages as long as a lower bound, such as a minimum wage restriction, is not reached. So in a dynamic general equilibrium setting there are two forces at work, the increased utility from the amenities directly and the reduced budget set from lower wages, and it is not always clear which force will dominate in equilibrium.

The economics growth literature has developed considerably in the latter part of the last century. In the next section a review of some of the major contribution to the economics growth field are discussed. Of particular importance here are those developments which have had a significant contribution to understanding the role and importance of technology in economic growth. Following this review, a two region economic model is developed to specifically examine two questions: 1) How do technology spillovers affect economic activity between two regions, and 2) Will recreational amenities provide incentive to partially offset the lack of high skill and high wage jobs to attract workers. In addition adding enlightenment to these two questions, the model also provides some interesting results relating to rural and urban interrelationships. The last section provides a discussion of the results in relation to real world applications and suggestions for future theoretical and empirical research.

Literature Review

The pioneering economic growth model is the Solow[1] growth model. In this model output is a function of a multiple input production function utilizing capital and labor to produce a single output. One of the crucial assumptions in this model is the production function must exhibit constant returns to scale. Technology growth enters into the model as a parameter affecting the "effectiveness" of labor. Technology is of the labor augmenting or Harrod-neutral type. One feature of this model is time does not enter the production function directly but only indirectly through evolution of the parameters over time. In the Solow model the savings rate is assumed exogenously given.

While the Solow model predicts correctly the effects of saving and population growth, the magnitudes of such values are not of the correct magnitude[2]. One of the major problems with the Solow model is the exogenously given savings rate. Without consumers explicitly included within the model it is impossible to talk about welfare and policy. Relaxing this assumption has a number of advantages. Firstly, it shows that the key conclusions of the Solow model hold with or without endogenous savings. Secondly, the inclusion of consumers' choices explicitly into the model allows for welfare analysis. Without consumers preferences taken into consideration it is impossible to determine whether one outcome is better or worse than another. Thirdly, infinite and finite-horizon models are used to study other economic issues and as such are useful tools (D. Romer, 1996).

The Solow growth model has been further developed into two branching areas using microeconomic foundations to determine savings within the model. The Ramsey-Cass-Koopmans (RCK) model based on the works of Ramsey (1928), Cass (1965), and Koopmans (1965) has foundations in a model with homogeneous consumers who are infinitely lived and competitive firms who rent capital owned by household and hire labor. The other extension is the overlapping generations (OLG) model developed by Diamond (1965). In OLG models individuals exist for a finite number of generations in

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[1] Based on Solow (1956) and is also known as the Solow-Swan model.
[2] However, Mankiw et al. (1992) show when population growth and capital accumulation is held constant, the Solow model augmented with human capital gives reasonable predictions.

the economy and each period there are new individuals introduced or "born" into the economy and the members of the oldest generation ceases to exist or "dies" but the economy itself lasts forever. OLG models are often used to examine policies such as social security and other intra-generational transfers.

The RCK model as an extension to the Solow growth model is a key advancement in the inclusion of household utility optimization within the model. However, the RCK is still plagued by some of the same shortcomings evident in the Solow model. King and Rebelo (1993) demonstrate that when looking at transitional dynamics i.e. moving toward the steady state, the neoclassical growth model with endogenous savings still gives unrealistic predictions. In particular, marginal products are required to be much larger than is realistic in early stages of development. While the RCK model may give inaccurate predictions as to the rate of growth to the steady state, Rappaport (2001) suggests the model may be augmented to include convex marginal adjustment costs to give more reasonable growth estimates. In a multi-input production process, assuming inputs are complementary, only one of the inputs need have this convex marginal cost structure. The basic concept here is really quite intuitive as this convex cost structure implies some type of input scarcity in one of the inputs required in the production process, effectively creating a bottleneck. King and Rebelo (1993) also suggest under reasonable parameterizations of the production function, transitional dynamics play a small role in explaining observed growth rates. They suggest better explanations of growth may be found in endogenous growth models placing greater importance on human capital formation and/or endogenous technical progress.

Further limitations and criticisms have been brought to bear on the RCK model. In the neoclassical framework one of the assumptions requires all regions have access to the same technology. Romer (1994) uses a simple example of the United States and Philippines to show under such an assumption of access to the same technology and under reasonable parameterization the model predicts unrealistic rates of saving. Relaxing the assumption of equal access to technology allows for more realistic predictions. Further detracting from the neoclassical model is the fact that real world effects like migration and wage differentials are difficult to reconcile within the model (Lucas, 1988).

Beyond the RCK model is a more compelling literature in the endogenous growth school of thought. In the neoclassical growth model technology is assumed to remain constant or grow at some exogenously given rate. In addition, all firms, regardless of location, are assumed to have access to the same technology. Endogenous growth essentially allows for the possibility of firms to influence directly or indirectly how this technology parameter changes over time. In the direct case, firms expend resources to influence the growth path of technology. Indirectly, technology may be influenced via spillover effects from other firms or industries. Major contributions to the endogenous growth literature come from Romer (1986,1987, 1990, and 1994), Schultz (1961), Uzawa (1965), Lucas (1988), Barro (1990), and Caballe and Santos (1993).

Lucas in his seminal 1988 paper on economic development considers three different models explaining development: 1) a model emphasizing physical capital accumulation and technological change, 2) a model emphasizing human capital accumulation through formal schooling, and 3) a model of human capital accumulation focusing on learning by doing. The model focusing on physical capital resembles the neoclassical Solow model, as was the authors intent. The second model with human capital produced through schooling is able to account for average rates of growth but is not capable of capturing diversity among countries or diversity overtime within a country. The last model builds on Arrow's (1962) notion of learning by doing. The basic concept here, as the notions term implies, is after repeating a task a number of times one becomes more efficient, or the marginal productivity increases with the number of past tasks. Learning to ride a bike or taking mathematical derivatives are good examples. In the later case the first derivative requires a good deal of effort and thought, after a few times however this task requires almost no effort. Arrow uses the example of airplane manufacture and notes that the marginal productivity of labor greatly increases after the first few aircraft have been produced.

In the Lucas adaptation, human capital accumulation is assumed to be specific to a particular production process or good and is acquired on-the-job. If different goods have different potentials for human capital growth then comparative advantage determines what country produces what good and also determines what are the countries respective human capital growth rates. This model thus is capable to explaining long-term differences of growth rates among countries and need not be linked to the countries initial level of capital, physical or human. Lucas also notes an effective model of economic growth needs to capture sustained growth with sustained diversity in income. In addition, theory needs to be able to allow the patterns of growth to change as well. Uzawa (1965) looks at an economic growth model where technology is advanced through conscious allocation of resources to increasing the level of knowledge. In this model Uzawa considers labor augmenting technology whose growth is impacted by the fraction of the labor force employed in education.

One assumption often imposed when modeling economic growth is perfect competition among firms. While perfect competition is a useful theoretical tool, its application to the real world is suspect. This is especially true in an environment where huge research expenditures require very large expected returns and the perfect competition result equating price and marginal cost leaves little incentive for the firm. Patents provide one method of allowing firms to recoup their investment cost. Such a concept is modeled by Nordhaus (1969) where patents effectively provide the innovator with the ability to earn monopoly rents for a specified period of time. To allow for firms to undertake conscious investments in technology Romer (1990) suggests an alternative market structure. In his model he assumes technology is an input in production and this input is non-rival and partially excludable. He shows equilibrium cannot exist in the context of perfect competition but rather monopolistic competition supports equilibrium. One key conclusion from the Romer (1990) paper is human capital stock drives economic growth rather than simply the size of the population.

Growth with produced inputs, such as technology and human capital, is often modeled while taking saving to be exogenous as in the Solow model. Models where inputs are produced and savings are taken to be endogenous are a degree more difficult. However, if one is interested in the welfare impacts, consumer optimization is necessary. D. Romer (1996) explores a simplified model with no population growth, and a single produced input with constant returns to scale. Models with endogenous saving and multiple inputs or non-constant returns are much more difficult. Some examples of such models however are found in Mulligan and Sala-I-Martin (1993) and Romer (1986). Mulligan and Sala-I-Martin look at a model with two produced inputs with constant returns to those inputs and no population growth. Romer develops a model with a single produced input and non-constant returns.

When considering research, development, and technological advance it is important to also take into account the effects of technological spillovers. Jacobs (1969) and Bairoch (1988) argue that innovations are made in cities due to larger interaction with people. Without the opportunity to learn from others and share ideas there would be no reason for people to pay large rents to work in a city (Glaeser et al. 1992). Glaeser et al. (1992) suggests that the relatively easy flow of ideas may explain how cities survive despite high costs of living. Two relatively polar ideas of market structure concerning knowledge spillovers and economic growth are discussed below. The first, MAR, as termed by Glaeser et al. (1992), is based on the works of Marshall, Arrow, and Paul Romer. The

MAR theory suggests concentration of an industry in an area helps knowledge spillovers and thus positively influences growth of that industry. Arthur (1989) used Silicon Valley as an example of such a phenomenon. MAR also predicts that local monopoly is better for growth than local competition. This prediction is similar to that made by Schumpeter (1942). Romer (1996) and Lucas (1988) argue that externalities, especially knowledge, are important determinants of growth. Lucas is primarily concerned with economic development across countries over time. Loury (1979) and Dasgupta and Stiglitz (1980) model knowledge spillovers. Griliches (1979) surveys empirical literature on the role of knowledge spillovers.

Porter (1990) believes that spillovers come from within the industry and that growth is fostered by competition and not monopoly. He gives the example of the Italian ceramics and gold jewelry industries. Jacobs (1969) believes that the most important spillovers come from between industries rather than within the industry. The conclusion here is industry diversity and not industry specialization that promotes growth. Jacobs also favors local competition rather than local monopoly as a market environment for encouraging growth. The Glaeser et al. (1992) empirical analysis lends support to the Jacobs frame of thought.

Much of the economic growth literature has been developed using infinite horizon models. However, a large amount of research on growth has developed from overlapping generations (OLG) models. Bencivenga and Smith (1997) uses a two period multi-region OLG model to examine rural to urban migration, specifically interested in employment. The model is characterized by rural-urban migration and urban unemployment arising from an adverse selection problem in the labor market. Production in rural areas is via a single input production function, using only labor, to produce an agricultural good. Urban production produces a manufactured good via a technology employing capital and skilled labor. Such a specification follows that used by Drazen (1982), Drazen and Eckstein (1988), Ranis (1988) and Rauch (1993). Bencivenga and Smith (1997) demonstrate that such rural to urban migration and underemployment can give rise to a large number of equilibria displaying undamped oscillation. Many of the equilibria display long periods of growth followed by short but severe recessions.

Another dual economy approach to look at rural growth is that of Drazen and Eckstein (1988). Here the authors develop a dual sector OLG model where the rural sector is characterized by production using labor and land and urban production is via labor and physical capital. They compare a fully competitive environment in the land market to one where land is controlled by a subset, landlords, of the population. They show that under a landlord regime, capital growth and aggregate income are higher than under a fully competitive environment. The rationale follows that when landlords are present the remainder of the population is able to store their savings only in the form of capital, which therefore increases the per-capita stock of capital and thus income, since landlords extract all excess rents from the land market.

OLG models have also been used to explain endogenous growth. Bencivenga and Smith (1991) look at the effects of financial intermediation and endogenous growth in a three period, closed economy model with two inputs. To model endogenous growth behavior so savings "matter" for growth, Bencivenga and Smith (1991) use an externality in production in a manner used by Romer (1986). In the first period agents save all their income and then find out at the beginning of the second period if they are entrepreneurs or not. In the first period agents must decide what types of investments to make, either in a liquid investment or an illiquid investment, capital, useful only to entrepreneurs in the 3rd period. The non-entrepreneur has no 3rd period utility and will liquidate all capital in the 2nd period if they realize they are not entrepreneurs. Bencivenga and Smith (1991) use financial intermediaries similar to those of Diamond and Dybvig (1983) to show that under certain conditions where the financial intermediaries shift the composition of savings to have a greater share of capital, there can be more economic growth. Essentially, financial intermediation in this case reduces the need to prematurely liquidate productive capital. Galor and Zeira (1993) show in the presence of credit market imperfections and indivisibilities in human capital, distribution of initial wealth can determine which capital steady state an individual may end up at. The authors argue this phenomenon may partially explain persistent cross-country income differences. Ehrlich and Lui (1991) use an OLG model of endogenous growth where human capital is the driving force behind economic growth. In their paper, parents invest in their children's education for both old age security and altruism.

OLG models have been used in a number of instances to examine various aspects of natural resources managements and provisions of public goods. To address provision of public goods and taxation, Batina (1990 a,b) demonstrates that when distortionary taxes are used in a dynamic economy, the social cost of the public good can actually be lower overall relative the first best case due to the effect of government tax policy on the dynamics of the system. This is in sharp contrast to the static result where the use of such distortionary taxes to finance a public good will generally raise the social cost of the good due to deadweight loss of taxation. Krautkraemer and Batina (1999) using an OLG model show that when amenity value is added to the stock of value for natural resources there is increased incentive for preserving the natural resources if the amenity values are captured by interregional transfers.

Model preliminaries

The set up used in this model is both a further development and a simplification of Bencivenga and Smith (1997) where the authors examine migration behavior of high skilled workers between rural and urban areas further developing the seminal work of Lewis (1954), Todaro (1969), and Harris and Todaro (1970). The Bencivenga and Smith (1997) are expanded in two areas related to current issued faced by rural regions. First, a technology or a knowledge spillover is introduced to examine the behavior of highly skilled workers to in part address the so called "brain drain" problem. The second explores the impact of amenities on migration behavior of the high skill individuals under two different methods of introducing amenity benefits in the rural area. These collectively address some of the more important issues facing economic growth in rural regions. In the discussion to follow a basic model is derived in its simplest form. Using a reasonable set of base parameter values, a sensitivity analysis of the effect of changes to parameter values on the steady state equilibrium values for the capital-labor ratio and high skilled labor migration are presented and discussed. The model is then augmented by introducing knowledge spillovers in the urban region and amenities in rural region. Following the development of the model sensitivity analysis is performed on key technology and amenity variables about the equilibrium. A discussion of the results and some final conclusions with implications ends this section of the dissertation.

There are two regions in this economy: one region, primarily rural, is devoted to the production of an agricultural good (v), the other region produces an aggregate technology intensive good (h) which is located primarily in urban areas. The technology intensive can be thought of a combination of financial services, high technology goods and services, research and scientific products may be thought to make up part of this high-tech good. The technology intensive good is produced in urban areas where many of the previously identified goods can only be produced by matching capital with high skill labor.

The economic agents within this economy live for two periods only and live where they choose to work. Each period there are n^t born into the economy and n^{t-1} die so the population growth rate within the economy is n. There are two types of workers in this economy, a low skill type and a high skill type and have a share in the total workforce of θ_1 and θ_2 respectively where $\theta_1 + \theta_2 = 1$. The workers level of skill is driven by human capital they possess. While human capital is acquired through education (Lucas 1988; Ehrlich and Lui 1991), acquisition of education is not modeled explicitly. The low skill worker is only suited to working in the agricultural industry in the rural region since they lack the necessary human capital or training to find employment in the high technology industry located in the urban area. While engaged in agricultural production, a low skill worker expending their entire labor endowment (=1) is able to produce π_1 units of the agricultural good. In this model all agents have preferences such that they consume only in the second period and necessarily supply all their labor endowment in the first time period. The high skill worker, however, has a choice where they can work and live. If they chose to work in the rural region on agricultural production, their one unit of labor endowment is able to produce π_2 units of the agricultural good. Since the agriculture sector in rural area is developed in the sense that production is highly dependant on managerial abilities, human capital, and risk and production strategies and planning, the high skill worker is assumed to be more productive in agriculture than the low skill worker so $\pi_2 > \pi_1$. This assumption is supported by a number of studies confirming this result (see Huffman 1977, 1980, and 2001). The high skill worker may, alternatively, find employment in the urban sector where they can earn a wage in the technology sector of w_t in period t. The price of the technology good is normalized to one and the relative price of the agricultural good at time t is p_t. The labor income for the low skill worker is thus $p_t\pi_1$ and either $p_t\pi_2$ or w_t for the high skill worker depending on where they ultimately work. The vehicle of savings here is through capital, K. In the first period consumers save all their income as capital and earn a rate of interest of r_{t+1} in the next period from their savings. In the second period they then decide how best to spend their income.

Utility Maximization

All people in this economy have the same twice differentiable, increasing, and quasiconcave utility function. Here the utility function is assumed to take on the following Cobb-Douglas functional form:

$$U(v,h) = v^{\alpha} h^{1-\alpha} \qquad (1)$$

where $\alpha \in (0,1)$. The parameters α and $1-\alpha$ are the relative preference for the agricultural and technology good respectively. Each agent faces the budget constraint that expenditures cannot exceed labor income

$$\psi \geq p_{t+1}v + h \quad (2)$$

where ψ is worker labor income and is equal to $r_{t+1}p_t\pi_1$ for the low skill worker, and either $r_{t+1}p_t\pi_2$ if the high skill worker is in rural region or $r_{t+1}w_t$ if they work in the urban area. Since utility is strictly increasing in its arguments and they die next period, the budget constraint in (2) will always hold with equality. Utility maximization follows standard procedure and given the type of utility function chosen, will satisfy the Kuhn-Tucker conditions for a local maximum. The resulting demand equations are:

$$v^* = \frac{\psi\alpha}{p_t} \quad (3)$$

and;

$$h^* = \psi(1-\alpha) \quad (4)$$

The fraction of type 2 agents seeking employment in the urban area is ϕ_t for $\phi_t \in (0,1]$. Also, the fraction of high skill workers seeking employment in the rural area is $(1-\phi_t)$. Given this the aggregate demand for the two goods in any given period is

$$\sum v^* = n^t \left[\theta_1 r_{t+1} \frac{p_t\pi_1\alpha}{p_{t+1}} + \theta_2(1-\phi_t)r_{t+1}\frac{p_t\pi_2\alpha}{p_{t+1}} + \theta_2\phi_t r_{t+1}\frac{w_t\alpha}{p_{t+1}} \right] \quad (5)$$

$$\sum h^* = n^t\left[\theta_1 r_{t+1}p_t\pi_1(1-\alpha) + \theta_2(1-\phi_t)r_{t+1}p_t\pi_2(1-\alpha) + \theta_2\phi_t r_{t+1}w_t(1-\alpha)\right] \quad (6)$$

The two relationships above are used in part to define the good markets clearing conditions to derive the competitive equilibrium in this economy.

Firm Behavior

Firms in the urban area use the proportion of type 2 workers and the saved capital to produce the technology good. This process is done through the use of a constant returns technology. The production function is of the form $F(K_t, L_t)$ where K and L are total capital and labor respectively. Complete or 100% depreciation is assumed so capital depreciates completely from one period to the next. L_t is the total labor force in formal manufacturing and can be written as $L_t = \theta_2 \phi_t n^t$. The production function is assumed to exhibit constant returns to scale from the point of view of firms, i.e. $F(\lambda K_t, \lambda L_t) = \lambda F(K_t, L_t)$. For this analysis the CES functional form is chosen to represent the production technology.

$$F(K_t, L_t) = \left(aK_t^\rho + bL_t^\rho\right)^{\frac{1}{\rho}}$$

or, dividing through by the labor employed in high tech production, expressed in intensive form:

$$f(k_t) = \left(ak_t^\rho + b\right)^{\frac{1}{\rho}}.$$

Firms are assumed to be competitive and pursue the objective of profit maximization. Setting up the firm profit maximization problem and optimizing gives the following two first order conditions for a maximum where both inputs are used in strictly positive quantities:

$$r_t = f'(k_t) = \left(ak_t^\rho + b\right)^{\frac{1-\rho}{\rho}} ak_t^{\rho-1} = a^{\frac{1}{\rho}}\left[1 + \left(\frac{b}{a}\right)k_t^{-\rho}\right]^{\frac{1-\rho}{\rho}} \tag{7}$$

$$\begin{aligned} w_t &= f(k_t) - k_t f'(k_t) = \left(ak_t^\rho + b\right)^{\frac{1}{\rho}} - k_t\left(ak_t^\rho + b\right)^{\frac{1-\rho}{\rho}} ak_t^{\rho-1} \\ &= b^{\frac{1}{\rho}}\left[\left(\frac{a}{b}\right)k_t^\rho + 1\right]^{\frac{1-\rho}{\rho}} \\ &= b^{\frac{1}{\rho}}\left(\frac{a}{b}\right)^{\frac{1-\rho}{\rho}} k_t^{1-\rho}\left[1 + \frac{b}{a}k_t^{-\rho}\right]^{\frac{1-\rho}{\rho}} \end{aligned} \tag{8}$$

The above two equations represent the marginal returns to the factors of production.

Equilibrium

We have defined the conditions necessary for both firms and workers to optimize their behavior. Here it is relevant to define the conditions necessary to bring this model economy into general equilibrium. An equilibrium consists of a sequences of prices, $\{p_t\}_{t=0}^{\infty}$, capital labor ratios, $\{k_t\}_{t=0}^{\infty}$, and migration decisions, $\{\phi_t\}_{t=0}^{\infty}$ such that:

i) agents maximize their utility,

ii) firms maximize profits,

iii) the capital (credit) market clears,

iv) the agricultural market clears; and

v) the technology goods market clears.

Condition i) is satisfied by equations (3) and (4). The profit maximizing behavior of firms is inherent in equations (7) and (8). The only method of savings here is via capital so condition iii) will be satisfied when:

$$K_{t+1} = n^t \left[\theta_1 p_t \pi_1 + \theta_2 (1-\phi_t) p_t \pi_2 + \theta_2 \phi_t w_t \right] \tag{9}$$

The amount of capital available in the current period is equal to the total savings, or here labor income, from the previous period. Market clearing in the agricultural market will require that all agricultural goods produced in the current period to be equal to the total demanded from the current old:

$$n^{t+1}\left[\theta_1\pi_1 + (1-\phi_{t+1})\theta_2\pi_2\right] = n^t\left[\theta_1 \frac{r_{t+1}p_t\pi_1\alpha}{p_{t+1}} + \theta_2(1-\phi_t)\frac{r_{t+1}p_t\pi_2\alpha}{p_{t+1}} + \theta_2\phi_t\frac{r_{t+1}w_t\alpha}{p_{t+1}}\right] \tag{10}$$

The final condition v) will be satisfied when the amount of goods produced in the current period is equal to the amount demanded by the current old in (6) plus the goods purchased by the current young from their labor income to be stored at no cost to become capital in the next period, K_{t+1}.

$$F(K_t, L_t) = n^t \begin{bmatrix} \theta_1 r_{t+1} p_t \pi_1 (1-\alpha) + \theta_2 (1-\phi_t) r_{t+1} p_t \pi_2 (1-\alpha) \\ + \\ \theta_2 \phi_t r_{t+1} w_t (1-\alpha) \end{bmatrix} + K_{t+1} \qquad (11)$$

While equations (9) thru (11) represent the market conditions that need to be satisfied in equilibrium, we in effect only need two of these to be satisfied and the third will also be satisfied according to Walras law.

There are some additional properties that will be useful in simplifying the above system. First, in order to have an "interesting" situation where type 2 workers work both in rural and urban areas requires that individuals' utility is the same regardless of the area where they actually work. Substituting the demand functions (3) and (4) into (1) we can derive the indirect utility function for type 2 workers under both employment regimes. It is clear high skill workers will only be indifferent between rural and urban employment when the following condition holds:

$$p_t \pi_2 = w_t \qquad (12)$$

The second relationship we can use deals with properties of the capital labor ratio.

$$k_{t+1} \equiv \frac{K_{t+1}}{L_{t+1}} = \frac{K_{t+1}}{\theta_2 n^{t+1} \phi_{t+1}}$$

$$\Rightarrow K_{t+1} = k_{t+1} \theta_2 n^{t+1} \phi_{t+1} \qquad (13)$$

Using equation (9) with the two equations above we can simplify the capital market

$$k_{t+1} = \frac{n^t}{\theta_2 n^{t+1} \phi_{t+1}} \left[\theta_1 \frac{w_t}{\pi_2} \pi_1 + \theta_2 (1-\phi_t) \frac{w_t}{\pi_2} \pi_2 + \theta_2 \phi_t w_t \right]$$

$$k_{t+1} = \frac{w_t}{n\phi_{t+1}}\left[\frac{\theta_1}{\theta_2}\frac{\pi_1}{\pi_2}+1\right] \tag{14}$$

Similarly, using (10) with the relationships in (12) and (13), we can simplify the market clearing condition for the agricultural good

$$n^{t+1}\left[\theta_1\pi_1+(1-\phi_{t+1})\theta_2\pi_2\right]$$

$$= n^t\left[\theta_1 r_{t+1}\frac{w_t}{\pi_2}\frac{\pi_1\alpha}{\left(\frac{w_{t+1}}{\pi_2}\right)}+\theta_2(1-\phi_t)r_{t+1}\frac{w_t}{\pi_2}\frac{\pi_2\alpha}{\left(\frac{w_{t+1}}{\pi_2}\right)}+\theta_2\phi_t r_{t+1}\frac{w_t\alpha}{\left(\frac{w_{t+1}}{\pi_2}\right)}\right]$$

$$n^{t+1}\left[\theta_1\pi_1+(1-\phi_{t+1})\theta_2\pi_2\right]=n^t\alpha\frac{r_{t+1}w_t}{w_{t+1}}\left[\theta_1\pi_1+\theta_2\pi_2\right]$$

$$\phi_{t+1}=\left[1-\alpha\frac{1}{n}\frac{r_{t+1}w_t}{w_{t+1}}\right]\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right] \tag{15}$$

The last set of substitutions involves introducing the conditions for a competitive profit maximizing firm equating value of marginal product (VMP) of labor and capital equal to their marginal costs in (7) and (8). Substituting the more concise version of the wage into (14) we can derive the following:

$$k_{t+1}=\frac{b^{\frac{1}{\rho}}}{n\phi_{t+1}}\left[\left(\frac{a}{b}\right)k_t^{\rho}+1\right]^{\frac{1-\rho}{\rho}}\left[\frac{\theta_1}{\theta_2}\frac{\pi_1}{\pi_2}+1\right] \tag{16}$$

To simplify further the equation in (15) we use the equation for the rental rate of capital and both versions of the equation representing the wage. The following relationship will be useful:

$$\frac{r_{t+1}w_t}{w_{t+1}}=\frac{\left(a^{\frac{1}{\rho}}\left[1+\left(\frac{b}{a}\right)k_{t+1}^{-\rho}\right]^{\frac{1-\rho}{\rho}}\right)\left(b^{\frac{1}{\rho}}\left[\left(\frac{a}{b}\right)k_t^{\rho}+1\right]^{\frac{1-\rho}{\rho}}\right)}{b^{\frac{1}{\rho}}\left(\frac{a}{b}\right)^{\frac{1-\rho}{\rho}}k_{t+1}^{1-\rho}\left[1+\frac{b}{a}k_{t+1}^{-\rho}\right]^{\frac{1-\rho}{\rho}}}$$

$$\frac{r_{t+1}w_t}{w_{t+1}} = k_{t+1}^{\rho-1}\left(\frac{a}{b}\right)b^{\frac{1}{\rho}}\left[\left(\frac{a}{b}\right)k_t^{\rho}+1\right]^{\frac{1-\rho}{\rho}} \qquad (17)$$

Substituting (17) into (15) will give:

$$\phi_{t+1} = \left[1 - k_{t+1}^{\rho-1}\frac{\alpha}{n}\left(\frac{a}{b}\right)b^{\frac{1}{\rho}}\left[\left(\frac{a}{b}\right)k_t^{\rho}+1\right]^{\frac{1-\rho}{\rho}}\right]\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right] \qquad (18)$$

The above equation along with the equilibrium equation of motion for the capital labor ratio, restated below for convenience, define the competitive equilibrium.

$$k_{t+1} = \frac{b^{\frac{1}{\rho}}}{n\phi_{t+1}}\left[\left(\frac{a}{b}\right)k_t^{\rho}+1\right]^{\frac{1-\rho}{\rho}}\left[\frac{\theta_1}{\theta_2}\frac{\pi_1}{\pi_2}+1\right] \qquad (19)$$

The two equations above represent the equilibrium laws of motion for the capital labor ratio and the proportion of high skill workers employed in the high tech area. A steady state is reached when there is no difference between the capital labor ratio over time, i.e. $k_{t+1} = k_t = k$, and the portion of high skill workers is not changing over time, i.e. $\phi_{t+1} = \phi_t = \phi$. While it is possible in principle to solve for the equilibrium steady state values, this task will be somewhat cumbersome given the non-linearity of the equations defining the equilibrium. However, using a set of initial parameters and arbitrary starting values, we can use various algorithms to 1) graph the path to the steady state and 2) compute steady state equilibrium values for the capital labor ratio, k, and the proportion of high skill workers working in the urban sector, ϕ [3].

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[3] The graph of the difference equation was obtained by converting the equations into a differential equation by using the relationships $k' = k_{t+1} - k_t$ and $\phi' = \phi_{t+1} - \phi_t$ and then using the ode45 program in MATLAB to generate the dynamic equilibrium path. When solving explicitly for the steady state equilibrium, it was found there are at least two non-zero pairs of the capital-labor ratio and the labor migration parameter for all of the

In the discussion to follow a presentation of some preliminary estimation results used to examine the sensitivity to changes in model parameters. Further model development of the model to include urban growth externalities and rural amenities occurs following this dialogue. The base model parameters are b=1.6, a=0.20, n=1.0, ρ=-1.5, θ_1=0.4, θ_2=0.6, π_1=1, π_2=10, and α=0.30. In figure 1 the equilibrium paths for ϕ and k are show when an initial starting value of 0.3 is given to both variables[4]. In figure 1 an equilibrium is reached when $dk_t = d\phi_t = 0$ after about t=22. Visual inspection reveals approximate values of $\bar{\phi} \approx 0.95$ and $\bar{k} \approx 1.9$ where $\bar{\phi}$ and $\bar{k}$ corresponds to the high steady state equilibrium values for labor migration and the capital labor ratio respectively. Table 1 contains the results from the base where we solve empirically for the high steady state pair, $\bar{\phi}$ and $\bar{k}$ (high-SS), and the low steady state pair, $\underline{\phi}$ and $\underline{k}$ (low-SS) for each of the capital-labor and labor migration parameter. In the low-SS equilibrium 27.1% of the high skilled workers are in the urban area, compared to the high-SS where 95.7% of these workers are employed in the urban area.

To test the models sensitivity to changes in the base parameters, next are examined the impacts of a 1% change in the value of initial parameters on the equilibrium for both the high-SS and low-SS equilibrium values[5]. For each set of empirical results we present both the actual change in equilibrium values as well as percent changes in the equilibrium values. The upper half of table 1 contains the new equilibrium values for $\bar{\phi}$ and $\bar{k}$, and $\underline{\phi}$ and $\underline{k}$ when we change key parameters by 1%. The lower portion of the table contains a matrix representing percentage changes in the equilibrium values from the base. For example, when the population growth rate, n, is increased by 1%, $\underline{\phi}$ increases by 7.2% and $\underline{k}$ increases by 6.6%. At the high-SS we find a 1% increase in n decreases $\bar{\phi}$ by 0.3% and $\bar{k}$ decreases by 2.2%. At the high-SS this is an interesting result since this is consistent with the development story followed by many countries in the past. In general, as a country tends to develop and becomes more modernized, they experience a decline in the population growth rate and more

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parameterizations. The fsolve function using the Newton method as part of the optimization toolbox in MATLAB was used to solve the system of non-linear steady state equations.

[4] If each generation of is to last say 30 years, then t=25 will imply a horizon of roughly 750 years.

[5] Here a continuous interpretation of 1% is used as we consider log changes in the initial parameter value. So, for example, if we consider a 1% increase in the population growth rate, $0.01 = \ln\left(\frac{n_{base+1\%}}{n_{base}}\right)$ then the new parameter value is found by multiplying the base parameter value by $e^{0.01}$. Percent changes in the new SS equilibrium values are calculated using logs.

people tend to move into urban areas. This result is driven largely by the wage rate in the urban area associated high tech production since the wage is positive in k, and k is negative in n. A similar pattern of results emerges when we look at the changes to the parameter ρ where an increase at the low-SS increases equilibrium values, but decreases equilibrium values at the high-SS[6].

To mimic increased demand for the agricultural good relative to the high technology product we can increase the value of α. When the value of α is increased by 1% we find there is a negative impact on $\bar{\phi}$ and a positive impact on $\bar{k}$. The effect on $\bar{\phi}$ is as expected since, *ceteris paribus*, one should expect as the (relative) demand for the agricultural good increases, the price for the agricultural goods will also rise and attract more of the high skill workers to work in rural areas. The resulting impact on k is a little less intuitive but may be explained by the fact that as more people move away from the urban area, the capital-labor ratio will necessarily rise since k is based on only on high skilled employed in the high tech industry and not all high skill workers. At the low-SS, both $\underline{\phi}$ and $\underline{k}$ fall in response to an increase in demand for agricultural goods. If we increase the productivity of the high skill workers relative to the low skill worker, i.e. make π_2 higher, then we find more high skill workers will seek employment in rural in both the high and low-SS equilibrium since both $\underline{\phi}$ and $\bar{\phi}$ are negative. The same basic result is realized when the relative size of the high skill workforce is increased, i.e. increasing θ_2 and decreasing θ_1. Since we are not at a corner where $\phi = 1$, an increase in the relative size of the skilled workforce leads to the urban sector appearing less attractive due to the "glut" of qualified workers. Interestingly the SS value for k is unaffected in either the low or high equilibriums by changes in π_2 or θ_2. While this may at first appear an unusual result this does make some good intuitive sense. Given we do not, or at least appear not, encounter any corner solutions, changes to π_2 and θ_2 do not influence the fundamental supply or demand conditions, i.e. the underlying production technologies and preferences remain unchanged. While the path to the equilibrium will most certainly be different, the equilibrium steady state capital-labor ratio is unaffected. This indifference result is not unique to this specification or to the parameter values chosen as is demonstrated in the appendix.

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[6] Recall that the elasticity of factor substitution is $\sigma = \frac{1}{1-\rho}$. However, it is not intuitively clear how this variable would be expected to impact the equilibrium SS values.

A rural-urban model with rural amenities and technology spillovers

In this section the OLG model developed above is further developed to answer our two primary questions: 1) how does a technology spillover associated with the production of the technology good influence labor migration activity of high skill workers; and 2) in what way will high skill workers respond to amenities in the rural region. Technology spillovers enter as a production externality often used in models of endogenous growth. To introduce rural amenities two approaches, I and II, are used to examine two different ways in which to incorporate amenities in the rural region. The first model takes the view amenities enters the consumers utility function directly and only those individual employed in the rural area, including high skill workers in the rural area, benefit from the rural amenities. The second specification of the model takes a transaction cost approach where individuals in urban areas need to incur a cost to benefit from amenities in the rural area. These enriched models will help us answer questions related to how endogenous growth affects the movement of labor between rural and urban regions and how an endowment of rural amenities influences worker location.

Technology Externality – Introduction of Urban Knowledge Spillovers

The technology or knowledge spillover acts on the efficacy of capital. In this version of the model the technology spillover enters the model in the form of a production externality in a manner similar to Romer (1986). The production externality enters the production function through the term $\mathbf{k}_t^{\delta}$ which is exogenous to the firm itself but is endogenous to the economy as a whole. The parameter δ represents the strength of the production spillover and is assumed to have the same sign as ρ coinciding with the notion of a positive externality. The new production function faced by firms in this new industrial world in intensive form is:

$$f\left(k_t;\mathbf{k}_t\right)=\left(a\mathbf{k}_t^{\delta}k_t^{\rho}+b\right)^{\frac{1}{\rho}} \tag{20}$$

The first order conditions for the profit maximizing firm which uses both labor and capital in strictly positive quantities in production and pays each factor of production its VMP is:

$$r_t=\left(a\mathbf{k}_t^{\delta}k_t^{\rho}+b\right)^{\frac{1-\rho}{\rho}}a\mathbf{k}_t^{\delta}k_t^{\rho-1}=\left(a\mathbf{k}_t^{\delta}\right)^{\frac{1}{\rho}}\left[1+\left(\frac{b}{a}\right)\mathbf{k}_t^{-\delta}k_t^{-\rho}\right]^{\frac{1-\rho}{\rho}} \tag{21}$$

$$w_t = b^{\frac{1}{\rho}}\left[\left(\frac{a}{b}\right)\mathbf{k}_t^{\delta}k_t^{\rho}+1\right]^{\frac{1-\rho}{\rho}}$$

or (22)

$$w_t = b^{\frac{1}{\rho}}\left(\frac{a}{b}\right)^{\frac{1-\rho}{\rho}}\left(\mathbf{k}_t^{\delta}\right)^{\frac{1-\rho}{\rho}}k_t^{1-\rho}\left[1+\frac{b}{a}\mathbf{k}_t^{-\delta}k_t^{-\rho}\right]^{\frac{1-\rho}{\rho}}$$

These equations are quite similar to those derived earlier with the exception of the production externality. Since $\mathbf{k}_t$ is exogenous to the firm itself it only becomes endogenous within the economy when all micro optimization steps have been taken. When the general equilibrium conditions are imposed then we can take $\mathbf{k}_t = k_t$ and examine how equilibrium conditions change in response to changes in δ.

Amenity Specification I – Direct Utility Effect

In this version of the model recreational amenities are assumed to be a non-excludable public good that exists only within the rural area and is accessible to only those individuals who work in the rural area. Further, without complicating the model by adding a means to fund these amenities i.e. taxes or fees, these amenities are assumed to occur naturally and may be improved upon at zero cost. This assumption of costless improvement in rural amenities allows examination of what happens to the equilibrium when either increasing or decreasing the level of amenity without worrying about the additional frictions due to taxation. Alternatively, it may be assumed that changes in the amenity value in rural areas are achieved through an entity, i.e. a government, which is external to the model. As a real world example of this type of behavior consider the US Federal government covering maintenance costs of United States Department of Agriculture Forestry Services recreational lands. Here the tax revenue generated from the residents who directly benefit from these amenities is negligible in comparison to total project costs. These amenities may include wilderness tracts of land, lakes, streams, forests, bike trails, etc. All low skill workers will be able to benefit from these recreational amenities since their only option for employment is in the agricultural sector located in the rural region. However, only those high type workers who work in the rural region will be able to enjoy these amenities[7]. Individual utility is linear in amenities, g, and takes the following form:

$$U(v,h) = g^{\tau} v^{\alpha} h^{1-\alpha} \tag{23}$$

where g^{τ} is the amenity benefit where τ=1 if the worker is employed in the agricultural sector, and τ=0 if the worker is employed in high tech industry located the urban area. Further, we can assume g≥1 to coincide with an ordinal increase in utility levels over the status quo. The budget constraint and the resulting demand equations for the agricultural and technology goods are exactly the same as in the previous model. We can substitute these optimized demand functions into the individuals utility function to derive their indirect utility function, $V(p_t,\psi)$. For the low skill laborer this is:

$$V(p_t,\psi_1) = g^{\tau}\alpha^{\alpha}(1-\alpha)^{1-\alpha} r_{t+1} \frac{\pi_1 p_t}{p_{t+1}^{\alpha}} \tag{24}$$

For the high skill worker the value of their indirect utility function will depend on whether they are employed in the rural or urban region.

$$\begin{aligned} &V(p_t,\psi_2|\text{rural}) = g^{\tau}\alpha^{\alpha}(1-\alpha)^{1-\alpha} r_{t+1} \frac{\pi_2 p_t}{p_{t+1}^{\alpha}} \\ &or \\ &V(p_t,\psi_2|\text{urban}) = \alpha^{\alpha}(1-\alpha)^{1-\alpha} r_{t+1} \frac{w_t}{p_{t+1}^{\alpha}} \end{aligned} \tag{25}$$

If $g^{\tau}\pi_2 p_t > w_t$ then all high skill workers will seek employment in the rural region and conversely, if $g^{\tau}\pi_2 p_t < w_t$ then all high skill workers be employed in the urban region. If we wish to consider only the interesting situation where high skill workers are working in both regions requires $g^{\tau}\pi_2 p_t = w_t$.

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[7] Actually all that is required is residents working in the rural area are able to benefit from the amenity more than those working in the urban area. The simplification to effectively exclude workers in the urban region from enjoying these amenities is to keep the model as simple as possible.

Consider once again a general equilibrium consisting of a sequence of prices, capital-labor ratios, and high-skill workers migration decisions that satisfies the usual profit maximizing, utility maximizing conditions, and market clearing. Using the property derived from the indifference condition above, $p_t = \frac{w_t}{g^\tau \pi_2}$, the new market clearing condition in the agricultural goods market while can be written as:

$$n^{t+1}\left[\theta_1\pi_1 + (1-\phi_{t+1})\theta_2\pi_2\right] = n^t\left[\theta_1 r_{t+1}\frac{w_t}{g^\tau\pi_2}\frac{\pi_1\alpha}{\left(\frac{w_{t+1}}{g^\tau\pi_2}\right)} + \theta_2(1-\phi_t)r_{t+1}\frac{w_t}{g^\tau\pi_2}\frac{\pi_2\alpha}{\left(\frac{w_{t+1}}{g^\tau\pi_2}\right)} + \theta_2\phi_t r_{t+1}\frac{w_t\alpha}{\left(\frac{w_{t+1}}{g^\tau\pi_2}\right)}\right]$$

$$\left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + (1-\phi_{t+1})\right] = \frac{r_{t+1}w_t}{w_{t+1}}\frac{\alpha}{n}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + (1-\phi_t) + \phi_t g^\tau\right]$$

or

$$\phi_{t+1} = \left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + 1\right] - \frac{\alpha}{n}\frac{r_{t+1}w_t}{w_{t+1}}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + 1 + \phi_t\left(g^\tau - 1\right)\right] \qquad (26)$$

The credit market the constraint that needs to be satisfied is:

$$k_{t+1} = \frac{n^t}{\theta_2 n^{t+1}\phi_{t+1}}\left[\theta_1\frac{w_t}{g^\tau\pi_2}\pi_1 + \theta_2(1-\phi_t)\frac{w_t}{g^\tau\pi_2}\pi_2 + \theta_2\phi_t w_t\right]$$

or

$$k_{t+1} = \frac{1}{\phi_{t+1}}\frac{w_t}{g^\tau n}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + 1 + \phi_t\left(g^\tau - 1\right)\right] \qquad (27)$$

We can now substitute the profit maximizing conditions for wages and capital rental rates into equations (26) and (27) to implicitly define the two equations for the equilibrium law of motion for the capital-labor ratio and high-skill labor migration. Recall since we are introducing endogenous growth in the form of a production externality we now treat $\mathbf{k}_t = k_t$. Noting the equations for the wage and capital rental rates implied by profit maximization we can derive the relationship $\frac{r_{t+1}w_t}{w_{t+1}} = k_{t+1}^{\delta+\rho-1}\left(\frac{a}{b}\right)b^{\frac{1}{\rho}}\left[\left(\frac{a}{b}\right)k_t^{\rho+\delta}+1\right]^{\frac{1-\rho}{\rho}}$. Thus our two equations of motion are:

$$\phi_{t+1} = \left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right] - \frac{\alpha}{n}k_{t+1}^{\delta+\rho-1}\left(\frac{a}{b}\right)b^{\frac{1}{\rho}}\left[\left(\frac{a}{b}\right)k_t^{\rho+\delta}+1\right]^{\frac{1-\rho}{\rho}}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1+\phi_t\left(g^{\tau}-1\right)\right] \quad (28)$$

and;

$$k_{t+1} = \frac{1}{\phi_{t+1}}\frac{b^{\frac{1}{\rho}}}{g^{\tau}n}\left[\left(\frac{a}{b}\right)k_t^{\rho+\delta}+1\right]^{\frac{1-\rho}{\rho}}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1+\phi_t\left(g^{\tau}-1\right)\right] \quad (29)$$

The two equations above embody all the information within the model required to solve for equilibrium, both dynamic and stationary. To verify the model has the same principle structure as in the previous section we can set $\tau=\delta=0$ in equations (28) and (29) to get the same equilibrium laws of motion as in (18) and (19).

As in the earlier simulation discussion we wish only to discuss the steady state equilibrium by setting $\phi_{t+1}=\phi_t=\phi$ and $k_{t+1}=k_t=k$. Changing the technology and amenity parameters allows us to conducting sensitivity around SS equilibrium values for ϕ and k. Tables 2 and 3 examine the impact on the SS equilibrium when the value of amenities is increased by 1%. Tables 4 and 5 are a set of results where a value of δ =-0.1 is introduced as a base parameter to the model and is then subjected to a 1% increase to examine the effect on SS equilibrium.

The results in table 2 are exactly the same as those in table 1 with the exception of the additional sensitivity around the parameter g which is used to capture amenities in the rural region. Increasing the parameter g by 1% results in an increase in $\underline{\phi}$ of about 2.5% and $\underline{k}$ by about 2.6%. At the high-SS we still notice a much small impact on the equilibrium values, an increase of 0.02% for $\bar{\phi}$ and a decrease in $\bar{k}$ of about 0.4%. These results would seem to indicate that when the value of amenities are increased in rural areas then high skill workers actually move away from the rural area as indicated by the positive percentage change in $\bar{\phi}$ for both the low and high equilibriums. While this may seem counter intuitive there is a reasonable explanation for this seemingly odd result. The presence of the natural amenity in the rural region represents a tradeoff between the wage in the urban region and the non-monetary amenity value. These results imply we are in the region of the solution space where the higher wage is valued more than the additional amenities received from living in the rural region. With this result in mind we should be able to find a parameterization where the additional non-monetary benefits of the amenities in the rural region appear more attractive than the higher wages in the urban area.

In table 3 under a different set of parameters, i.e. n=1.15, we do actually find the more intuitive result at the high steady state where the high skill labor has a tendency to move back to the rural are under increased amenities. The same set of sensitivity analysis was performed in table 3 as in table 2. In the lower portion of table 3 a 1% increase in the amenity level, g, results in a 0.22% decrease in the number of high skill workers that are employed in the urban sector when at the high-SS equilibrium. In this scenario it is also found the equilibrium capital labor ratio is smaller by a magnitude of 1.2%. The higher population growth rate has a depressing effect on the urban wage which will in turn make the rural sector appear more attractive with its amenities. However, at the low steady state we find an increase in amenities results in a decrease in high skill workers in rural areas as the relatively higher wages in the urban sector are more attractive.

In tables 4 and 5 are given the base SS equilibrium values for a value of δ=-0.01 corresponding to a positive production externality embodying knowledge spillovers. Recall that for a positive externality requires the sign of δ to be the same as the sign of ρ, since ρ is negative, so to is δ. Table 4 has an initial population growth rate of n=1 and table 5 contains results where the base population growth rate is n=1.15. Sensitivity to the equilibrium is once again conducted based on a 1% increase in these initial parameters. As we can see from these last two tables the same general model results hold when the production externality is introduced while the actual magnitudes have changed slightly. Examining the last row in the lower segment of tables 4 and 5 indicates both ϕ and k are increasing in the (negative) value of δ at both the low and high-SS equilibrium. This result highlights the overall ability of (urban) regions with the type of knowledge externality described within this paper to attract high skill workers under a variety of different conditions. While rural areas are loosing high skill workers here, the low skill workers within the rural area are still better off in with the urban externality for two reasons. First, since their labor income is a function of the price of agricultural goods, p, and is also a function of k, they are receiving a higher price for their agricultural goods. Secondly, since there are fewer high skilled workers in the rural region there is an implied tightening of the supply of agricultural goods which causes the supply curve to shift to the left allowing the price of agricultural goods to increase further. The combination of these two results leaves the low skill workers better off than they would otherwise be since their overall incomes are higher.

Amenity Specification II – Cost of Amenity Access

In this specification of the model it is assumed once again amenities exist only in the rural areas. However here it is assumed all individuals desire this amenity and incur a cost to benefit from the amenity in contrast to the previous model where only rural residents were able to enjoy amenities. Individuals working in rural areas, i.e. all low skill workers and high skill workers who seek employment in the agricultural market, are able to benefit from the readily accessible amenity at zero cost. However, high skilled workers in urban areas incur a fixed cost of c to be able to enjoy the same amenities as their rural counterparts. For example these extra costs may include long periods of time in traffic to get out of the city to access rural amenities. Further to keep the model as transparent as possible it is assumed all workers in the urban area incur this fixed cost c to enjoy amenities or they receive zero utility as opposed to allowing marginal choices over the amount of amenities enjoyed by urban workers. While this is obviously a stretch the analysis allows a clear indication of how increases or decreases in access costs to amenities affect equilibrium behavior. As in the previous model the rural amenities enter the utility function through a linear fashion in the strictly positive parameter g. Formally a high skill worker living and working in the urban region faces the utility maximization problem

$$MaxU\left(v,h|urban\right)\begin{cases} = gv^{\alpha}h^{1-\alpha} \text{ st. } p_t v + h \le r_{t+1}\left(w_t - c\right) \\ = 0 \text{ otherwise} \end{cases} \qquad (30)$$

To follow from the same notation as before High skill workers then face the problem of deciding which area they will work in and will choose to work in the area where their utility is highest. That is:

$$Max\begin{cases} V\left(p_t,\psi_2\,|\text{urban}\right)\begin{cases} = g\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha} r_{t+1}\dfrac{\left(w_t - c\right)}{p_{t+1}^{\alpha}} \\ = 0 \text{ otherwise} \end{cases} \\ \\ V\left(p_t,\psi_2\,|\text{rural}\right) = g\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha}\dfrac{r_{t+1}\pi_2 p_t}{p_{t+1}^{\alpha}} \end{cases} \tag{31}$$

High skill workers will be indifferent between working in either of the two regions when

$$p_t = \frac{w_t - c}{\pi_2} \tag{32}$$

This is the indifference condition imposed once again since we are interested primarily in the situation where high skill workers choose to work in both regions. For completeness, the indirect utility function for low skill workers is given by

$$V\left(p_t,\psi_1\right) = g\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha} r_{t+1}\pi_1 p_t^{(1-\alpha)} \tag{33}$$

As in the previous form of the model we can use the agricultural and credit markets to define the market equilibrium. Finally, equating supply and demand in the capital and goods markets will close out the equilibrium. The market clearing in the agricultural market will imply:

$$n^{t+1}\left[\theta_1\pi_1 + \left(1-\phi_{t+1}\right)\theta_2\pi_2\right] = n^t\left[\theta_1\frac{\alpha r_{t+1}\pi_1 p_t}{p_{t+1}} + \theta_2\left(1-\phi_t\right)\frac{\alpha r_{t+1}\pi_2 p_t}{p_{t+1}} + \theta_2\phi_t\frac{\alpha r_{t+1}\left(w_t - c\right)}{p_{t+1}}\right]$$

$$n^{t+1}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + \left(1-\phi_{t+1}\right)\right]\theta_2\pi_2 = n^t\alpha r_{t+1}\frac{\left(w_t - c\right)}{\left(w_{t+1} - c\right)}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + 1\right]\theta_2\pi_2$$

$$\phi_{t+1} = \left(1 - \frac{\alpha}{n} r_{t+1}\frac{\left(w_t - c\right)}{\left(w_{t+1} - c\right)}\right)\left[\frac{\theta_1\pi_1}{\theta_2\pi_2} + 1\right] \tag{34}$$

The credit market clearing constraint is going to now use the indifference equation in (32) to substitute for p_t:

$$K_{t+1} = n^t \left[\theta_1 \pi_1 p_t + \theta_2 \left(1-\phi_t\right) \pi_2 p_t + \theta_2 \phi_t w_t\right]$$

$$k_{t+1} = \frac{n^t}{\theta_2 \phi_{t+1} n^{t+1}} \left[\theta_1 \pi_1 \frac{w_t - c}{\pi_2} + \theta_2 \left(1-\phi_t\right) \pi_2 \frac{w_t - c}{\pi_2} + \theta_2 \phi_t w_t\right]$$

$$k_{t+1} = \frac{1}{\phi_{t+1} n} \left[\left(\frac{\theta_1 \pi_1}{\pi_2 \theta_2} + 1\right)\left(w_t - c\right) + c\phi_t\right] \tag{35}$$

In steady state the two equations that implicitly define the equilibrium values for the capital labor ratio and the amount of high skill workers in the urban area are:

$$k = \frac{1}{\phi n}\left[\left(\frac{\theta_1 \pi_1}{\theta_2 \pi_2} + 1\right)\left(w(k) - c\right) + \phi c\right] \tag{36}$$

and

$$\phi = \left[1 - \frac{\alpha}{n} r(k)\right]\left[\frac{\theta_1 \pi_1}{\theta_2 \pi_2} + 1\right] \tag{37}$$

Note the above function are written in terms of r and w. Recalling the profit maximizing conditions for firms in equations (21) and (22), these equations can be further simplified to derive two equations in k and ϕ:

$$k = \frac{1}{\phi n}\left[\left(\frac{\theta_1 \pi_1}{\theta_2 \pi_2} + 1\right)\left(b^{\frac{1}{\rho}}\left[\frac{a}{b} k^{\delta+\rho} + 1\right]^{\frac{1-\rho}{\rho}} - c\right) + \phi c\right] \tag{38}$$

$$\phi = \left[1 - \frac{\alpha}{n} a^{\frac{1}{\rho}} k^{\frac{\delta}{\rho}} \left(1 + \frac{b}{a} k^{-(\delta+\rho)}\right)^{\frac{1-\rho}{\rho}}\right]\left[\frac{\theta_1 \pi_1}{\theta_2 \pi_2} + 1\right] \tag{39}$$

We can rearrange the terms in (38) to solve for k, and rearrange (39) to solve for ϕ[8]. Considering first the equation in (38):

$$\phi\left(\frac{kn-c}{kn}\right)=\frac{1}{kn}\left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)\left(b^{\frac{1}{\rho}}\left[\frac{a}{b}k^{\delta+\rho}+1\right]^{\frac{1-\rho}{\rho}}-c\right)$$

$$\phi=\frac{1}{(kn-c)}\left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)\left(b^{\frac{1}{\rho}}\left[\frac{a}{b}k^{\delta+\rho}+1\right]^{\frac{1-\rho}{\rho}}-c\right) \qquad (40)$$

Likewise, using (39) we can solve for the steady state capital labor ratio as a function of high skill labor migration

$$\frac{\alpha}{n}a^{\frac{1}{\rho}}k^{\frac{\delta}{\rho}}\left(1+\frac{b}{a}k^{-(\delta+\rho)}\right)^{\frac{1-\rho}{\rho}}=1-\phi\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right]^{-1}$$

$$\left(1+\frac{b}{a}k^{-(\delta+\rho)}\right)^{\frac{1-\rho}{\rho}}=\frac{n}{\alpha}\left(ak^{\delta}\right)^{\frac{-1}{\rho}}\left(1-\phi\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right]^{-1}\right)$$

$$k=\left\{\left(\frac{a}{b}\right)\left(\left[\frac{n}{\alpha}\left(ak^{\delta}\right)^{\frac{-1}{\rho}}\left(1-\phi\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right]^{-1}\right)\right]^{\frac{\rho}{1-\rho}}-1\right)\right\}^{\frac{-1}{\delta+\rho}} \qquad (41)$$

Equations (40) and (41) implicitly define the equilibrium for this model. As with the previous models, these two equations do not provide any obvious results and the non-linearity of these equations does not allow easy interpretation so numerical optimization is used to gain insight. The results from the numerical optimization are contained in tables 6, 7 and 8.

As with the previous numerical analysis, the base parameter variables in the left most column were subjected to a 1% increase, except where noted, to examine the impact on the equilibrium steady state

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[8] While this may seem a menial task and possibly irrelevant, it turns out the new forms of the equations are much easier to solve for an optimum numerically than the current equations.

values. For each of tables 6,7, and 8 the initial cost for urban working residents to enjoy the rural amenities, c, is set at 0.1. To examine increased costs of amenities in the absence of any production knowledge externalities, in table 6 we assume $\delta = 0$. In table 7 the technology externality is introduced with a values $\delta = -0.1$, and table 8 considers the case where $\delta = -0.1$ and n=1.15. The analyses in tables 7 and 8 are to make comparable the results in tables 4 and 5 under different methods of introducing amenities into the model based on the same initial parameter values.

A casual glance at these last three tables reveals remarkable consistency throughout regardless of the parameters chose as the base thus rather than dwell on the specifics of each of the tables individually it is more useful to consider the general results of these three together. What is apparently evident from each of these tables is that at the high steady state an increase in c of 1% (also 10% in the lower tier of table 6) results in a decrease in both $\overline{\phi}$ and $\overline{k}$. This is consistent with the conventional wisdom that the greater is the opportunity cost of enjoying amenities, the more likely one will be to move there. In addition the low steady state values $\underline{\phi}$ and $\underline{k}$ in each of these three tables demonstrate the not-so-quite intuitive result an increased cost in amenities translates into a larger tradeoff between rural and urban wages for high skill workers favoring the relatively higher urban wages.

Conclusions

There are a few interesting results and implications that can be taken from this analysis. Probably the most important result to be drawn from this analysis is the role of knowledge spillovers on rural-urban migration behavior. It has often been argued one reason companies are willing to pay for expensive office space downtown in large cities or in hotbeds of new innovation and technology like Silicon Valley has to do with the interaction among economic agents. In such areas it is much easier to copy another companies business style, improve on a design, or hire away bright employees from competitors and thus realize externalities. This paper has demonstrated when such externalities exist in urban areas there is further increased migration of high skill workers away from rural areas. In short, lacking the informal network allowing highly skilled, bright individuals to effectively interact and readily exchange ideas and thoughts may be one reason why rural areas appear to be loosing their highly educated individuals to more developed urban areas. This apparent brain drain effect has caused considerable concern among political leaders and resident alike in rural regions since this loss of high skill workers leads to both a decrease in both total area incomes as well as per capita incomes. However, while it is true that rural areas are on average worse off in terms of total average per capita income when more high skill workers seek employment in the urban area, the low skill workers are actually be made better off since their incomes are correlated with the wages of high skill workers regardless of whether they are in employed in the high technology sector or engaged in agricultural production. Thus if higher wages may be realized in the urban centers by the high skilled individuals then this migration is in the best interests of low skill workers. So while it has been a common rural policy problem that rural counties continue to lose their brighter and more educated individuals, the low skilled workers are not necessarily worse off. The low skill workers may actually be benefiting from this migration since there is less overall agricultural production and there rural and urban wages are correlated. The persistent correlation of wages and incomes across rural and urban regions over time is a fairly strong indicator to support these stylized facts discussed in this paper. Also, there are additional benefits for low skill workers in the urban area since limiting rural workers will necessarily shift the supply curve to the right and thereby making low skilled workers real value of labor higher.

The second notable result deals with the role of amenities in rural regions and relating these findings to various periods of growth in the last century. In the early stages of development it held that labor tended to move away from rural and into urban centers, largely driven by the rural-urban wage differential favoring urban employment. While rural amenities were obviously not the only factor contributing to this wage differential they may have had an impact. However, more recently as real incomes have continued to rise we are beginning to see more and more individuals opting for an increasingly rural or county lifestyle much more removed from urban centers. The model presented here demonstrates that under certain parameterizations we do appear to get this type of behavior favoring rural areas at higher levels of development where the non-monetary amenity benefits outweigh the urban wage benefits resulting in a return of high skill and educated individuals to rural regions. This type of behavior has become increasingly common with the development of the internet and a general overall improvement in the communication infrastructure allowing individuals to work from home as effectively as if they were in a downtown office. While the model is not developed enough to provide consumers both a choice of work location and location of residence it does give a flavor for the tradeoffs between non-monetary amenity benefits and wages. At lower stages of development, i.e. at the low income steady state, the tradeoff appears to unambiguously favor higher wages over the amenities consistent with the growth experience of many developed countries. Further, the analysis has shown this trade off is not always obvious at high stages of development, i.e. at the high steady state, and depends to a large extent on how amenities are interpreted to enter the model and what are the model parameterizations.

The two period overlapping generations model developed in this paper makes two important contributions on the roles of knowledge spillovers and rural amenities as they relate to labor migration between rural and urban areas. It is reassuring the stylized facts on population and labor migration in the US and other developed countries generally matches the results obtained in the theoretical model. The model here is unique in the manner in which knowledge spillovers and amenities enters into a complete, albeit quite simple, full general equilibrium model. Arguably such models are better suited to examining any number of rural issues where a rural-urban interaction is important as opposed to more narrowly focused partial equilibrium models. Of course there is a cost in terms of how intricate and complex our representative economy can be, but when long run growth impacts and policy are the goal, certain sacrifices must been made to paint a more reliable picture of general economic activity.

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Appendix

The equations used to solve for the steady state are:

Steady State: Basic Model

$$\bar{\phi} = \frac{b^{\frac{1}{\rho}}}{n\bar{k}}\left[\left(\frac{a}{b}\right)\bar{k}^{\rho}+1\right]^{\frac{1-\rho}{\rho}}\left[\frac{\theta_1}{\theta_2}\frac{\pi_1}{\pi_2}+1\right]$$

$$\bar{k} = \left[\frac{n}{\alpha}\frac{b}{a}b^{\frac{-1}{\rho}}\left(1-\bar{\phi}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right]^{-1}\right)\right]^{\frac{1}{\rho-1}}\left[\left(\frac{a}{b}\right)\bar{k}^{\rho}+1\right]^{\frac{1}{\rho}}$$

Steady State: Amenity Specification I – Direct Utility Effect

$$\bar{\phi} = \frac{b^{\frac{1}{\rho}}}{ng^{\tau}\bar{k}}\left[\left(\frac{a}{b}\right)\bar{k}^{\delta+\rho}+1\right]^{\frac{1-\rho}{\rho}}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1+\bar{\phi}\left(g^{\tau}-1\right)\right] \quad (42)$$

$$\bar{k} = \left(\frac{1}{a}\frac{n}{\alpha}b^{\frac{\rho-1}{\rho}}\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+\left(1-\bar{\phi}\right)\right]\left[\frac{\theta_1\pi_1}{\theta_2\pi_2}+1+\bar{\phi}\left(g^{\tau}-1\right)\right]^{-1}\left[\left(\frac{a}{b}\right)\bar{k}^{\rho+\delta}+1\right]^{\frac{\rho-1}{\rho}}\right)^{\frac{1}{\delta+\rho-1}} \quad (43)$$

To demonstrate that none of $\theta_1, \theta_2, \pi_1$, or π_2 impact the steady state level of capital regardless of the steady state, first rearrange (42) as follows:

$$\left(\frac{b^{\frac{1}{\rho}}}{ng^{\tau}\bar{k}}\left[\left(\frac{a}{b}\right)\bar{k}^{\delta+\rho}+1\right]^{\frac{1-\rho}{\rho}}\right)^{-1} = \left[\left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)\frac{1}{\bar{\phi}}+\left(g^{\tau}-1\right)\right]$$

$$\bar{\phi} = \left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)\left[\left(\frac{b^{\frac{1}{\rho}}}{ng^{\tau}\bar{k}}\left[\left(\frac{a}{b}\right)\bar{k}^{-\delta+\rho}+1\right]^{\frac{1-\rho}{\rho}}\right)^{-1}-\left(g^{\tau}-1\right)\right]^{-1} \tag{44}$$

Now rearrange the terms in (43)

$$\bar{k} = \left(\frac{1}{a}\frac{n}{\alpha}b^{\frac{\rho-1}{\rho}}\frac{\left[\left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)\frac{1}{\bar{\phi}}-1\right]}{\left[\left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)\frac{1}{\bar{\phi}}-1+g^{\tau}\right]}\left[\left(\frac{a}{b}\right)\bar{k}^{-\rho+\delta}+1\right]^{\frac{\rho-1}{\rho}}\right)^{\frac{1}{\delta+\rho-1}}$$

$$\bar{k} = \left(\frac{1}{a}\frac{n}{\alpha}b^{\frac{\rho-1}{\rho}}\left[1+\frac{g^{\tau}}{\left[\left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)\frac{1}{\bar{\phi}}-1\right]}\right]^{-1}\left[\left(\frac{a}{b}\right)\bar{k}^{-\rho+\delta}+1\right]^{\frac{\rho-1}{\rho}}\right)^{\frac{1}{\delta+\rho-1}} \tag{45}$$

It is now obvious that when equation (44), is substituted into (45) the term $\left(\frac{\theta_1\pi_1}{\theta_2\pi_2}+1\right)$ will cancel out resulting in an equilibrium capital-labor ratio that does not depend on agricultural productivity or on the relative proportion of either high or low skill workers.

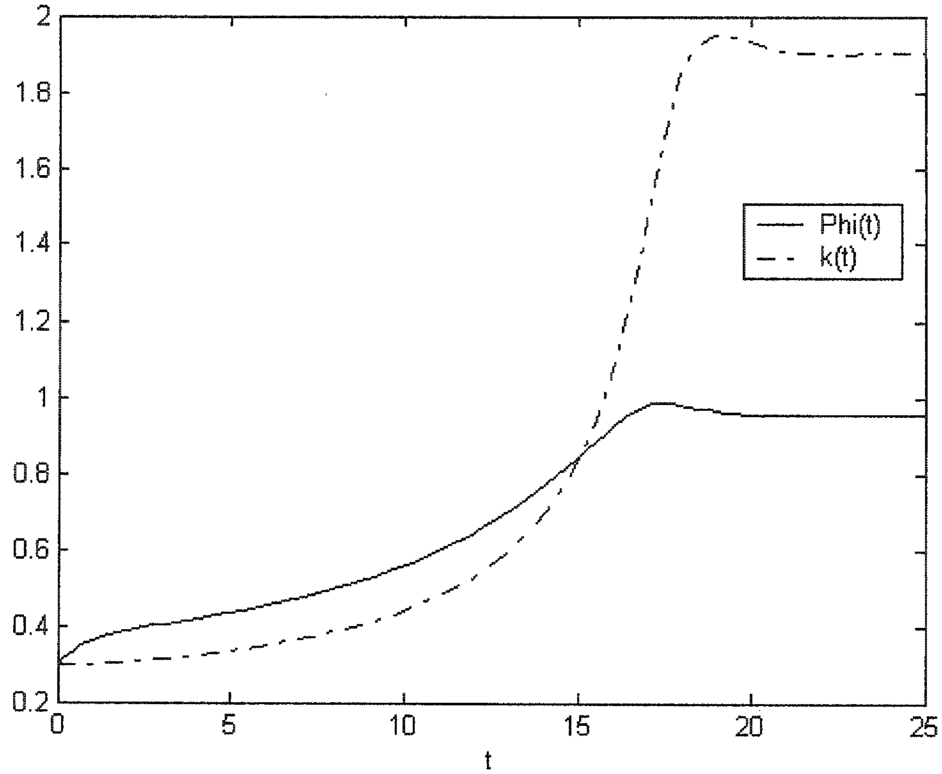

Figure 1. Base – Convergence to High Capital-Labor Ratio Steady State

Table 1. Sensitivity Under Base Scenario

	Absolute Changes (from the Base)			
	Low Steady State		High Steady State	
	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
base	0.2711	0.2186	0.9572	1.9022
Parameter				
n	0.2914	0.2334	0.954	1.8611
α	0.2537	0.2076	0.9566	1.9064
ρ	0.2913	0.2368	0.9565	1.8813
π_2	0.2709	0.2186	0.9566	1.9022
θ_2	0.2707	0.2186	0.9557	1.9022

	Percentage Change (from the Base)			
	Low Steady State		High Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
n	7.22%	6.55%	-0.33%	-2.18%
α	-6.63%	-5.16%	-0.06%	0.22%
ρ	7.19%	8.00%	-0.07%	-1.10%
π_2	-0.07%	0.00%	-0.06%	0.00%
θ_2	-0.15%	0.00%	-0.16%	0.00%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3
b=0.2	n=1	θ_2=0.6	π_2=10	

Table 2. Impact of Rural Amenities – Small n Parameter Value

Absolute Changes (from the Base)

	Low Steady State		High Steady State	
	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
base	0.2711	0.2186	0.9572	1.9022
Parameter				
n	0.2914	0.2334	0.954	1.8611
α	0.2537	0.2076	0.9566	1.9064
ρ	0.2913	0.2368	0.9565	1.8813
π_2	0.2709	0.2186	0.9566	1.9022
θ_2	0.2707	0.2186	0.9557	1.9022
g	0.278	0.2243	0.9574	1.8946

Percentage Change (from the Base)

	Low Steady State		High Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
n	7.22%	6.55%	-0.33%	-2.18%
α	-6.63%	-5.16%	-0.06%	0.22%
ρ	7.19%	8.00%	-0.07%	-1.10%
π_2	-0.07%	0.00%	-0.06%	0.00%
θ_2	-0.15%	0.00%	-0.16%	0.00%
g	2.51%	2.57%	0.02%	-0.40%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3
b=0.2	n=1	θ_2=0.6	π_2=10	g=1

Table 3. Impact of Rural Amenities – Large n Parameter Value

Absolute Changes (from the Base)

	Low Steady State		High Steady State	
	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
base	0.5688	0.4898	0.8832	1.2775
Parameter				
n	0.5942	0.5221	0.8727	1.2212
α	0.5545	0.4757	0.8833	1.2867
ρ	0.5905	0.5206	0.8783	1.2478
π_2	0.5685	0.4898	0.8826	1.2775
θ_2	0.5679	0.4898	0.8818	1.2775
g	0.5815	0.5053	0.8813	1.2617

Percentage Change (from the Base)

	Low Steady State		High Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
n	4.37%	6.39%	-1.20%	-4.51%
α	-2.55%	-2.92%	0.01%	0.72%
ρ	3.74%	6.10%	-0.56%	-2.35%
π_2	-0.05%	0.00%	-0.07%	0.00%
θ_2	-0.16%	0.00%	-0.16%	0.00%
g	2.21%	3.12%	-0.22%	-1.24%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3
b=0.2	n=1.15	θ_2=0.6	π_2=10	g=1

Table 4. Impact of a Production Externality – Low n Parameter Value

Absolute Changes (from the Base)

	Low Steady State		High Steady State	
	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
Base	0.4128	0.3535	0.9703	1.9960
Parameter				
n	0.4284	0.3673	0.9673	1.9544
α	0.4007	0.3452	0.9697	1.9997
ρ	0.4256	0.3682	0.9696	1.9735
π_2	0.4126	0.3535	0.9697	1.9960
θ_2	0.4122	0.3535	0.9688	1.9960
g	0.4197	0.3600	0.9706	1.9892
δ	0.4139	0.3546	0.9705	1.9969

Percentage Change (from the Base)

	Low Steady State		High Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
n	3.71%	3.83%	-0.31%	-2.11%
α	-2.98%	-2.38%	-0.06%	0.19%
ρ	3.05%	4.07%	-0.07%	-1.13%
π_2	-0.05%	0.00%	-0.06%	0.00%
θ_2	-0.15%	0.00%	-0.15%	0.00%
g	1.66%	1.82%	0.03%	-0.34%
δ	0.27%	0.31%	0.02%	0.05%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3	δ =-0.1
b=0.2	n=1	θ_2=0.6	π_2=10	g=1	

Table 5. Impact of a Production Externality – Large n Parameter Value

Absolute Changes (from the Base)

	Low Steady State		High Steady State	
	$\underline{\phi}$	$\underline{k}$	$\overline{\phi}$	$\overline{k}$
Base	0.6548	0.6296	0.9003	1.3538
Parameter				
n	0.6772	0.6659	0.8897	1.2931
α	0.6438	0.6167	0.9004	1.3628
ρ	0.6712	0.6585	0.8955	1.3221
π_2	0.6544	0.6296	0.8998	1.3538
θ_2	0.6538	0.6296	0.8989	1.3538
g	0.6658	0.6459	0.8987	1.3382
δ	0.6554	0.6307	0.9005	1.3547

Percentage Change (from the Base)

	Low Steady State		High Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\overline{\phi}$	$\overline{k}$
n	3.36%	5.61%	-1.18%	-4.59%
α	-1.69%	-2.07%	0.01%	0.66%
ρ	2.47%	4.49%	-0.53%	-2.37%
π_2	-0.06%	0.00%	-0.06%	0.00%
θ_2	-0.15%	0.00%	-0.16%	0.00%
g	1.67%	2.56%	-0.18%	-1.16%
δ	0.09%	0.17%	0.02%	0.07%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3	δ=-0.1
b=0.2	n=1.15	θ_2=0.6	π_2=10	g=1	

Table 6. Sensitivity to Changes in Amenity Access Cost, δ=0

Absolute Changes (from the Base)

	Low k Steady State		High k Steady State	
	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
Base	0.4567	0.4408	0.9548	1.8794
Parameter				
n	0.4704	0.4507	0.9513	1.8372
α	0.4467	0.4359	0.9541	1.8836
ρ	0.4690	0.4533	0.9540	1.8581
π_2	0.4564	0.4408	0.9542	1.8794
θ_2	0.4559	0.4407	0.9533	1.8793
c (1%)	0.4578	0.4422	0.9548	1.8791
c (10%)	0.4681	0.4555	0.9545	1.8769

Percentage Change (from the Base)

	Low k Steady State		High k Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
n	2.96%	2.22%	-0.37%	-2.27%
α	-2.21%	-1.11%	-0.07%	0.22%
ρ	2.66%	2.80%	-0.08%	-1.14%
π_2	-0.06%	0.00%	-0.06%	0.00%
θ_2	-3.56%	0.00%	-0.16%	0.00%
c (1%)	0.25%	0.32%	-0.00%	-0.01%
c (10%)	2.47%	3.28%	-0.03%	-0.13%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3	δ=0
b=0.2	n=1	θ_2=0.6	π_2=10	c=0.1	

Table 7. Sensitivity to Changes in Amenity Access Cost, δ=-0.1, n=1

Absolute Changes (from the Base)

	Low k Steady State		High k Steady State	
	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
Base	0.5194	0.5126	0.9685	1.9767
Parameter				
n	0.5321	0.5237	0.9653	1.9341
α	0.5106	0.5076	0.9678	1.9804
ρ	0.5295	0.5247	0.9677	1.9538
π_2	0.5191	0.5126	0.9679	1.9767
θ_2	0.5186	0.5126	0.9670	1.9767
c	0.5202	0.5138	0.9684	1.9765
δ	0.5199	0.5132	0.9686	1.9776

Percentage Change (from the Base)

	Low k Steady State		High k Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
n	2.41%	2.14%	-0.33%	-2.18%
α	-1.72%	-0.98%	-0.07%	0.19%
ρ	1.92%	2.33%	-0.08%	-1.17%
π_2	-0.06%	0.00%	-0.06%	0.00%
θ_2	-0.16%	0.00%	-0.16%	0.00%
c	0.15%	0.23%	-0.01%	-0.01%
δ	0.09%	0.11%	0.01%	0.04%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3	δ =-0.1
b=0.2	n=1	θ_2=0.6	π_2=10	c=0.1	

Table 8. Sensitivity to Changes in Amenity Access Cost, δ=-0.1, n=1.15

Absolute Changes (from the Base)

	Low k Steady State		High k Steady State	
	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
Base	0.7339	0.7962	0.8860	1.2840
Parameter				
n	0.7604	0.8529	0.8689	1.2004
α	0.7247	0.7829	0.8867	1.2956
ρ	0.7514	0.8342	0.8780	1.2409
π_2	0.7334	0.7962	0.8855	1.2840
θ_2	0.7328	0.7962	0.8847	1.2840
c	0.7346	0.7978	0.8858	1.2832
δ	0.7342	0.7970	0.8863	1.2850

Percentage Change (from the Base)

	Low k Steady State		High k Steady State	
Parameter	$\underline{\phi}$	$\underline{k}$	$\bar{\phi}$	$\bar{k}$
n	3.55%	6.88%	-1.96%	-6.74%
α	-1.26%	-1.68%	0.08%	0.90%
ρ	2.35%	4.66%	-0.91%	-3.42%
π_2	-0.06%	0.00%	-0.06%	0.00%
θ_2	-0.16%	0.00%	-0.16%	0.00%
c	0.10%	0.21%	-0.02%	-0.07%
δ	0.05%	0.10%	0.03%	0.08%

Base Parameters

a=0.2	ρ =-1.5	θ_1=0.4	π_1=1	α =0.3	δ =-0.1
b=0.2	n=1.15	θ_2=0.6	π_2=10	c=0.1	

PART II. EMPIRICAL ANALYSIS OF TECHNOLOGY SPILLOVERS EMPLOYMENT GROWTH

CHAPTER 2 - INNOVATIVE BEHAVIOR AND SPATIAL LOCATION – USING PATENTS COUNT AND GEOGRAPHIC LOCATION TO ESTIMATE INNOVATIVE SPILLINS

A paper to be submitted to the
review of economics and statistics

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Abstract

In this paper we examine the relation between geographic location and innovative behavior. Knowledge spillins, as opposed to knowledge spillovers, are modeled as an externality which exists between geographically close economic agents and enters the representative inventor production function explicitly from neighboring regions. To proxy new innovative behavior and new knowledge generated we use counts of patent filings per county. The proposed geographic spillin is tested for the US Midwestern States of Iowa, Minnesota, Missouri, Kansas, Nebraska, South Dakota and North Dakota using a newly constructed data set and implementing spatial statistical methods. The data set is comprised of primary inventor utility patent filings per county for the years 1975-2000. The results do indeed suggest spatial interaction does occur and innovative activity in surrounding counties is an important factor in explaining new innovative behavior. Further analysis also reveals lagged patenting behavior within the county also has a significant impact on patenting activity suggesting innovative externalities exist over both space and time.

Introduction

The modern economy is more and more driven by new technology, ideas, and innovation and less and less by physical capital accumulation. This has represented a fundamental shift in the general understanding and conceptual model of the process of economic growth and wealth accumulation. In a recent article in Forbes online a columnist writes: "...scientists, engineers, *patents* and R&D grants-

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-the seed corn of wealth"[3] (Karlgaard, 2003). If new technology and innovation, such as embodied in patents, truly are the seeds of wealth, we must strive to better understand the factors underlying innovative behavior and technological growth if we want to better understand economic growth. Given the paramount role of technology in explaining economic growth it is amazing we as economists have yet to examine every facet of its creation.

The location of innovative activity is clearly not random. From what we observe in practice it is clear some regions have a tendency to generate more ideas, knowledge, and new technology than other areas. If innovative activity truly was random we should expect people in the hinterlands of Nebraska to invent with the same propensity as researchers at the University of Minnesota in Minneapolis, such a proposition is obviously ludicrous. In close proximity to centers of innovative activity, such as universities, regularly are found research parks and companies that specialize in technology and related innovative behavior (Anselin, Varga, and Acs 1997). When there is increased research activity among economic agents, both within and between industries and fields, we can expect there will be positive externalities generated between firms as dissemination of new ideas and technologies is typically casual over short distances. Less obvious, but possibly no less important, are factors contributing to new idea creation through the informal interaction among bright and capable individuals whether they are interacting at work, sitting beside one another at a football game, or interacting indirectly through mutual friends, acquaintances, colleagues, or even adversaries. It is obvious we should expect novel ideas and innovative thought will much more readily cross hallways, dinner tables, and streets than expanses of land, mountains and forests (Glaeser et al. 1992). In this paper we believe proximity is likely to play an important role in this exchange of ideas, conscious or unintentional, between economic agents. In this paper we refer to this symbiotic relationship between economic agents interacting with one another as a spillin[4]. This relationship captures not only the effect of the own inventors activity on surrounding economic agents, firms and individual inventors, traditionally referred to as a spillover (see McCunn and Huffman (2000); and Huffman and Evenson (1992)), but also the effect surrounding inventive behavior has on the home inventors themselves. In an effort to better understand the factors underlying technological growth and new knowledge creation the first question this paper addresses is if such a an innovative or technological spillin does exist locally, can we postulate a model and test for this hypothesized spillin empirically? The second

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[3] Italics added.

[4] The term "spillin" was, according to our knowledge, first coined by Khanna, Huffman, and Sandler (1994) where the authors examined research spillins from neighboring States into the home State.

follows that if we can empirically test for and identify a local innovative spillin, how large are these impacts and are the results meaningful?

The role and mechanism of technological growth and creation of new knowledge is not as well understood as would be desirable given the importance of technology in an economic growth context. On this subject Simon Kuznets in 1962 suggested one of the largest obstacles in understanding economic growth was the inability of scholars to empirically capture technological change. While there is a general understanding that human capital and research expenditures play an important role in new knowledge and technology creation, there are additional factors which have been given little or no attention. One such relationship is the so called "innovative externality". To understand and quantify the importance of these externalities one must address the underlying factors. The mechanism which allows the realization of these externalities may be quite important. In general endogenous growth and endogenous technical changes are modeled as positive externalities in the literature. It is in this way that production externalities enter the pioneering growth model of Romer (1986)[5]. If the mechanism is one of journal articles and scientific newsgroups on the internet then geographic location is unlikely to be a factor. However, if the externality is realized via the local coffee shop, over dinner, or at a meeting, then geographic location will play a much more important role than in the former. Such geographic considerations motivate the work of Glaeser et al. (1992) where the authors argue intellectual breakthroughs must cross hallways and streets more readily than oceans and mountains. The possibility for such intellectual spillins between firms to occur is one justification of the high rental rates and long traffic commutes incurred in situating in a large city. In an attempt to quantify the importance of innovative externalities of a specific type Jaffe (1989) looks at geographic spillovers and finds university research has a significant effect on corporate patents, as well as indirectly on local innovation.

In this paper we examine more closely the link between innovative behavior and innovative spillins in a spatial framework. The conceptual framework is based on a county aggregated production function where technology is an input in addition to usual labor and non-labor inputs. The technology production function used here has roots in the knowledge production function of Grilliches (1979). Following the general discussion, a simple model is presented to highlight the role geographic closeness plays in the innovation process. In this model patents are used to capture new knowledge

[5] This type of externality is alluded to in Shell (1966).

produced (other studies using patents in this manner include Jaffe 1989 and 1993; Hall, Jaffe, and Trajtenberg 2001; Anselin, Varga, and Acs 1997; and Acs, Anselin, and Varga (2002)). Aditionally, there has been some work devoted to the location of innovative activity (Sweeney, 1987; Hall and Markusen, 1985). The mechanism of the spillin postulated in this study is underscored by the role of physical interaction and physical closeness between economic agents. The proposed relationship is tested empirically using a patent-inventor filing dataset for the US Midwest over the years 1975-2000 using spatial econometric techniques which incorporates the notion of spillovers between "neighboring" inventors.

A Conceptual Model with Innovative Spillins

In the model that follows, representative inventors are assumed to solve a profit maximization problem by choosing the level of firm specific technology through patenting behavior. Inventors utilize their time and cognitive ability to create an economically useful new technology. In this model an innovative spillin occurs as a result of geographic proximity to other innovative activity. In the framework to follow a representative inventor can be thought to be representative of the inventive activity within a certain geographical area like a county, state, or county.

The representative inventor's revenue is based on the quality of the innovations they produce, and on the price they are able to capture for their innovation. The revenue function for a representative inventor may be represented as

$$P(I_i) * I_i \qquad (1)$$

where I(.) is an index of the quality of innovative discoveries. The quality of new discoveries is assumed to occur along some positive continuum where larger values represent higher quality. For example, a new highly efficient fuel cell made up of many smaller complex ideas and innovations would appear near the top of the continuum whereas a new type of oscillating sprinkler drawing on a small number of relatively simple ideas would appear considerably lower on the same continuum. An innovation of a given quality will be able to receive a return of P, which is also a function of the quality of the invention. This reflects the notion of monopoly power the inventor is able to exert over their own invention. This may occur through a legal mandate, such as a patent, or secrecy through a trade secret. The index of innovative quality is captured by the function g(.)

$$I_i = g\left(d_i, \tilde{D}_i, h_i; E_i\right) \qquad (2)$$

The representative inventor in region i's own contribution to discoveries in their respective region is d_i and the "innovative spillin" from other inventors $\tilde{D}_i$. Endowed human capital (h_i) or intrinsic inventive ability, and other environmental impacts (E_i) capturing local economic conditions are also included. It is assumed quality of innovation is increasing in the first three arguments, $g_1, g_2, g_3 > 0$, where g_l is the first partial derivative with respect to the l^{th} argument for l=1,2,3. The sign with respect to local environmental conditions is indeterminate, i.e. sign of g_4 is indeterminate, without additional specific information to the components of the vector E. The innovative spillin is premised on the idea that "nearer" inventive activity is more beneficial than "further" inventive activity. Returning to our example of the fuel cell created in region r, the local contributions to the new innovation would be embodied in d_r whereas the spillin from other neighboring or geographically close regions is captured in $\tilde{D}_r$. Essentially the closer an inventor is to other inventive behavior, the greater will be the spillin effect. If we consider the idea of geographic spillin neighborhoods then as one moves further away the spillin effect decreases. There are a total of N of these neighborhoods, than in its extended form is related to all other inventive behavior. That is, there is a complete network and each regions inventive activity affects all other regions according to some type of distance decay criteria. The spillin can be formalized in the following manner:

$$\tilde{D}_i = \phi_1 \sum_{j \in n_1} d_{j,1} + \phi_2 \sum_{j \in n_2} d_{j,2} + \phi_3 \sum_{j \in n_3} d_{j,3} + \ldots + \phi_N \sum_{j \in n_N} d_{j,n} = \sum_{n=1}^{N} \phi_n \sum_{j} d_{j,n} \qquad (3)$$

The strength of the different neighborhood spillins are constrained by the ϕ_j's which are assumed to be contained in the interval $\phi_j \in (1,0] \ \forall j$ and the closer is the neighboring innovator the larger is the potential for spillin i.e. $\phi_1 \geq \phi_2 \geq \phi_3 \geq \ldots \phi_N \geq 0$. It is quite possible for reasonable applications that beyond some critical distance the parameter $\phi_j = 0$. If we assume the neighboring innovative activity interacts with the inventors own discoveries in a positive manner then these two complement one another so $g_{12} > 0$.

Patents have often been used to proxy new innovative ideas and discoveries of new knowledge (Hall et al. 2001, and Acs, Anselin, and Varga (2002)). Following this here too are assumed discoveries are a function patents. The relationship linking patented ideas with discoveries is via the function f(.). This function could be thought of as embodying risk and uncertainty associated with turning patentable ideas into useful discoveries and the fact that many patented ideas are not economically useful.

$$d_i = f(x_i) \tag{4}$$

The function f(.) satisfies the properties $f' > 0, f'' < 0$ where the primes represent the first and second derivatives respectively. For the other discoveries

$$\tilde{D}_i = \sum_{n=1}^{N} \phi_n \sum_j f(x_{j,n}) = k\left(\sum_{\forall j \neq i} x_{j,n}\right) = k(\tilde{X}_i) \tag{5}$$

where $\tilde{X}_i = \sum_{n=1}^{N} \phi_n \sum_j x_{j,n}$ and h(.) satisfies the properties $k' > 0, k'' < 0$. Using (2)-(5) the profit maximization problem facing the representative inventor is written as:

$$\prod = P\left(g\left(f(x_i), k(\tilde{X}_i), h_i; E_i\right)\right) * g\left(f(x_i), k(\tilde{X}_i), h_i; E_i\right) - P_x x_i \tag{6}$$

The inventors choice variable is x_i and faces an opportunity cost to inventing or patenting of P_x. This cost of patenting, P_x, is assumed to be exogenous but constant across all inventors. The resulting first order condition for an interior solution from (6) can be solved to yield

$$x_i^* = x_i\left(P_x, \tilde{X}_i, h_i, E_i\right) \tag{7}$$

For estimation purposes (7) is the equation of primary interest since. Essentially this equation relates patenting activity of the representative inventor to the activity of surrounding inventors in addition to human capital and the usual input and output prices. This equation is in effect a reaction function which takes the actions of the other firms as given[6]. However, in our representative agent framework it is unlikely any one agent will perceive its actions affecting others in surrounding counties. This lack of information between agents suggests the relationship $\frac{dx_i^*}{d\tilde{X}_i}$ is a true externality since inventors themselves do not realize how their actions affect other inventors and how surrounding inventors affect their behavior. From a practical point of view this is a reasonable assumption since it is unlikely an individual inventor understands or knows how their actions affect those of surrounding inventors. The relationship described here embodies the innovative spillin described by neighboring inventors and innovators and will in general have a positive impact given the functional forms chosen.

Econometric Model and Spatial Estimation Considerations

The innovative spillin embodied in function (7) is essentially a geographically mediated innovative or knowledge externality. Since we are dealing explicitly with locations in space the use of spatial statistical methods is an obvious choice to estimate any hypothesized innovative spillin. Unfortunately spatial econometric techniques have been almost non-existent in main-stream econometric texts so economists in the past have generally little exposure to both the application, estimation, and interpretation of spatial statistical results. For example, Amemiya (1985), Chow (1983), Greene (2002), Intrilligator (1979), Maddalla (1977), and Pindyck and Rubinfeld (1981) make no mention of spatial issues whatsoever. An exception to this is the text by Anselin (1988) which is devoted entirely to spatial econometric issues and estimation. Recently there has been an explosion in the literature relating to applied spatial econometrics to answer a variety of different economic questions. In particular, in a recent article by Acs, Anselin, and Varga (2002) the authors examine the impacts of private and university research on creation of new knowledge where new knowledge is defined as either innovation or patent counts. However, their analysis is based on 125 MSA regions in 1982 so the spatial structure in their models is best described by clusters rather than a

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[6]The above equation will be the primary focus of the empirical work since in such a representative model it is unlikely any one agent within the (county) will perceive their actions effects either within or between counties even if collectively these actions have effects. However, for completeness it may be useful to go a step further to impose a non-competitive equilibrium condition. Defining $X_i = x_i + \tilde{X}_i$, and invoking a Nash equilibrium condition will require $\tilde{X}_i = \tilde{X}_j \quad \forall j \neq i$. That is, in equilibrium all inventors would choose the same aggregate amount of patenting activity. This requires no collusion, only optimization by firms but also requires a full information assumption which is relaxed in the current model.

continuous spatial lattice. In addition the authors do not examine other factors such as human capital which may be an important factor in new knowledge creation.

New technology and innovation, while obviously an important component of economic growth, are difficult to quantify and obtain empirical estimates. In the literature patents have been used as indicators of innovation and new ideas (Anselin, Varga, and Acs 1997;Acs, Anselin, and Varga 2002;Hall, Jaffe, and Trajtenberg 2001;Jaffe 1989). However, it must be noted many patented innovations are not economically useful themselves and some useful innovations are not patented. In academia a similar parallel can be drawn on the usefulness of actual journal publications as indicators of useful new knowledge (Griliches (1979), and Pakes and Griliches (1980)). Nevertheless in this study we use utility patent counts aggregated at the county level for intervals over the years 1975-2000 as an indicator of new innovative behavior. The definition given by the US Patent and Trademark Office (USPTO) for the definition of a utility patent states:

> "(a utility patent) may be granted to anyone who invents or discovers any new, useful, and non-obvious process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof."

This definition clearly identifies utility patents as reasonable indicators of new innovative activity and an implied embodiment of new knowledge.

The explanatory variable of primary interest is the amount of innovative activity and new knowledge generated in surrounding counties, i.e. the quantity of patents filed, which is drawn from a neighborhood around the home county. Additional explanatory variables include indicators of human capital. Endowed human capital within the county is indicated by the percentage of individuals with a college degree. A college education, in addition to an indicator of human capital, also provides training that provides a foundation to understand science and technology. Per capita income is also included here as an indicator of economic viability within the county and may be interpreted as an additional indicator of human capital. In addition to these the local environment vector is comprised of number of important county characteristics to control for other location specific factors such as distance from a MSA, presence of an interstate within the county. State characteristics, as reflected by a vector of State dummies, are used to control for differing government policies, tax incentives and/or disincentives, programs, and even citizen attitudes related to new knowledge and innovation. The addition of population as an explanatory variable is an obvious choice as we should expect, *ceteris* *paribus*, more populous counties to report a greater number of patents. In terms of the cost of inventing, P_x, there is unfortunately no county level data that we are aware of to indicate how expensive is inventing within the county. However, since we have already controlled for human capital and per-capita income, it is not unreasonable to assume the term P_x is relatively constant across counties and will captured in our regression analysis via the constant term. A Cobb-Douglas functional form is proposed for empirical estimation of the relationship described in (7) and takes on the following form:

$$h_i = a\left(\sum_{j\in N_i} h_j\right)^{\rho} c^{\beta_1}\left(pci_i\right)^{\beta_2}\left(pop_i\right)^{\beta_2}\left(dm_i\right)^{\beta_3} e^{\beta_5(Id)+\sum_{k=6}^{11}\beta_k s_{i,k-5}+\varepsilon} \qquad (8)$$

where the above parameters are defined by:

h_i – the total number of inventor patent filings +1 per county for the time period[7];
c_i - the average percent of the education with a college education per county in period;
pci_i – the average county per capita income for the given period;
dm_i - the distance from the center of the county to a MSA in 1970;
Id_i - an interstate dummy =1 if the county had an interstate in 1970;
s_i - a dummy variable to capture State level effects, Iowa is the default State;
ε - a random error not correlated with the other regressors; and
parameters $\rho, a,$ and β_1 through β_{11} are to be estimated by the regression.

The expression in (8) is made econometrically tractable by taking a log transformation which allows the parameter estimates themselves to be interpreted directly as elasticities. However this logarithmic transformation presents somewhat of a problem since patents are a count variable and there were a small number of counties which reported no patent filings during the time periods analyzed in this paper. One method to control for this is to throw out any counties reporting zero patents and then

[7] The dependant variable here is defined as the log of the sum of county patents over the period of interest, T, plus one i.e. $\ln\left(\sum_{i=1}^{T} pat_i + 1\right)$ rather than the log of average patents filed over the period plus one i.e. $\ln\left(\frac{\sum_{i=1}^{T} pat_i}{T} + 1\right)$. Note that augmenting the dependant variable with "+1" is required since a small number of counties did not report any patent filings. Due to the extreme variability and potential for heteroskedasticity and the need to maintain a complete spatial structure the use of logarithms necessitates augmenting the dependant variable in this manner. The chosen method augmenting the sum of patents rather than the average is chosen as addition of the "+1" will have a smaller relative impact. The need to both take logs and also maintain the spatial integrity of the data set does not allow us to simply "throw out" counties which did not report any patents.

proceed accordingly. This method is rejected as it will inherently alter the spatial structure of the dataset which is the key focus of this study. A second approach would be to adopt some type of limited dependant variable model such as a spatial probit model (McMillen, 1992) or tailor some other type of limited dependant variable model (such as Tobin, 1958) to a spatial problem. These approaches are rejected here since the patent groupings would be arbitrary at best given the continuous nature of patent data and the relatively small number of counties for which zero patents were reported. In this paper we take a third approach by augmenting the dependent variable, ie. average patent filings, with "+1"[8]. The natural log formulation of the model is:

$$\begin{aligned} \ln h_i = \beta_0 + \rho\left(\sum_{j \in N_i} \ln h_j\right) + \beta_1 \ln c_i + \beta_2 \ln pci_i + \beta_3 \ln p_i + \beta_4 d_i \\ + \beta_5 Id_i + \sum_{k=6}^{11} \beta_k s_{i,5-k} + \varepsilon \end{aligned} \tag{9}$$

where $\beta_0 = \ln a$ and the other variables are defined as previously. For each cross section of data studied we use period averages to smooth over any bumps or yearly irregularities that may exist in the data with the exception of the dependant variable. For example, for the period 1975 to 2000, the sum of patents is the dependant variable, averages are used for college graduates, per capita income, and population, and the remaining variables remain constant over time. For purposes of estimation the functional form in (9) is described with the following matrix notation:

$$\begin{aligned} h = \rho W h + X\beta + \varepsilon \\ \varepsilon \sim N\left(o, \sigma^2 I_n\right) \end{aligned} \tag{10}$$

where h is a nx1 matrix described by inventor patent filings, W is a nxn standardized spatial weights matrix, X is a nxk matrix of explanatory variables described in (8), and β and ρ are a kx1 matrix and a scalar, respectively, are the parameters to be estimated. The spatial neighborhood structure is embodied in the spatial weights matrix W. The matrix W is a standardized and symmetric spatial weights matrix that relates counties based on their geographic location. Here a Delaunay triangulation routine is implemented to determine the neighborhood structure embodied in W (see Pace and LeSage

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[8] Such an approach was taken by Roe, Irwin, and Sharp (2002) when estimating a spatial lag model similar to that proposed here.

(2003) a) and b) for examples using the Delaunay routine). There are no restrictions imposed on any of the parameters except ρ which is required to be contained in the interval $\rho \in \left(\frac{1}{\lambda_{\min}}, \frac{1}{\lambda_{\max}} \right)$ where $\lambda_{\min}$ and $\lambda_{\max}$ are the minimum and maximum eigen values for the spatial weights matrix W respectively (Sun et al., 1999).

As a modification to the relationship described in (9) we can include a lag variable. This lag in patent filings would capture the effect previous inventive activity has on the current period inventive activity. This new relationship accounting for both a spatial and time lag relationship is written as:

$$\begin{aligned} \ln h_i = \beta_0 + \rho \ln \left(\sum_{j \in N_i} \frac{1}{\eta_j} h_j \right) + \alpha \ln h_{i,-t} + \beta_1 \ln c_i + \beta_2 \ln pci_i + \beta_3 \ln p_i + \beta_4 d_i \\ + \beta_5 Id_i + \sum_{k=6}^{11} \beta_k s_{i,5-k} + \varepsilon \end{aligned} \quad (11)$$

where $h_{i,-t}$ is the number of patents filed in the previous time period within the county and α is the parameter to be estimated quantifying this relationship. All other variables and parameters are the same as they appear in (9). Equation (11) will allow us to examine not only the effect of neighboring inventive activity but also the effect the recent stock of local patents has on future patenting behavior. Thus we are able to capture an inventive spillin of types over both space and time.

The above relationships may be estimated using OLS when ρ=0, that is, when a spatial relationship is absent. However, in the presence of a spatially lagged dependant variable in (10), simultaneity of will cause OLS estimates to be both biased and inefficient.[9] We thus opt for maximum likelihood estimation which can be used to derive efficient and unbiased estimates. To simplify the estimation procedure we use a concentrated log-likelihood function and follow the algorithm of Anselin (1988) to derive maximum likelihood estimates[10]. Additionally, we can test for the presence of a spatial relationship in our model residuals using a Lagrange Multiplier, Likelihood ratio, and a modified

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[9] A potential problem with an OLS treatment of the spatial model with a lagged dependant variable may be explained as follows: If we compute $Z_i = \sum_{j \in N_i} \ln h_i$ and regress $\ln h_i = \beta_0 + \rho Z_i + X_i \beta + \varepsilon_i$, we would need to condition on Z_i otherwise we would be ignoring measurement errors in Z_i.

[10] The estimation was performed in Matlab using sparse matrix algorithms written by Lesage (1999).

Lagrange Multiplier test (Anselin, 1988). The next section describes in detail our dataset and is followed by presentation of the results.

Data

Using data from the USPTO and census listings of town names for each county, a dataset of patents per county was created. A list of all utility patents filed in the United States for the years 1975-2000 was obtained from the USPTO for the US Midwestern states of Minnesota, Iowa, Kansas, Missouri, Nebraska, South Dakota, and North Dakota. This Midwestern sample represents a unique set of observations as people have not flocked in general to the Midwest unlike regions in California and Colorado. Thus do to the nature of this Midwestern sample we are able to control to a large extent the endogenous location decisions of agents. Further, this region has not been a hotbed of innovative activity and the endogenous nature of inventor location has also been controlled. The dataset from the USPTO contained the following information on each utility patent filed: i) a patent number the year, ii) the inventors name, iii) the inventors mailing address, and iv) rank of the inventor[11]. While the year the patent was filed was not contained in the dataset, supplemental information from the USPTO was used to assign a year based on the patent number. Using the inventors mailing address and cross-referencing this with a list of cities by county we were able to determine how many patents were filed for each county per year using two different criteria: 1) patent counts based on first inventors only and, 2) patent counts based on the combination of first and co-inventors. A case may be made for using each one of these as indicators of new innovative activity. Using only first inventors we are essentially capturing the driving force behind each patent filed and give each patent equal weight. Using the combination of both first inventor and co-inventors, we account for all new innovation contributing to the new innovation. However, we do create a double-counting problem since patents listing more than one inventor will be given greater weight.

For the data description to follow we highlight primarily the 1975-2000 period with a complete listing of summary statistics for all periods given in Table 1. For the years 1975 through 2000 there were a total of 77,502 patents filed within our area of study based only on the number of primary inventor patent filings. There were a number of counties that did not have any patents filed within the county and the county with the highest patent count filed during this period reported a total of 12,065 patents.

[11] Similar to journal articles, patents commonly have multiple inventors associated with the patent with the first inventor as the primary and others as co-inventors.

The mean patent filing is 125 with a relatively high standard deviation of 666 patents[12]. Figure 1 maps the spatial distribution of patent filings summed over the years 1975-2000. What we see is there is a large amount of activity near and around large cities like Minneapolis-St.Paul, St.Louis, Kansas City, and Des Moines. There appears to be quite a clear spatial relationship with clusters in these areas. Using all inventors, inventors names appeared on patents a total of 138,050 times with 22,024 occurring in one county alone. Using total inventors we find an average inventor-patent count of 223 with a standard deviation of 1,251. A map of the total inventor patent count is given in figure 2. This figure has basically the same pattern as in figure 1 with the scaling being the predominant difference between the two.

The average percentage of the population with a college degree is 8.1% with a standard deviation of 2.8%. While there is considerably less variation as compared to patent filings, the range is actually quite wide with a minimum of 3.1% and the most highly educated county averaged just over 25% of its residents having a college degree. Mean per capita income average $13.3 thousand with a relatively small standard deviation of $2.1 thousand. The county with the smallest per capita income was found to have an average income $6.2 thousand which is about a quarter of the county with the highest per capita income of $23.5 thousand. Since our data sample is based on a select group of Midwestern states, many of which are rural and a number which are home to some very large cities, we should expect a large range of population. The average county had a population of just under 29 thousand residents with a standard deviation of almost 78 thousand. The smallest county had a population averaging only 486 while the largest county averaged over 1 million people.

For each county we are also interested in whether or not the counties had an interstate and how far were the counties away from a metro area. For this analysis we hold both of these variables constant based on presence of an interstate within the county in 1972 and distance from a MSA in 1968. We find that the average distance from the center of the county to a large metro area was 109 miles with a standard deviation of 68 miles. The largest distance between any one county and a metro area was just over 358 miles. For counties which essentially contain MSA's themselves the distance is negligible. In addition, 176 or roughly 16% of the counties in our sample had an interstate within the county.

[12] The median patent filing is 14 so it is clear there is potential for heteroskedasticity which necessitates the need to take logarithms.

Results

In this section we present the results from our regression analysis of equations (9) and (11). Equation (11) is estimated for the periods 1980-84, 1985-1989, 1990-94, and 1995-2000 since these are the blocks for which an appropriate lag in patenting activity is available. Equation (9) is estimated along side the periods coinciding with periods previously mentioned in addition to the years 1975-79, and the entire sample period 1975-2000. The results of these estimations are in tables 2-7. When appropriate we also conduct tests to determine if the spatial structure of the data has been handled in a satisfactory manner.

The set of results for the broader 1975-2000 time period are shown in table 2. In this table two groupings of results are given with the first a set of results for first inventor patents only and a second set of results where all inventor patent filings, primary plus all secondary inventors, are the dependant variable. In each of these the spatial model is presented along side an OLS specification which omits the spatial interaction parameter. We compute likelihood ratio (LR) and Lagrange multiplier (LM) test statistics to check for a spatial relationship in the data. The LR and LM test statistics are 16.0 and 17.6 respectively, both of which imply rejection of the hypothesis: no spatial relationship exists in the residuals[13]. In light of this fact we will not dwell upon these OLS results as this model specification does not adequately capture the spatial relationship inherent in the data. A spatial LM test a test statistic of 2.9 suggesting we cannot with a high level of statistical confidence reject the null hypothesis: no spatial relationship exists in the model residuals.

The spatial model based on the sum of first inventor patent filings over the period 1975-2000 in the second column of table 2 is able to explain about 82.5% of the variation in patent filings and the spatial model where all inventor, primary plus all secondary inventors, patent filings are used explains almost 83% of the variability in patent filings as shown in the fourth column of table 2. Both of these indicate a relatively good fit for our patent model given the cross-sectional data. Using first inventor patent filings the estimated coefficient for spatial interaction is 0.13 and is significantly different from zero with at least a 99% level of confidence. Since this is a log-log formulation this coefficient can be interpreted directly as an elasticity. That is, a 10% increase in the first inventor patents filed by inventors in neighboring counties will *ceteris paribus* result in a 1.3% increase in the number of

[13] Both the LR and LM tests are distributed Chi-Square with one degree of freedom. The critical value for the Chi-square distribution is 6.35 at the 99% level of confidence so both test easily reject the hypothesis of no spatial interaction.

patents filed in the home county. This finding would suggest innovative spillins do occur between counties. The fourth column of table 2 reports an estimate for rho of 0.165 and is significantly different from zero with a high probability suggesting a 10% increase in the number of total inventors, not just primary inventors, in neighboring counties as defined by the spatial weights matrix W will be met with a 1.65% increase in the number of inventor patent filings in the home county. This spillin estimate is similar in magnitude to that computed using only first inventors i.e. 0.165 vs. 0.13.

In our earlier discussion of the model we identify a number of other variables believed to play and important role in new innovative activity, i.e. patents, and we discuss these here. Human capital as embodied in college graduates and represented as the (average) percentage of the population with a college degree is computed to be 0.83 for first inventor and 0.86 for total patents summed over the period 1975-2000, both of these estimates are statistically different from zero. This result gives further support human capital provides a foundation for understanding science and technology and plays an important role in new technology creation process. Another indicator of human capital, per capita personal income, averaged over this period also had a positive and statistically significant impact on patent filings. The estimation results suggest a 1% increase in per capita income results in a 1.08% increase in the number of patents filed in the home county and this result is statistically different from zero with at least a 99% level of probability. The same variable for total patents is very similar in magnitude with a computed elasticity of 1.18 and is also statistically different from zero with a high level of confidence. If we are to correctly interpret both percent of the population with a college degree and average per capita county income as indicators of human capital then we have established another clear convincing link between innovative behavior and new knowledge creation.

As expected population plays an important role in explaining new patents within the county. This result is consistent with Romer (1986) where his growth model has a large population advantageous to innovation. The elasticity computed for the sum of first inventors only suggests a 1% increase in the population will result in a 0.92% increase in the number of patents filed within the county and for total inventors the comparable elasticity is 0.97. Once again both of these results are statistically different from zero. The parameters for market access included distance to a MSA and presence of an interstate. The spatial models for both first and total patent inventor filings resulted in an estimated elasticity of -0.1 and was marginally significant with at least a 95% probability the coefficient is different from zero. A 10% increase in the distance from a metro area is met with a 1% decline in the level of patenting under either first or all inventor patent counts. This parameter is of the expected sign since it was expected distance would impede the ability of economic agents to interact. It was found presence of an interstate did not have an appreciable effect on patent filings.

Returning to figures 1 and 2 with the mapping of patent filings for our Midwestern selection of States, we can see Iowa and Minnesota appear to perform relatively better than the other States in terms of patenting behavior. This observation is evident when examining the State dummies in table 2. With Iowa as the default State, Minnesota performs better and the rest of the States generally perform poorer than Iowa. These results may be an indication of the State attitudes and programs designed to encourage new innovation. The variable estimates and level of significance are generally quite similar when using either the first or total inventor patent filings as was the case in the above discussion. Thus when discussing further results in the remainder of the paper we consider only the first inventor patent filings as the results do not appear to differ a great deal with those estimates obtained using the total inventor patent counts.

While it is useful to examine the period 1975-2000 as a whole, it is also important to examine sub sections in greater detail. We examine sub sections of the data for two reasons. The first is to examine the check for changes in this spillin relationship over time. The second is that by examining smaller cross sections we can explicitly introduce a time lag in our patent relationship. We thus further consider the five year increments from 1975-79, 1980-84, 1985-89, 1990-94, and a six year bloc from 1995-2000. Also, by using sub sections we are also able to include a lagged patent variable for the most recent four of these sub-periods. The analysis for the years 1975-1979 are presented in table 3, the spatial model is able to explain about 70% of the variability in first inventor patent filings and the spatial LM indicates the spatial structure of the data has been handled in a satisfactory manner in this model. The innovative spillin elasticity is computed at 0.156, a value similar to that computed for the period 1975-2000, and is significantly different from zero with a high level of statistical confidence. Human capital as captured by percent of the population with a college degree is again found to have a positive and significant impact with an estimated coefficient of 0.71. Another indicator of human capital, per capita income, is also found to be positive and significantly different from zero with an estimated elasticity of 0.91 once again suggesting human capital was an important factor in innovative activity during the earlier stages of our sample period. Since all analysis is cross-sectional for any given time period, per capita income was believed to be more representative of human capital than a possible income effect favoring innovation. Population was once again found to be highly significantly different from zero with an estimated elasticity of 0.67. The market access parameters indicate distance to a metro area is important with an estimated elasticity of -0.18 and is significantly different from zero. The interstate variable is once again not found to be significant. Examining the State dummies it is interesting to note that only Minnesota performed better relative to Iowa and all other States were statistically insignificant.

The remaining four periods of study, 1980-84, 1985-89, 1990-1994, and 1995-2000 allows us to add an additional variable, namely lagged patents, as described by the relationship in equation (11). In this specification we are able to examine not only the spillin across counties, but the relationship with innovative activity overtime in the home county as well. The results for these four periods are presented in tables 4-7. In each table three sets of results are presented: 1) OLS, 2) spatial, and 3) spatial with a lag. In all four periods of study we find evidence of a spatial relationship in the data as indicated by the LM and LR test statistics so we consider only the spatial and spatial-time lag models which are contained in the last two columns of each table.

First we consider the results of these four sub-periods of study under the same parameters as tables 2 and 3, the following paragraph is devoted to interpreting results which include patent lag parameter. The results from the spatial model estimation for these last four sub-periods are quite similar in terms of the general interpretation and significance of the broader period 1975-2000 but with some key differences. Consistent with our conceptual model the importance of innovative spillins do appear to exist between counties over time as the spatial interaction terms were of similar both in terms of statistical significance and magnitude. Other parameters like education, and population continued to have a positive and significant impact on patenting activity. A departure from general results enters when we examine per capita income plays continued to play a significant role for the periods 1980-85 and 1985-89, but is only marginally significant for the period 1990-94 and is not found to be significant for the period 1995-2000. This may be an indicator of the per capita income variable decreasing over time as an indicator of human capital within the county. Distance continues to play an important role in explaining patenting activity where greater distances from a metro area imply less patenting activity. State impacts as captured in the State dummies are mixed but generally imply Minnesota performs better than Iowa while States like Kansas and South Dakota tend not to perform quite as well in comparison to Iowa.

In each of the spatial specifications with time lagged patents the model parameter estimates are given in the third column and we find this specification was able to explain 81% or more of the variability in first inventor patent filings. The r-squares for these models are quite similar to those in table 2 where more time varying impacts are implicitly captured due to the longer time period. Considering the last column now for each of tables 4 through 7, the spatial interaction term is found to range from 0.06 to 0.12 with the coefficient either marginally or strongly different from zero in a statistical sense. The patent time lag parameter is much larger than the spatial spillin parameter by comparison. The estimated coefficients, which can also be directly interpreted as an elasticity, exhibit a very tight range from a low of 0.580 in 1985-89 to a high of 0.598 for the period 1990-94. All of these time lag coefficients were found to be statistically different from zero with a high degree of statistical confidence. For the period 1980-84 this lag variable implies that an increase of 10% in patents filed for the previous years 1975-79 resulted in a 0.597% increase in the number of patents filed. Also of interest is these coefficients relationship to one. As seen by the very low standard errors all these coefficients are also statistically different from 1 so there is not a one-to-one relationship between how many patents are filed this period and how many patents will be filed next period. To make a casual interpretation of this parameter may be to interpret new innovation, as measured by patents, as concave function of patents filed in the previous period possibly implying decreasing returns over time. Although the other coefficients are not as large in the simple spatial model, education and population do retain a significant role in explaining patent filings in all of these periods. The tremendous explanatory power of lagged patents no doubt had a dwarfing impact on the other parameters within the model.

Discussion and Conclusions

In this paper we used spatial econometric methods to test for the presence of a geographic innovative spillin. We do indeed find the hypothesized innovative spillin does have a positive and significant effect on new knowledge creation giving us a further understanding of the important factors underlying technological growth. In models where a time lag was not used in the estimation, the innovative spillin effect was found to have an elasticity ranging from 0.13 to 0.20 depending on the time period used. When a five-year patent lag was introduced into the model we found the spillin ranged from 0.06 to 0.12. In either of these model specifications however, it is apparent an innovative spillin of the type hypothesized in this paper is supported by the data given the high level of statistical confidence in parameter estimates for the spillin parameter. While at first glance these effects may seem small, especially when compared to the relatively large effect from lagged patents, this is not necessarily the case. In reality it is likely the actual spillin is larger than what was estimated here. The empirical model was set up to estimate the innovative spillin from geographically close counties and in doing so is not able to pick up activity occurring within the county itself. That is, interaction among agents within the county itself and experiencing similar externalities is not captured at all. The structure of the spatial weights matrix, W, used here does not allow us to pick up the interaction between individuals themselves, only the interactions that cross county lines so we should expect actual values to be larger. In any case given the macro nature of the data, from the point of view of an individual inventor, our estimates do provide a lower bound and future research with more concise data may be able to improve upon the reliability of our estimates.

While the primary objective of this paper was to test for the presence and the magnitude of the so called innovative spillin, we do gain some useful insights into some of the other variables that also play a role in generating patents. Most notable of these is the importance of human capital. The results are really quite convincing that areas with higher concentrations of individuals with a high level of education will also experience a larger level of patenting behavior. These results add to the already quite well developed literature suggesting human capital plays an important role in the creation of new ideas, knowledge, and technology. Further, if we interpret per capita income as an indicator of human capital, then new technology created as indicated by new patents also responds in a positive manner to this variable. Other variables found to have a generally significant effect on patenting activity include population and distance to a metro area, both of these tend to speak for themselves. It should however be noted that with respect to population, while it will obviously play an important role, the relationship is generally not one-to-one suggesting further it is not simply stock of people that generates new ideas that in turn generate new growth. Rather, stock of knowledge as embodied by both lagged patents, and concentration of educated individuals, play a much more important role.

Given the broad scope of our indicator used in this paper as an indicator of new knowledge, i.e. patents, it would be misleading to interpret these results as only applied to patents. Noting that while patents are good indicators of new technology created they are not indicators of economic value (Griliches, 1979; Pakes and Griliches, 1980; Hall et al., 2001). The proper interpretation for these conclusions needs to be applied to a much broader interpretation of innovative thought and ideas that includes informal technology creation, possibly for either actual inventions or processes, that are not or cannot be patented but still have significant economic value. While we concede the use of patents as a proxy for new technology is a limited indicator for technology as applied to our economic models in general, however, given that more precise indicators of new knowledge are not readily available; the current analysis lists cautious evidence to the existence of knowledge externalities over space. An opportunity for future research is to identify and create better indicators and provide more precise estimates of the magnitude of knowledge externalities between economic agents at various levels of aggregation.

In this paper we formulated a model to describe how technological and innovative spillins may affect local innovative activity. It has long been believed that technological spillins as defined by this paper do exist. Working within the confines of the available data we test for the presence and estimate the relative size of these so called innovative spillin effects. The model specification appears to be robust to both the specific choice of explanatory variables and the years chosen. Even taking into consideration the limitations of using patents to proxy innovative behavior, these results are still quite impressive. While we have indicated some of the limitations of our analysis, in particular drawing micro conclusions from aggregate county data, it does seem apparent an innovative spillin does exist. Refinements to the data and methods may improve the accuracy of the estimates but the general conclusions will most likely remain unchanged.

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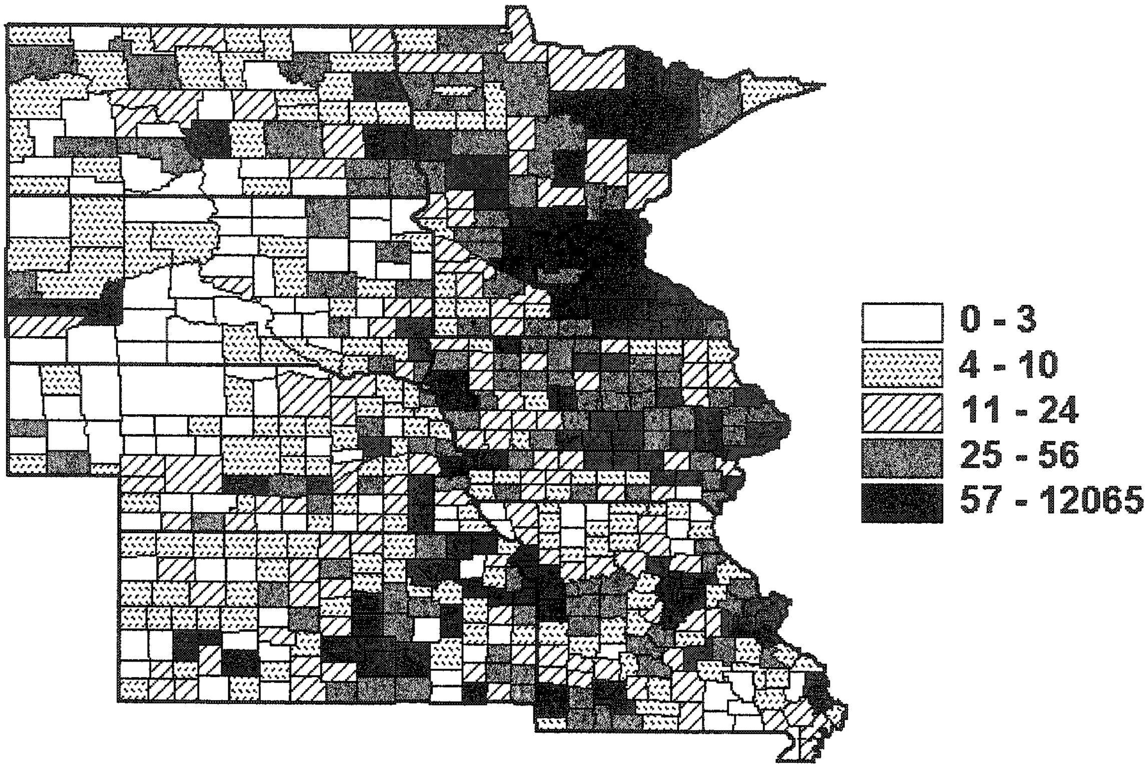

Figure 1: Sum of First Inventor County Patent Filings, 1975-2000

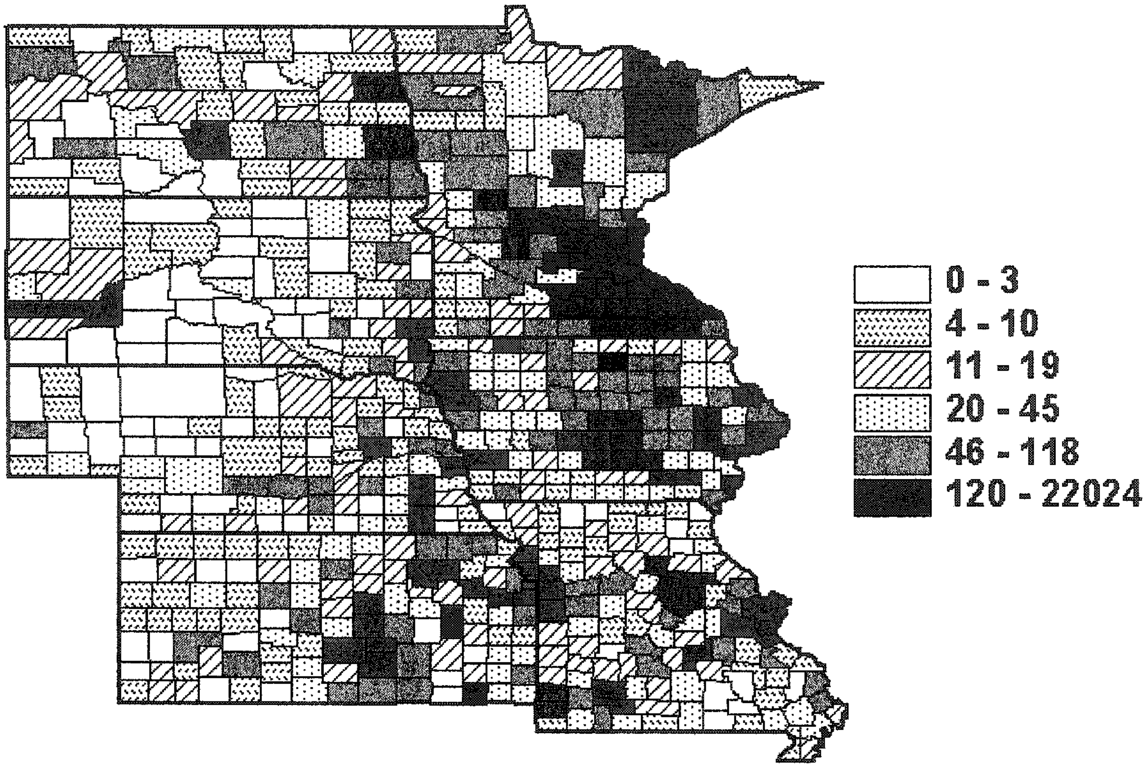

Figure 2: Sum of Total Inventor County Patent Filings, 1975-2000

Table 1. Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Count
Sum of First Inventor Patents					
1975-2000	125	666	0	12065	77502
1975-79	19	97	0	1654	11790
1980-84	18	91	0	1552	10845
1985-89	20	111	0	2121	12640
1990-94	26	141	0	2554	15875
1995-2000	43	233	0	4184	26352
Sum of All inventor Patents					
1975-2000	223	1251	0	22024	138050
1975-79	27	142	0	2408	16976
1980-84	26	136	0	2320	15938
1985-89	32	184	0	3514	20038
1990-94	46	271	0	4752	28701
1995-2000	91	533	0	9030	56397
Mean Percent with a College Degree					
1975-2000	8.07	2.76	3.11	25.22	
1975-79	6.55	2.37	2.46	22.36	
1980-84	7.02	2.29	2.59	21.49	
1985-89	7.95	2.63	2.19	24.59	
1990-94	9.00	2.92	2.07	27.38	
1995-2000	10.16	3.22	2.38	29.87	
Mean Per-Capita Income					
1975-2000	13.28	2.16	6.17	23.46	
1975-79	6.56	1.01	3.01	10.46	
1980-84	9.86	1.67	4.03	16.80	
1985-89	13.20	2.23	5.19	23.04	
1990-94	16.58	2.91	7.96	36.50	
1995-2000	20.64	3.70	5.68	37.87	
Mean Population					
1975-2000	28762	77657	486	1012285	
1975-79	27405	73464	578	967993	
1980-84	28269	76861	463	1006842	
1985-89	28269	76861	463	1006842	
1990-94	29177	79886	458	1051443	
1995-2000	30606	83288	439	1095946	

Table 1 (cont'd)

Variable	Mean	Std. Dev.	Min	Max	Count
Other County Characteristics					
Distance to a MSA	109	68	0.47	358.5	
Presence of an Interstate	.16				176
Iowa					99
Kansas					105
Minnesota					87
Missouri					115
Nebraska					93
North Dakota					53
South Dakota					66

Table 2. 1975-2000 First and Total Inventor Patent Filings per County

	(log) Sum First Inventor Patent Filings (+1)		(log) Sum Total Inventor Patent Filings (+1)	
	OLS	Spatial	OLS	Spatial
Independent Variables				
Spatial Interaction				
rho		0.1345		0.1650
		(3.7927)***		(4.7068)***
Education Attainment				
Percent with 4 years college	0.7564	0.8303	0.7564	0.8597
	(5.8206)***	(6.4742)***	(5.3776)***	(6.2404)***
County Characteristics				
(log) per capita income	1.2285	1.0817	1.3724	1.1779
	(5.4847)***	(4.8849)***	(5.6604)***	(4.9496)***
(log) population	0.9547	0.9163	1.0244	0.9724
	(22.6343)***	(21.5792)***	(22.4380)***	(21.2971)***
Market Access				
log distance to a MSA	-0.1475	-0.1010	-0.1637	-0.0995
	(-3.4553)***	(-2.3134)**	(-3.5432)***	(-2.1234)**
presence of interstate	0.0098	-0.0121	0.0436	0.0161
	(0.1387)	(-0.1751)	(0.5718)	(0.2174)
State Effects				
Kansas	-0.3015	-0.2478	-0.3741	-0.2975
	(-2.8839)***	(-2.4016)**	(-3.3051)***	(-2.6791)***
Minnesota	0.2515	0.1907	0.2585	0.1782
	(2.4118)**	(1.8516)*	(2.2900)**	(1.6124)
Missouri	-0.2345	-0.1764	-0.2838	-0.2038
	(-2.2186)**	(-1.6887)*	(-2.4802)**	(-1.8142)*
Nebraska	-0.3163	-0.2024	-0.4262	-0.2648
	(-2.9596)***	(-1.8574)*	(-3.6845)***	(-2.2489)**
North Dakota	-0.0973	-0.0087	-0.1221	-0.0060
	(-0.7642)	(-0.0687)	(-0.8860)	(-0.0438)
South Dakota	-0.5271	-0.3735	-0.6266	-0.4175
	(-4.4006)***	(-3.0221)***	(-4.8321)***	(-3.1354)***
Constant	-10.0104	-10.0515	-10.6571	-10.7332
	(-15.3982)***	(-15.8181)***	(-15.1444)***	(-15.7248)***
Diagnostics				
R-Square	0.8205	0.8254	0.8210	0.8285
R-Adj-Square	0.8173	0.8222	0.8178	0.8253
LR	16.0066***		24.4018***	
LM	17.5674***		27.6017***	
Spatial LM		2.8927*		3.9917**

Note: All values in parentheses are t-values, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

Table 3. 1975-79 First Inventor Patent Filings per County

	(log) Sum First Inventor Patent Filings (+1)	
	OLS	Spatial
Independent Variables		
Spatial Interaction		
rho		0.1561
		(3.5217)***
Education Attainment		
Percent with 4 years college	0.6643	0.7149
	(5.1333)***	(5.6080)***
County Characteristics		
(log) per capita income	1.0386	0.9065
	(4.2122)***	(3.7179)***
(log) population	0.7001	0.6662
	(15.1018)***	(14.4195)***
Market Access		
log distance to a MSA	-0.2292	-0.1867
	(-5.0661)***	(-4.0038)***
presence of interstate	0.0426	0.0212
	(0.5671)	(0.2886)
State Effects		
Kansas	0.0791	0.0838
	(0.6993)	(0.7567)
Minnesota	0.2679	0.2210
	(2.3644)**	(1.9793)**
Missouri	0.0396	0.0806
	(0.3363)	(0.6963)
Nebraska	0.0327	0.1109
	(0.2839)	(0.9678)
North Dakota	-0.0326	0.0616
	(-0.2415)	(0.4592)
South Dakota	0.0279	0.1190
	(0.2130)	(0.9108)
Constant	-7.3755	-7.3374
	(-11.3766)***	(-11.5673)***
Diagnostics		
R-Square	0.6940	0.7014
R-Adj-Square	0.6885	0.6960
LR	11.1262***	
LM	11.6987***	
Spatial LM		0.9972

Note: All values in parentheses are t-values, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

Table 4. 1980-84 First Inventor Patent Filings per County

	(log) Sum First Inventor Patent Filings (+1)		
	OLS	Spatial	Spatial - time lag
Independent Variables			
Spatial Interaction			
rho		0.1781	0.0673
		(4.0728)***	(1.8172)*
Time Lag			
Previous 5-year county sum of patents			0.5966
			(18.7754)***
Education Attainment			
Percent with 4 years college	0.7153	0.7751	0.2613
	(5.1095)***	(5.6587)***	(2.3123)**
County Characteristics			
(log) per capita income	0.9441	0.7914	0.3122
	(4.0822)***	(3.4891)***	(1.6933)*
(log) population	0.6657	0.6326	0.2465
	(15.1574)***	(14.5038)***	(6.0432)***
Market Access			
log distance to a MSA	-0.2225	-0.1714	-0.0702
	(-5.0197)***	(-3.7699)***	(-1.9137)**
presence of interstate	0.0481	0.0279	0.0227
	(0.6526)	(0.3883)	(0.3933)
State Effects			
Kansas	-0.1399	-0.0955	-0.1122
	(-1.2804)	(-0.8936)	(-1.3083)
Minnesota	0.2900	0.2280	0.1469
	(2.6476)***	(2.1162)**	(1.6969)*
Missouri	0.0666	0.0972	0.0964
	(0.6018)	(0.8989)	(1.1100)
Nebraska	-0.1608	-0.0570	-0.0781
	(-1.4303)	(-0.5067)	(-0.8610)
North Dakota	-0.0759	0.0141	0.0189
	(-0.5700)	(0.1074)	(0.1790)
South Dakota	-0.0932	0.0159	-0.0436
	(-0.7237)	(0.1236)	(-0.4209)
Constant	-7.4351	-7.3894	-2.8205
	(-11.5407)***	(-11.7711)***	(-5.0380)***
Diagnostics			
R-Square	0.7017	0.7113	0.8143
R-Adj-Square	0.6963	0.7061	0.8106
LR	20.4001***		
LM	23.0835***		
Spatial LM		3.5284*	2.0772

Note: All values in parentheses are t-values, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

Table 5. 1985-89 First Inventor Patent Filings per County

	(log) Sum First Inventor Patent Filings (+1)		
	OLS	Spatial	Spatial - time lag
Independent Variables			
Spatial Interaction			
rho		0.1732	0.0969
		(4.1667)***	(2.8196)***
Time Lag			
Previous 5-year county sum of patents			0.5796
			(19.0158)***
Education Attainment			
Percent with 4 years college	0.9833	1.0394	0.5410
	(7.2577)***	(7.8370)***	(4.9767)***
County Characteristics			
(log) per capita income	0.6774	0.5444	0.2367
	(3.1178)***	(2.5427)**	(1.3781)
(log) population	0.6959	0.6587	0.2896
	(16.8994)***	(16.0589)***	(7.6304)***
Market Access			
log distance to a MSA	-0.1985	-0.1475	-0.0520
	(-4.6545)***	(-3.3747)***	(-1.4896)
presence of interstate	0.0352	0.0145	-0.0058
	(0.4994)	(0.2113)	(-0.1053)
State Effects			
Kansas	-0.2589	-0.2051	-0.1388
	(-2.4844)**	(-2.0036)**	(-1.7020)*
Minnesota	0.3719	0.2876	0.1969
	(3.5597)***	(2.7751)***	(2.3842)**
Missouri	-0.0276	0.0175	0.0151
	(-0.2625)	(0.1707)	(0.1843)
Nebraska	-0.1446	-0.0560	0.0257
	(-1.3459)	(-0.5223)	(0.3003)
North Dakota	0.1281	0.1649	0.1978
	(0.9836)	(1.2962)	(1.9537)**
South Dakota	-0.1942	-0.0804	-0.0197
	(-1.5832)	(-0.6578)	(-0.2020)
Constant	-7.8820	-7.8040	-3.6754
	(-12.0907)***	(-12.2913)***	(-6.6873)***
Diagnostics			
R-Square	0.7411	0.7497	0.8416
R-Adj-Square	0.7364	0.7451	0.8385
LR	15.3472***		
LM	16.6983***		
Spatial LM		1.4808	0.0595

Note: All values in parentheses are t-values, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

Table 6. 1990-94 First Inventor Patent Filings per County

	(log) Sum First Inventor Patent Filings (+1)		
	OLS	Spatial	Spatial - time lag
Independent Variables			
Spatial Interaction			
rho		0.1508	0.0618
		(3.6876)***	(1.7869)*
Time Lag			
Previous 5-year county sum of patents			0.5982
			(17.9832)***
Education Attainment			
Percent with 4 years college	1.1539	1.2024	0.4556
	(7.0619)***	(7.5086)***	(3.3391)***
County Characteristics			
(log) per capita income	0.4616	0.3645	0.1054
	(2.1207)**	(1.7056)*	(0.6043)
(log) population	0.7709	0.7360	0.3429
	(18.8647)***	(17.9667)***	(8.5899)***
Market Access			
log distance to a MSA	-0.1431	-0.1027	-0.0198
	(-3.2787)***	(-2.2964)**	(-0.5421)
presence of interstate	0.0658	0.0415	0.0375
	(0.9165)	(0.5905)	(0.6569)
State Effects			
Kansas	-0.2588	-0.1989	-0.0793
	(-2.4534)**	(-1.9119)*	(-0.9345)
Minnesota	0.2776	0.2138	0.0561
	(2.6111)***	(2.0271)**	(0.6502)
Missouri	-0.1222	-0.0725	-0.0464
	(-1.1547)	(-0.6972)	(-0.5488)
Nebraska	-0.1113	-0.0229	0.0240
	(-1.0191)	(-0.2099)	(0.2710)
North Dakota	0.1002	0.1501	0.0728
	(0.7633)	(1.1666)	(0.6956)
South Dakota	-0.3284	-0.2071	-0.1071
	(-2.7027)***	(-1.6871)*	(-1.0674)
Constant	-8.3437	-8.2759	-3.6379
	(-12.6563)***	(-12.8473)***	(-6.2261)***
Diagnostics			
R-Square	0.7515	0.7581	0.8404
R-Adj-Square	0.7470	0.7537	0.8372
LR	15.1946***		
LM	16.9142***		
Spatial LM		2.0698	0.0015

Note: All values in parentheses are t-values, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

Table 7. 1995-2000 First Inventor Patent Filings per County

	(log) Sum First Inventor Patent Filings (+1)		
	OLS	Spatial	Spatial - time lag
Independent Variables			
Spatial Interaction			
rho		0.1986	0.1197
		(5.1265)***	(3.6077)***
Time Lag			
Previous 5-year county sum of patents			0.5822
			(16.8854)***
Education Attainment			
Percent with 4 years college	1.0881	1.1264	0.4327
	(7.8463)***	(8.4011)***	(3.6489)***
County Characteristics			
(log) per capita income	0.3418	0.2340	0.2493
	(1.6843)*	(1.1909)	(1.5265)
(log) population	0.8142	0.7699	0.3364
	(19.2726)***	(18.3744)***	(7.7615)***
Market Access			
log distance to a MSA	-0.1868	-0.1192	-0.0746
	(-4.0875)***	(-2.5603)**	(-1.9448)*
presence of interstate	0.0213	-0.0062	-0.0254
	(0.2838)	(-0.0855)	(-0.4224)
State Effects			
Kansas	-0.3470	-0.2518	-0.1415
	(-3.1695)***	(-2.3503)***	(-1.5826)
Minnesota	0.2227	0.1270	0.0410
	(2.0090)**	(1.1718)	(0.4553)
Missouri	-0.2302	-0.1608	-0.0848
	(-2.0685)**	(-1.4845)	(-0.9399)
Nebraska	-0.2922	-0.1561	-0.1354
	(-2.5579)**	(-1.3703)	(-1.4289)
North Dakota	-0.1070	-0.0011	-0.0840
	(-0.7799)	(-0.0082)	(-0.7543)
South Dakota	-0.4290	-0.2457	-0.1002
	(-3.4027)***	(-1.9423)*	(-0.9463)
Constant	-8.3390	-8.4017	-3.7789
	(-12.6612)***	(-13.2006)***	(-6.3561)***
Diagnostics			
R-Square	0.7729	0.7841	0.8512
R-Adj-Square	0.7687	0.7802	0.8482
LR	42.6285***		
LM	48.9950***		
Spatial LM		13.2569***	1.9551

Notes: 1) All values in parentheses are t-values, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

CHAPTER 3 - SPATIAL LABOR MARKETS AND TECHNOLOGY SPILLOVERS - ANALYSIS FROM THE US MIDWEST

A paper to be submitted to
the journal of economic growth

Daniel C. Monchuk[1] and John A. Miranowski[2]

Abstract

The primary focus of this paper is the impact of knowledge creation and innovative activity on non-farm employment growth. Non-farm employment growth is modeled in a stylized model where new knowledge and local economic externalities are key factors driving technology growth. For our empirical application we assume that new knowledge and innovative activity are embodied in new patent filings within the county. To explicitly capture technological spillovers between counties we apply spatial econometric techniques. The econometric model, based on a 2-stage spatial econometric estimation procedure, is tested for all counties in US Midwestern States of Iowa, Minnesota, Missouri, Kansas, Nebraska, South Dakota and North Dakota. The results indicate the positive influence of knowledge creation and innovative activity, as captured by patents, on non-farm employment growth during the period 1969-2000. We also find strong evidence of local spatial employment growth spillovers contributing in a positive manner to explaining non-farm employment growth. The key results also hold when we consider sub-samples of the study period suggesting our model is quite robust to the time period of analysis.

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Introduction

In the last half of the Twentieth Century, many small towns in the U.S. Heartland declined both in population and business activity and the majority of rural counties lost population. Declining transportation costs, growing agglomeration economies, changing structure of agriculture, and declining relative economic contribution of agriculture fueled a period of out-migration in many rural communities. However, some rural counties grew in terms of non-agricultural employment and gross county product without being in central locations or adjacent to metro areas. Identifying and understanding the factors explaining employment and output growth in these counties may provide useful information in developing rural growth incentives and promoting growth in other local areas and regions.

It has long been appreciated that technological change plays an important role in the economic growth process. Advancing technology is a necessary condition for economic growth but is not sufficient and requires the appropriate institutional framework and ideological adjustments to reap any potential benefits. There have been a number of research efforts devoted to the location of innovative activity (Sweeney, 1987; Hall and Markusen, 1985). Unfortunately, the role and mechanism of technological change and spillovers in economic growth is not well understood. While technological change is clearly an important component of economic growth (Schumpeter, 1934; Solow, 1970; Grossman and Helpman; 1994), there is a growing literature providing evidence that technology spillovers are important to the growth process (Jaffe, 1989; Jaffe, Trajtenberg, and Henderson, 1993; Anselin, Varga, and Acs, 1997; Anselin, Varga, and Acs, 2000). In both theoretical and empirical research technology spillovers are generally viewed as positive externalities, and it is in this way that production externalities were introduced into the pioneering growth model of Romer (1986)[3].

Conceptually, Romer's model is developed in a more aggregate, national framework that does not address the more micro fundamental of technological change and technology spillovers and the transmission of new knowledge in the local economic growth process. The mechanism through which new technology and technological externalities are transmitted may be quite important. If the new knowledge is transmitted through journal articles and scientific information available on the internet, then geographic location is not likely an important factor. However, if new knowledge and other technological externalities are acquired via the local coffee shop, over dinner, or at a local business

[3] This type of externality is alluded to in Shell (1966).

meeting, locational fundamentals may play an important role in knowledge transmission. Such geographical considerations motive the applied growth work of Glaeser et al. (1992), where the authors argue that intellectual breakthroughs must cross hallways and streets more readily than oceans and mountains. The possibility that such intellectual spillovers occur between firms is one justification for the high rental rates and long traffic commutes incurred in a large city. Considering the importance of innovative externalities of a specific type, Jaffe (1989) finds that the location of university research has a significant effect on corporate patents, as well as indirectly on local innovation. Further, matching patent citations with patents cited, Jaffe, Trajtenberg, and Henderson 1993 find evidence of geographically localized knowledge spillovers.

In this paper we are specifically interested in the role of new knowledge and innovation in the rural growth process. In Glaeser et al. (1992) and Glaeser et al. (1995), the authors focus their analyses on growth of U.S. cities and the local ("within city") and national ("across cities") knowledge and innovation spillovers. Our questions are: Do knowledge and innovative spillovers occur between counties in rural areas as well as within cities? Do such spillovers partially compensate for not locating in a city? And how do such spillovers influence rural employment growth? We hypothesize that spatial proximity of knowledge creation and innovative activity spills over into adjacent counties, and that those spillovers coupled with own county knowledge creation and innovative activity is an important engine of county employment growth. Similarly, we hypothesize that employment growth in adjacent counties stimulates own county employment growth via a spatial technology externality. By taking into consideration the spatial relationships of both innovative activities as well as in employment growth, we provide a more robust framework for explaining rural employment growth in the presence of knowledge creation and employment growth externalities.

The paper is arranged as follows: First, a conceptual framework is presented highlighting the role of technological change and technology spillovers in employment growth drawing on current macroeconomic thinking. Second using data from 618 counties in the U.S. Heartland states (Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota, and North Dakota) and developing a new patents database for these counties to proxy the creation of new knowledge and innovative activity, we explain the creation of new knowledge and innovative activity and use the results to create an instrumental variable for the employment growth model. Third, non-farm employment growth during the 1969-2000 period is explained by predicted knowledge creation and innovative activity, knowledge and innovative spillovers, spillovers from employment growth in adjacent counties and a set of initial conditions. Fourth, based on the empirical results of the previous sections, policy implications are drawn and conclusions are presented.

Analytical Framework

The modern economic growth literature is generally shifting away from the traditional neoclassical models to an increased focus on endogenous growth factors. Modern growth theories focus on the roles of ideas and technology embodied in human capital (Lucas 1988), physical capital (Romer 1986), social capital (Goldin and Katz 1999), and natural capital (Castle 1998). A number of studies have added cross-industry externalities and derived empirical estimates of total and sector employment growth in key industries for U.S. cities (Glaeser et al. 1992; Glaeser, Scheinkman, and Sheifer 1995). Unfortunately the primary focus of these theoretical and empirical works has been directed towards counties and cities and have generally not considered specifically rural economic growth. Obviously, economic growth is far more complex than captured by these stylized macro models, but these marco models, esp Glaeser et al. 1992, do provide a useful starting point for analysis.

The underlying theoretical model for this analysis follows Glaeser et al. 1992 which described employment growth in city-industries in the U.S. In the model adopted here a representative firm in region i=1,2,3,…,n is assumed to take prices, wages, w_t, and technology, A_t, in their region as given and maximize a single input production function

$$A_{i,t} f\left(l_{i,t}\right) - w_{i,t} l_{i,t} \qquad (1)$$

Firms choose labor input, l_t, such that the marginal product of labor is equal to the wage rate. Taking this derivative again with respect to labor in t+1 we can write the ratio of these two derivatives at two points in time:

$$\frac{A_{i,t+1}}{A_{i,t}} \frac{f'\left(l_{i,t+1}\right)}{f'\left(l_{i,t}\right)} - \frac{w_{i,t+1}}{w_{i,t}} = 0 \qquad (2)$$

Assuming a Cobb-Douglas functional form for the production technology of $f(l) = l^{\alpha}$ where $\alpha \in (0,1)$, we can substitute into (2) and take logs to get an equation of labor growth shown in (3)

$$\ln\left(\frac{l_{i,t+1}}{l_{i,t}}\right) = \tau_1 \ln\left(\frac{w_{i,t+1}}{w_{i,t}}\right) + \tau_2 \ln\left(\frac{A_{i,t+1}}{A_{i,t}}\right) \quad (3)$$

$$\text{where } \tau_1 = \frac{1}{\alpha - 1}, \text{ and } \tau_2 = \frac{1}{1-\alpha}$$

Glaeser, et al (1992) divide growth in technology into two parts - local (city) and national. Here also technology is divided into two components - local (county) and Heartland regional. We write this relationship using a Cobb-Douglas functional form, $A = R^{\delta} A_c^{\gamma}$ where R is regional technology, and A_c is local technology. The parameters δ and γ represent the relative importance of such technology. Thus, we can express the growth in employment as a function of the growth in wages, regional technology growth and local technology growth or

$$\ln\left(\frac{l_{i,t+1}}{l_{i,t}}\right) = \tau_1 \ln\left(\frac{w_{i,t+1}}{w_{i,t}}\right) + \tilde{\tau}_2 \ln\left(\frac{R_{t+1}}{R_t}\right) + \tilde{\tau}_3 \ln\left(\frac{A_{c,i,t+1}}{A_{c,i,t}}\right) \quad (4)$$

$$\text{where } \tilde{\tau}_2 = \frac{\delta}{1-\alpha}, \text{ and } \tilde{\tau}_3 = \frac{\gamma}{1-\alpha}$$

Glaeser, et al (1992; 1995), using data from U.S. cities conducted empirical tests of various theories of economic growth. In Glaeser, et al (1992), they focus on the role of technological spillovers, and they assert knowledge spillovers in cities are particularly effective where there are ample opportunities for communication among people. They also find industry variety and local competition encourage industry growth while regional specialization has the opposite effect, implying knowledge spillovers may be more important between industries than within industries.

A number of fascinating questions arise with respect to the Glaeser, et al (1992) analysis of rural economic growth. First, is urban employment growth significantly different from rural employment growth because of the lack of knowledge spillovers and agglomeration externalities? Second, would the same factors that explain firm growth in cities explain the growth of rural firms? Rural counties are typically at an earlier "stage of development" with respect to employment growth in sectors than in more mature city-industries, identified by Glaeser, et al (1992). Alternatively, entering at a later stage of development in a more service-oriented national, or at least regional economy, we might expect a different pattern of growth to emerge.

We model county employment growth as a function of similar dynamic externalities and local spillovers as well as initial endowments. However, explicit attention is given to the role of new knowledge and innovation within the county. The period 1969-2000 is examined as opposed to 1957-1987 growth, and unlike many of the cities in Glaeser, et al (1992) most of the Heartland counties witnessed population declines in the 1970's and 1980's and some witnessed employment growth rates that exceeded population growth rates in the 1990's. Obviously, these differences create difficulties in directly comparing the two studies, but the results do provide some useful insights into modern economic growth, especially in rural areas.

Econometric Model

The employment growth models estimated are based on a cross-section of Heartland counties. Total employment growth between 1969 and 2000 is explained by resource endowments and new technology and innovation created within the county. As a measure of new technology and innovation, total patent filings within each county for the years 1975-2000 is used to capture new knowledge created. In addition to the role of new technology and innovation in employment growth we are also interested in a number of additional factors. Specifically these are classified in term of human capital, and knowledge externalities that are county-specific.

Realizing technological growth is a somewhat amorphous term; we realize technological growth is itself best considered as a function of a number of reasonable variables. The relations on the right hand side of (4) can be broken into components. The growth in county specific technology, $A_{c,i}$, is of considerable interest here as the primary objective is to examine the impact of new technology and knowledge on employment growth. Local technology growth is assumed to take on the following relationship

$$\ln\left(\frac{A_{c,i,t+1}}{A_{c,i,t}}\right) = g\left(\sum_{j\in N_i} \ln\left(\frac{l_{i,j,t+1}}{l_{i,j,t}}\right), \sum_{k\in[t,t+1]} pat_{i,k}, ss_{i,t}, cr_{i,t}\right) \qquad (5)$$

where: $\sum_{j \in N_i} \ln\left(\frac{l_{i,j,t+1}}{l_{i,j,t}}\right)$ is the employment growth in "neighboring" counties as indicated by the counties in the neighborhood of county i, N_i.

pat_i - is the number of patents filed within the county;

ss_i - is social security dependence; and

ct_i - is a concentration index of the intensity of employment industry domination.

Spatial externalities are believed to play a role in the new geographic economy (Fujita, Krugman, and Venables 1999) and should be modeled explicitly. This social interaction (Akerlof, 1997) among agents emphasizes the need to consider the behavior of agents together rather than independently (Anselin, 2003). Clearly such interaction is going to take place more readily for nearer agents. The term $\sum_{j \in N_i} \ln\left(\frac{l_{i,j,t+1}}{l_{i,j,t}}\right)$ embodies a type of spatial externality from neighboring counties as defined the neighborhood N_i for county i. The exact criteria used to define the neighborhood structure N_i for any given county is discussed in greater detail later in this section. There are reasons to believe greater interaction among economic will bring about greater exchange of ideas and thoughts. These ideas and thoughts are much more readily exchanged over short distances than great expanses of land or other geographic impasses. Thus it is expected if a county has the opportunity to benefit from spillovers from neighboring counties, these spillovers should have a positive effect on own county employment growth. That is, $g_1 > 0$ where the subscript refers to the partial with respect to the first argument i.e. $g_1 \equiv \frac{\partial g(.)}{\partial \sum_{j \in N_i} \ln\left(\frac{l_{i,j,t+1}}{l_{i,j,t}}\right)}$. Consistent with the belief that new patents are a proxy for new knowledge and innovation (Jaffe 1989 and 1993; Hall, Jaffe, and Trajtenberg 2001; Anselin, Varga, and Acs 1997), this measure is expected to contribute positively to knowledge and technology growth (Romer 1986; Lucas 1988), it is expected $g_2 > 0$. Notice that total county patents are used here rather than say patents per-capita. The rationale here is based on the idea of a public good. While it is true that the very nature of patenting implies a certain degree of excludability of the actual item, process, or idea, the knowledge embodied in the patented innovation is most likely both non-rival and non-excludable. Since we are interested in a fairly broad sense of growth at the county level, the total amount, rather than a relative measure, of innovative and knowledge stock is appropriate.

To control further for economic activity within the county we include a measure of dependence on the social welfare system, namely social security dependence. This measure is defined as the ratio of total social security payments[4] paid in the county to total personal income. We are interested here in controlling for a innovatively or entrepreneurially "viable" population. Including this variable in our analysis implies we believe counties with a higher dependence on payments like Social Security are less likely to be areas of economic growth[5]. Thus we expect $g_3 < 0$. The final measure included in the specification of (5) is an industry concentration measure and deals with cross-industry externalities. This measure is computed as the squared share in employment summed for the largest four employment categories[6]. Higher values imply less industry diversity while lower values imply a greater degree of diversity in industry type. The theoretical roots how industry concentration affects growth may be separated into the two competing areas. One school of thought believes diversity among industries promotes technology spillovers (Jacobs 1969). The idea is technological spillovers are more important between rather than within sectors due to greater diversity of technologies and ideas. The competing belief suggests industry specialization is the best method to bring about technological development through exchange of ideas in the same area rather than a variety of fields (Marshall 1890; Romer 1986; Arrow 1962). An appropriate example is Silicon Valley (Arthur 1989) where imitation, spying, and high labor mobility foster new innovation and advancement. Thus under the Jacobs school of thought it is expected $g_4 < 0$ and $g_4 > 0$ under the Marshall-Arrow-Romer hypothesis as higher concentrations reflect lower amounts of diversity.

Regional technology growth is further defined in terms of State policies, programs, and possibly even constituent attitudes. It has often been argued that one reason rural areas have not been able to enjoy as much economic growth as their urban counterparts is due to the distance to larger metro areas and lack of transportation infrastructure facilitating market access. To examine whether rural areas are apparently disadvantaged in this respect we include distance to a metro center and presence of an interstate. These variables address the ability to interact with other economic agents and access to larger markets will increase the amount of technology spillover among agents Glaeser et al. 1992. This relationship may be formalized by:

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[4] This includes both Social Security and Medicare payments.
[5] While there is the possible growth in retirement services and/or medical services, these are mostly likely not sustainable in the long run given the segment of the population targeted by this measure.
[6] This computed in a manner similar to the Herfindalh-Hirschman index. Only the top four industries were used since data limitations prevented us from computing this index based on larger number of sectors.

$$\ln\left(\frac{R_{t+1}}{R_t}\right) = f\left(s_{k=1},...,s_{k=7}, dmsa, Id\right) \qquad (6)$$

where: s_k - are State effects for each of the k=1,2,…,7 States;

dmsa - is the distance to a metro area; and

Id - is an interstate dummy.

The signs for the State parameters cannot be assigned exante without more information on historical and current state policies and programs. With respect to distance to a metro area a negative relationship is expected, and for the presence of an interstate, a positive relationship. The idea here basically suggesting the greater the opportunity and probability to interact with other individuals, the greater will be the spillover impacts.

Wage growth in the county can be explained to a certain degree by the initial employment conditions within the county. Specifically, wage growth can be thought of as a function of initial wages and initial employment. The relationship between wage growth and these variables is represented by the function $h(.)$

$$\ln\left(\frac{w_{t+1}}{w_t}\right) = h\left(w_t, emp_t\right) \qquad (7)$$

The expected sign of wage growth with respect to initial wage is negative since the higher is the initial wage, the lower will be wage growth other things equal implying $h_1 < 0$. This would be an argument for conditional convergence in wage growth, a reasonable assumption given a highly mobile work force. The second parameter in h(), initial employment, the more employment in a region, the tighter will be the market and the faster should be the wage growth. The expected sign for the last argument in (7) is positive, $h_2 > 0$.

In postulating the factors underlying local technology growth, considerable attention was given to the role of spatial externalities. To incorporate this explicit spatial structure of the data the use of spatial econometric techniques is evident. The use of spatial econometric techniques has been quite prevalent in recent literature where the role of space is an important factor (Roe, Irwin, and Sharp 2002; Acs, Anselin, and Varga 2002).

Assigning log-linear relationship to the functions $g(.), f(.)$ and $h(.)$ and applying this to relations (5)-(7) and substituting into (4) will result in an estimable relationship. This specific empirical relationship takes the form

$$\ln\left(\frac{l_{i,t+1}}{l_{i,t}}\right) = \beta_0 + \rho \sum_{j \in N_i} \ln\left(\frac{l_{j,t+1}}{l_{j,t}}\right) + \beta_1 \ln \sum_{k \in [t,t+1]} pat_{i,k} + \beta_2 \ln ss_{i,t} + \beta_3 \ln cr_{i,t} + \beta_4 dmsa_{i,t} + \beta_5 w_{i,t} + \beta_6 emp_{i,t} + \beta_7 Id_{i,t} + \sum_{k=1}^{6} \beta_{7+k} s_k + \varepsilon \quad (8)$$

where ε is a random error term distributed normally with constant variance, the parameters ρ, and β_0-β_{13} are to be estimated, and the other variables are defined as before. Under the spatially lagged dependant variable model a spatial parameter ρ, following conventional notation in the spatial econometric literature, is used to capture an explicit spatial relationship in the data. For completeness, based on the conceptual framework given the parameter terms τ_1, $\tilde{\tau}_2$, and $\tilde{\tau}_3$ are negative, positive, and positive respectfully in (4), the expected signs for the betas in (8) are; $\beta_1 > 0$; $\beta_2 < 0$; β_3 ambiguous; $\beta_4 < 0$; $\beta_5 > 0$; $\beta_6 < 0$; $\beta_7 > 0$; and β_8 through β_{13} ambiguous. In matrix notation this equation can be described by

$$\begin{gathered} y = \rho W y + X\beta + \varepsilon \\ \varepsilon \sim N\left(0, \sigma^2\right) \end{gathered} \quad (9)$$

In equation (9) y is the vector of county (log) employment growth rates related spatially to neighboring counties by the spatial interaction parameter, ρ, to be estimated. The explanatory variables and their associated parameter estimates are embodied in the matrix X and the vector β respectively. The matrix W is characterized by zeros along the main diagonal and has off diagonal elements representing the neighboring counties. The matrix W is created using a Delaunay triangulation[7] routine (Pace and LeSage 2003a and 2003b) that selects the nearest three counties using latitude and longitude coordinates based on the center of the county. The method used to derive

[7] Delaunay triangulation computes a set of triangles such that no data points are contained in any triangle's circumcircle.

estimates for (9) follows is based on a concentrated likelihood function and parameter estimates are computed based on the algorithm of Anselin (1988).

Aggregate county patent filings are used to capture new technology and innovation and it may be that patents themselves are a function of economics growth. That is, there are obvious reasons to believe there are underlying growth and technological forces not explicitly accounted for in the data that may result in patenting activity correlated with the error. To control for this potential problem an instrumental variable (IV) approach is used. In this two stage IV estimation a number of instruments are used. As with any IV approach the task is to find instruments correlated with the independent variable, in this case patents, but not the error term. It is difficult to envision an instrument for the current application where patent filings, themselves indicators of a broader set of technological growth, are not correlated with other underlying economic growth forces that are not correlated with the unobserved growth captured in the error for labor growth. In any case, the instruments used here include percentage of the population with a college degree, population, and per-capita personal income. In addition to these three instruments a spatial lag is also used as an instrument. The spatial lag for patents is computed in the same manner as for the standard employment growth equations. The relationship used to generate the patent IV is:

$$x = \rho_x Wx + X_x \beta_x + \varepsilon_x \qquad (10)$$
$$\varepsilon \sim N\left(0, \sigma_x{}^2 I\right)$$

where x is a nx1 matrix of (log) total inventor patent filings +1 per county[8], W is the same nxn standardized and symmetric spatial weights matrix used in (9), X_x is a nxk_x matrix of explanatory data, and β_x is a k_x x1 matrix of coefficients to be estimated. The error structure is assumed to adhere to the standard normality and homoskedastic conditions[9].

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[8] The reliance on augmenting the patent variable with a constant, here 1, is necessary to ensure the spatial integrity of the sample. While in regular analysis one may just remove the observation from the sample, such omission of data in this case however results in an incomplete spatial structure. Removing an observation from a spatial dataset effectively creates an "empty void". It is thus of the utmost importance the spatial nature of the data be maintained.

[9] It is reasonable to expect variability in patents to be larger for populous counties, thus heteroskedasticity may be an issue. In response, the classical assumption of homoskedasticity may relaxed in favor of the following error structure $\varepsilon \sim N\left(0, \sigma^2 V\right)$ where V is a diagonal matrix whose elements need not be constant. In the estimations where homoskedasticity is not assumed a Heteroskedastic Bayesian Linear model is used based on a Markov Chain Monte Carlo or Gibbs sampling method (Geweke, 1993;Lesage, 1999). However, estimation of

Since this is a two stage problem there is an issue of correcting the standard errors in the second stage. There are two approaches that may be taken here to correct for this. The first is to simply do nothing and concede the precision of our estimates is questionable. The second, and more agreeable, approach is to correct our standard errors to control for the fact we are using a two-stage estimation procedure. In this case however we much proceed with caution since while a method like standard bootstrapping may seem reasonable it is in fact not since we need to maintain the spatial structure of the model which would be destroyed by simple random sampling with replacement. It is the random sampling in regular bootstrapping which makes this method unworkable. However alternatives have been suggested to compute appropriate standard errors in a spatial two stage model (Anselin 1988; Kelejian and Prucha 1999 and 2002). To compute standard errors to determine the precision of our estimates we follow an augmented spatial bootstrap method and use the spatial sampling method of Anselin (1988). A description of this augmented spatial bootstrap method is found in the appendix.

Empirical estimation of the models presented in (9) and (10) are conducted in Matlab using various spatial econometric functions and programs making use of sparse matrix algorithms (Lesage, 2003). These equations may be estimated using OLS when $\rho=0$, that is, when no spatial interaction is assumed. Note that in the presence of a spatially lagged dependant variable the simultaneity will result in OLS estimates which are both biased and inefficient. However, maximum likelihood estimation can be used to derive efficient and unbiased estimates. The following section describes the data used to estimate the above relationships.

Data

County growth in non-farm employment is considered over the period 1969-2000. Further, to capture the effect of business cycle and recession, the sample is split into two sub periods: 1969-1984 and 1985-2000. This splitting of the sample allows us to examine whether our model is robust over the time period chosen and if there are significant difference in the factors influencing non-farm employment growth over time. The sample includes 618 counties in the U.S. Heartland states of Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota, and North Dakota. Due the lack of population density and absence of a city of significant size, most counties in the region are classified as rural. A spatial view of non-farm employment growth for our cross-sections of interest are shown

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the heteroskedastic model for the first stage of the2-stage IV estimation did not appreciably affect results so further discussion based on this model has been suppressed.

in figures 1,2, and 3. From these geographic maps we can see there appears to be a spatial pattern and employment growth appears to be occurring in clusters in many cases and does not appear random. While the pattern is not the same for all three of these maps, all appear to indicate a spatial relationship. These maps highlight the fact we clearly need to understand this spatial relationship better.

Information on technology embodied in capital and infrastructure does not exist at the county level. However, a common approach in the economics literature has been to use patents as a proxy for innovation and new knowledge. Positive results have been reported by Anselin, Varga, and Acs (1997), Acs, Anselin, and Varga (2002), Hall, Jaffe, and Trajtenberg (2001), and Jaffe (1999). To capture new knowledge creation within the county, a database of patents filed by residence of the lead inventor was developed for all counties in our sample. A list of utility patents filed in the United States for the years 1975 through 2000 was obtained from the United States Patent and Trademark Office. This dataset contained the mailing address for the lead inventor for each utility patent filed for this period. Using the lead inventor's mailing address and cross-linking with a list of cities by county from Census, a count of patents filed for each county and year was constructed[10]. For the period 1975-2000 counties filed an average of 125 patents with a median filing of 14. The county with the largest number of patents had a total of 12,065 patents and there were also counties that had no patent filings during the period.

Non-farm employment, population, and other county level data were obtained from primarily Bureau of Economic Analysis (BEA) data complied on the Regional Economic Information System (REIS) dataset. Additional data on educational attainment were from the census of population. Summary statistics are presented in table 1. Over the 1969-2000 period, employment grew an average of 46%. The fastest growing county experienced employment growth of an astounding 207%, while the most unfortunate county halved its non-farm employment. The average county employed almost 11,000 in 1969, the largest county employment was about 545,000, and the smallest county non-farm employment numbered only 105. County population averaged 26,000 with the largest county having 968,000 people and the smallest county having only 624 individuals. Wages are defined as total county earnings divided by total county employment, and as indicated by the low standard deviation,

[10] Similar to journal articles, patents often have more than one individual listed as the primary source of the work. Our analysis herein focuses on counts from only the lead author. However, further analysis by the authors suggests the general results would not greatly differ had all inventors rather that just the lead inventor for each patent been used.

they exhibit little variation in our sample. The measure of county non-farm employment concentration is the sum of the squared employment shares across the largest 4 sectors multiplied by 1,000 within the county using employment levels from 1969 or 1985 depending on the time frame of interest. The concentration measure has an average of 1,858 with relatively low standard deviation. The human capital measure, percent of county population with a college degree, averaged about 6.5% in 1970. This measure ranged from about 30% to less than 0.5%, and displayed a high standard deviation. When evaluating the later period 1985-2000 similar data are used to compute a comparable set of starting values for 1985[11].

Results and Implications

The results from the estimation are presented in tables 2-5. The first three of these tables contain the results from the employment growth model estimation. For each time period of study the model is based on a cross-sectional data set of the 618 counties in addition with non-farm employment growth as the dependant variable and our set of explanatory variables including technology on the right-hand side. The equations used to fit the patent data two-stage estimation are presented in table 5. For each of tables 2, 3, and 4 regression results are given for each of an OLS specified model with no spatial interaction, a spatial model, and a spatial model using a two-stage process where we predict patents in the first stage and then estimate the employment growth equation. Throughout this discussion comparisons are made with the two sub growth periods highlighting some of the more interesting similarities and departures between the broader growth period. Finally, a brief discussion is devoted to the model estimates used to predict patents table 5.

For the growth period from 1969-2000 presented in table 2, the first column of results, OLS estimates not controlling for any spatial relationship, suggests 38% of the variability in employment growth is explained by this model. Using the OLS model two tests are carried out to check for the presence of spatial autocorrelation in the error structure. Test statistics based on the likelihood ratio (LR) and Lagrange multiplier (LM) tests can be computed for the OLS specified model. Similarly, a spatial LM (LM Sar) test statistic can be computed for the model estimated with a spatial lag (Anselin 1988).

[11] For 1985 there were three counties for which the calculation for the concentration index could not be computed directly due to missing data for either the third or fourth largest industry. Consequently where missing sector data was encountered a value of zero was used in the calculation of the index. Traditionally one would simply throw out the data point in question but this is not an option here since the use of spatial statistics requires the spatial lattice to be completely intact.

Values of 36.6 and 36.1 are computed for the LR and LM tests respectively indicating a spatial relationship further exists in model residuals implying estimates may be inefficient[12]. Further discussion thus concentrates attention on the results in the last two columns of table 2: a model with a spatially lagged dependant variable and a model with a spatially lagged dependant variable where we control for endogeneity using a two-stage spatial IV model.

The spatial model in the second column of table 2 is essentially equation (8). This model is able to explain approximately 43% of the variability in non-farm employment growth for Midwestern counties over the years 1969-2000. The Spatial LM test statistic was computed at 0.3 suggesting the spatial structure of the data appears to have been handled in a satisfactory manner. Since the model is a log-log formulation most of the parameter estimates themselves, except of course the dummy variables, can be interpreted directly as elasticities. The coefficient estimate for the patent parameter can be interpreted as follows: a 10% increase in the number of patents filed within the county will be met with a 1.5% increase in employment growth. Since patents are our indicator of new knowledge within the county it appears that new knowledge and knowledge spillovers within the county do contribute in a significant manner to employment growth. This result is found to be statistically greater than zero with at least a 99% level of confidence. The spatial coefficient representing technological spillovers between counties, "rho", is estimated to be a sizable 0.34 and is statistically different from zero with at least a 99% level of confidence. This result does appear to add support for the presence of geographically mediated spillovers. This parameter may also be interpreted directly as an elasticity. The spatial lag parameter is interpreted to imply a 1% increase in the employment growth rate of surrounding counties, as defined by the spatial contiguity matrix W will, *ceteris paribus*, result in a 0.34% increase in employment growth in the home county. To interpret this parameter in a more meaningful manner a county whose neighboring counties are growing are likely better positioned to enjoy growth spillovers and other externalities generated by surrounding counties than those counties which are isolated. Of course the negative of this also holds, if a county whose neighboring counties experiences a recession or an economic downturn, proximity can have the effect of suppressing home county economic activity. In the presence of this sort of depressed growth environment a type of "trap" may occur where it is difficult to stimulate home county employment growth in the absence of regional or area growth.

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[12] The LR, LM, and LM Sar tests are distributed Chi-square with one degree of freedom. The critical value at the 99%, 95% and 90% levels are 6.63, 3.84, and 2.71 respectively.

We generally find our set of other parameters consistent with our theoretical framework. The parameter for initial non-farm employment suggests a 10% increase in initial employment results in a 1.4% decrease in employment growth. Initial wage was only marginally significantly different from zero and had a positive influence on non-farm employment growth. The parameters for market access as measured by distance to a MSA and presence of an interstate did not appear to have an appreciable effect on labor growth for this time period. Examining the state effects, Minnesota, Missouri, and South Dakota appear to have a more amiable environment for growth than the other states (Iowa is the default state).

As discussed earlier there are strong reasons to believe our patent measure of innovation may be correlated with unobservable growth forces that will appear in our model residuals. To account for this we take a two stage IV approach to improve the reliability of our results, these results are shown in the 3rd column of table 2. In general, the same general conclusions hold, however the estimated coefficients themselves are more pronounced in a number of cases. For example, the patent parameter used to proxy knowledge and innovation within the county is found to have an elasticity of 0.27, considerably larger than estimated in the standard spatial model. If these estimates are deemed to be better than the impact of innovative spillovers on employment growth is really quite large. In terms of cross industry externalities and spillovers we find support here for the Marshall (1890)-Arrow (1962)-Romer (1986), aka MAR, school of thought since a 1% increase in industry specialization in a county results in a 0.18% increase in employment growth. This result tends to support the idea greater industry specialization promotes growth rather than industry diversity. The spatial spillover parameter was computed with a value of 0.32, similar both in size and magnitude to the estimate in the standard model. In any case, within county, and between county externalities remain important factors regardless of the set of estimates used to draw conclusions.

To examine more closely any time varying relationship that may exist, the growth period was further split into two periods: 1969-1984, and 1985-2000. The set of results where we instrument patents in a two stage process is generally going to result in a more reliable set of results from an efficiency perspective. The results from the spatial and two-stage spatial IV model are substantively the same, consequently we focus our attention on the two-stage spatial model. Examining first the growth period 1969-1984 in table 3, the spatial IV model is able to explain 28% of the variability in employment growth. The spatial interaction parameter, rho, is found to have an elasticity of 0.27 which is quite comparable to the estimate in table 2. The estimate for new patents was found to be positive and significant at 0.16 which is smaller than the full growth period estimate of 0.27. Initial non-farm employment, wages, and State effects were found to have a significant impact on employment growth. However, the additional parameters, with the exception of the presence of an interstate, were not found to play a significant explanatory role in a statistical sense. The spatial IV model for this later growth period 1985-2000 in table 4 was able to explain about 38% of the variability in non-farm employment growth over the period. The spatial interaction term was estimated to be 0.295 suggesting a 10% increase in employment growth will result in roughly a 3% increase in employment growth in the home county. Patents summed over 1985-2000 as a proxy of new knowledge and technology was found to be positive and significantly different from zero with an estimated elasticity of 0.07. While it is difficult to directly compare the estimated coefficients of the patent parameter for the entire growth period and the two sub-growth periods it is interesting to note how small this estimate is for either of the sub periods, 0.16 and 0.07 for 69-84 and 85-2000 respectively, as compared to 0.27 for the full growth period 69-2000. One may even go so far as to further interpret this result as further evidence that it is the stock of knowledge that is important to growth rather than knowledge at discrete points in time. In the later period the coefficient for the concentration index is 0.17 and is significantly different from zero with at least a 99% level of statistical confidence. This result further supports the hypothesis that spillovers occur more readily in concentrated rather than diverse local economies. This implication was not present in the earlier sub-sample suggesting a more specialized county economy structure has only been more beneficial in the more recent history. Neither distance to a MSA or presence of an interstate was found to have a significant impact on non-farm employment growth. The lack of significance in these two parameters may even imply an improvement in communication networks like long distance service and the internet may have taken on a more important role. At the same time, access is important for knowledge generation, i.e., patenting as shown in table 5. In table 4 the state dummies do illustrate significant differences in employment growth relative to Iowa (the excluded dummy). In general, Iowa has faired worse, in a statistical sense, than most of the other States. The State with the best performance relative to Iowa was Missouri, no doubt driven in part by tourism. Tourism however is not likely to be the only factor in explaining these State differences as Nebraska also outperformed Iowa.

Given the subject matter of this paper and the interest in knowledge creation and new technology, a short discussion of the equations used to obtain predicted patents in table 5 is warranted. To fit patents a similar spatial lag model was used as in the employment growth equations, and as such the spatial interaction parameter, rho, can be interpreted in a similar externality manner. In this case however, this variable is interpreted more precisely as an innovative externality or "spillin" directly. That is, a 10% increase in the number of patents filed in neighboring counties, will be met with a 1.5% increase in patents filed in the home county. This is further evidence purporting the existence and providing an estimate of the magnitude of geographically mediated technological spillovers. Also found to play an important role in explaining patent filings in the US Midwest are per-capita income, population, and percent of the population with a college degree. With an elasticity near unity, an obvious result, population plays an important role in patent filings. Distance has a negative and significant role in patent filings suggesting innovation is occurring nearer centers of MSA's rather than in remote areas. Also of interest here is the sign of the concentration index and the estimated coefficient of -0.41 which implies a 10% increase in the concentration index actually reduces patent filings by just over 4%. Thus when interested in knowledge creation, the Jacobs school of though purporting industry diversity appears to be the rule of thumb. State effects do not appear to play a large role except for Minnesota. Examining the equations used to generate predicted patents for the two sub-periods 75-84, and 1985-2000 presented in the 2nd and 3rd columns of table 5 respectively, the general results appear to hold throughout, this model does appear to be quite robust to the time period chosen. With all three equations side-by-side in table 5 it is remarkable how consistent the relationships have been over time.

Conclusions and Extensions

The predominant motivation of this paper was to analyze the impact of new technology and new knowledge on non-farm employment growth in a cross section of Midwestern counties which are primarily rural. In a recent column in Forbes commenting on where to find economic growth was written: "The most valuable natural resource in the 21st century is brains. ... Watch where they go! Because where they go, robust economic activity will follow" (Karlgaard, 2003). This casual quote captures to a large degree much of the motivation to examine local impacts of new technology and technology spillovers on economic activity in rural areas. Using total new patents filed as an indicator of new technology and knowledge creation we have found a convincing relationship with non-farm employment growth. The results do seem to suggest considerable innovation spillovers do exist since we find areas with high patenting rates, indicating higher incidence of new technology, do experience greater employment growth. For the sub growth periods we also found evidence new knowledge contributes to employment growth in a positive manner albeit to a lesser degree suggesting our results are generally robust to the time period chosen. This difference in the coefficients overtime may imply knowledge accumulates over time and the stock, not just the flow, are important factors of economic growth. This is a realistic conclusion since the traditional view of knowledge is one of accumulation over time. In addition to the impact of new technology and innovation, explicit spillover effects from neighboring counties as captured by the spatial lag model do seem to exist and what is more, appear to be quite large. Finally, state programs, policies, and growth climates do matter to a degree.

Initial employment was found, in general, to have a negative and statistically significant impact on employment growth. This would seem to support part of the convergence theory – the greater the county employment to begin with, the slower will be its growth rate implying a higher level of development has been reached. This result is consistent with conditional convergence. On a positive note for current and future policy makers residing in more remote rural regions and faced with the task of developing an economic development plan, distance to a MSA was either small or insignificant for the period 1985-2000 as was the impact of having an Interstate within the county. These results are encouraging for remote rural areas since the conventional wisdom suggesting simply rural counties need to be located near large urban centers alone in order to grow does not appear to hold. Rather, it is more important how much technology and innovative activity is generated locally and who are your neighbors that will ultimately influence future economic growth.

While it is difficult to discuss policy based on a limited amount of empirical analysis, a few seemingly important generalizations appear evident. The spatial econometric estimation has suggested there exist considerable positive economic growth spillovers between counties. From a rural policy perspective, counties that hope to improve their economic outlook should exploit this spatial relationship. In part, this result may argue for regional, as opposed to local, growth strategy and cooperation and coordination among neighboring counties rather than direct competition for new business. If there is positive neighboring growth, counties are better able to benefit from this growth. However, if there is surrounding stagnation or decreased employment growth, the challenge may be insurmountable to achieve local growth. In such a case a low level equilibrium trap of sorts may be encountered in which it may be very difficult to experience any prolonged periods of local employment growth. In any case it is evident from out analysis new technology and interaction in space has apparent local growth impacts even when examining a fairly rural cross-section of predominantly rural counties in the US Midwest.

For rural areas to benefit from new technologies and the accompanying economic growth requires, in particular, a shift in conventional thinking in many cases since in the rural model of life is not compatible with modern technology (Kuznets, 1973). Rural policy has generally focused on maintaining the status quo and has to a certain extent fueled continued reliance on government handouts. Further, this type of reliance tends to stifle new innovation which comes from reacting to market forces. The analysis here has demonstrated that new technology does indeed play an important role in local economic activity and it is thus perilous for rural constituents to try and improve their economic standings without adopting a policy, either implicit or explicit, to encourage the adoption and development of new technologies.

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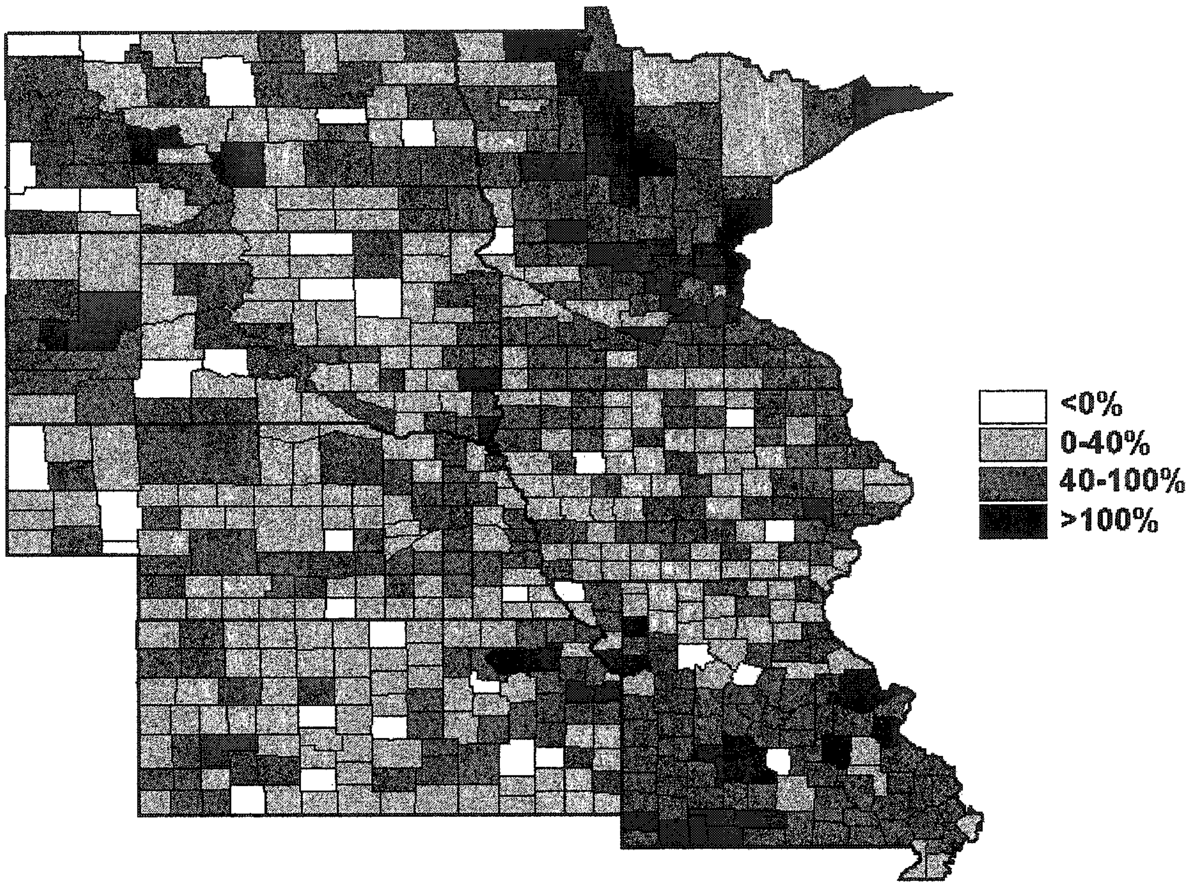

Figure 1. Spatial Distribution of Non-Farm Employment Growth 1969-2000

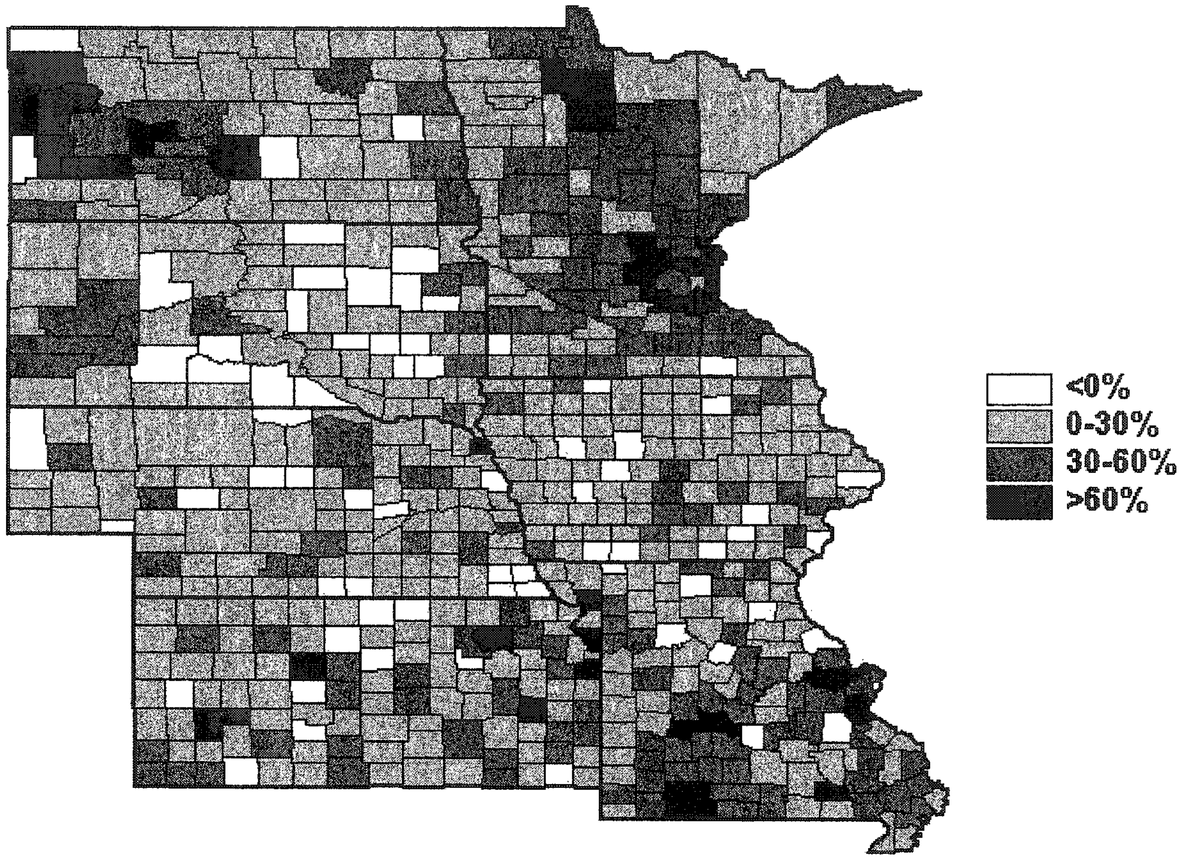

Figure 2. Spatial Distribution of Non-Farm Employment Growth 1969-1984

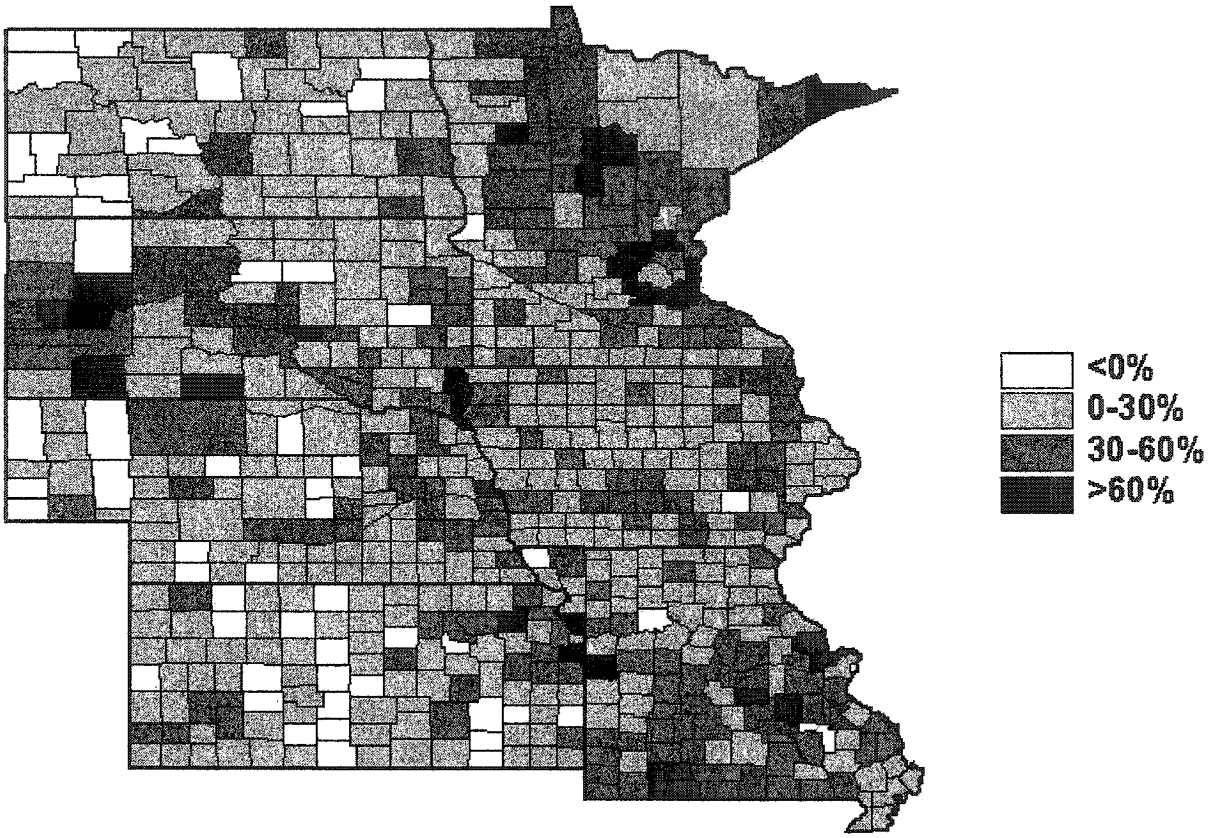

Figure 3. Spatial Distribution of Non-Farm Employment Growth 1985-2000

Table 1. Summary Statistics

Variable	Mean	Std. Dev.	Median	Minimum	Maximum	Count
Dependant Variable						
Employment Growth 1969-2000	0.4687	0.3664	0.4133	-0.5041	2.0744	
Employment Growth 1969-1985	0.2289	0.2258	0.2075	-0.5921	1.5380	
Employment Growth 1985-2000	0.2381	0.2002	0.2230	-0.3885	1.2124	
Independent Variables						
Total Patents Filed 1975-2000	125	666	14	0	12065	
Total Patents Filed 1975-1984	37	187	5	0	3206	
Total Patents Filed 1985-2000	89	483	9	0	8859	
Total Employment 1969	10876	40286	3431	105	544944	
Total Employment 1985	14521	52511	4362	86	794689	
Wage 1969	5.112	0.786	5.011	3.505	8.552	
Wage 1985	14.518	2.490	14.112	8.818	26.350	
SS Dependence 1969	0.0711	0.0221	0.0687	0.0000	0.1632	
SS Dependence 1985	0.1256	0.0345	0.1267	0.0296	0.2607	
Concentration Index 1969	1858	372	1783	1273	4521	
Concentration Index 1985	1055	447	976	230	5398	
Distance to a MSA 1968	109	68	97	359	0.5	
Interstate 1972						176
Instruments for Patent Equation						
Percent College Degree 1969	6.562	3.343	5.890	0.463	30.024	
Percent College Degree 1985	7.484	2.448	7.154	2.463	23.038	
Population 1969	26217	73742	11657	624	967826	
Population 1985	28158	75791	11919	478	985599	
Per capita income 1969	3.116	0.553	3.088	1.468	5.340	
Per capita income 1985	12.155	2.204	12.197	4.386	23.995	
State Counts						
Iowa						99
Kansas						105
Minnesota						87
Missouri						115
Nebraska						93
North Dakota						53
South Dakota						66

Table 2. Employment Growth - 1969-2000
Dependent Variable: ln (Non-farm $Employment_{2000}$/Non-farm $Employment_{1969}$)

Variable	OLS	Spatial Model	Spatial IV Model
Spatial Interaction			
Rho		0.339	0.326
		(6.636)***	(5.637)***
New Technology Created			
(log) Total Patents – Sum 1975-2000 (+1)	0.156	0.147	0.272
	(10.341)***	(10.203)***	(5.463)***
County Characteristics			
Wage 1969	0.312	0.284	0.353
	(2.524)**	(2.426)**	(2.889)***
Employment 1969	-0.160	-0.148	-0.267
	(-7.762)***	(-7.580)***	(-5.538)***
SS Dependence 1969	-0.272	-0.319	0.489
	(-0.376)	(-0.465)	(0.592)
Concentration Index 1969	0.110	0.102	0.179
	(1.459)	(1.437)	(2.203)**
Market Access			
log distance to a MSA 1968	-0.048	-0.019	0.015
	(-2.738)***	(-1.115)	(0.677)
Presence of Interstate 1972	0.054	0.050	0.037
	(1.822)*	(1.788)*	(1.190)
State Effects			
Kansas	0.058	0.050	0.060
	(1.365)	(1.253)	(1.289)
Minnesota	0.244	0.135	0.063
	(5.377)***	(2.983)***	(1.112)
Missouri	0.327	0.243	0.265
	(7.600)***	(5.714)***	(5.351)***
Nebraska	0.045	0.045	0.069
	(1.017)	(1.076)	(1.414)
North Dakota	0.075	0.059	0.057
	(1.407)	(1.170)	(1.007)
South Dakota	0.179	0.160	0.220
	(3.525)***	(3.333)***	(3.781)***
Constant	0.086	-0.130	-0.408
	(0.135)	(-0.215)	(-0.632)

Table 2. (continued)

Diagnostics			
R-Square	0.381	0.432	0.368
R-Adj-Square	0.368	0.420	0.355
LR	36.693***		
LM	36.130***		
LM Sar		0.300	1.819

[§] All values in parentheses are t-statistics reflecting for the test H_0: the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

[#] The patent variable used in this regression is based on predicted values obtained using elements of Table 5.

[@] The standard errors were computed based on 1000 iterations of the augmented spatial bootstrap method described in the appendix.

Table 3. Employment Growth - 1969-1984
Dependent Variable: ln (Non-farm $Employment_{1984}$/Non-farm $Employment_{1969}$)

Variable	OLS	Spatial Model	Spatial IV Model
Spatial Interaction			
rho		0.281	0.267
		(4.928)***	(4.745)***
New Technology Created			
Total Patents - Sum 1975-1984	0.051	0.049	0.163
	(4.973)***	(4.985)***	(4.427)***
County Characteristics			
Wage 1969	0.278	0.273	0.314
	(3.297)***	(3.367)***	(3.747)***
Employment 1969	-0.058	-0.055	-0.145
	(-4.501)***	(-4.453)***	(-4.851)***
SS Dependence 1969	0.001	0.042	0.832
	(0.001)	(0.088)	(1.473)
Concentration Index 1969	-0.104	-0.100	-0.065
	(-2.035)**	(-2.043)**	(-1.156)
Market Access			
log distance to a MSA 1968	-0.019	-0.010	0.021
	(-1.619)	(-0.894)	(1.333)
Presence of Interstate 1972	0.055	0.052	0.041
	(2.700)***	(2.654)***	(1.927)*
State Effects			
Kansas	0.103	0.077	0.066
	(3.549)***	(2.734)***	(2.236)**
Minnesota	0.179	0.123	0.078
	(5.835)***	(3.954)***	(2.235)**
Missouri	0.184	0.141	0.154
	(6.256)***	(4.781)***	(4.879)***
Nebraska	0.068	0.058	0.074
	(2.251)**	(2.005)**	(2.451)**
North Dakota	0.167	0.129	0.140
	(4.626)***	(3.642)***	(3.620)***
South Dakota	0.026	0.034	0.065
	(0.762)	(1.028)	(1.804)*
Constant	0.904	0.785	0.790
	(2.091)**	(1.883)*	(1.706)*

Table 3. (continued)

Diagnostics			
R-Square	0.241	0.280	0.275
R-Adj-Square	0.225	0.264	0.259
LR	23.871***		
LM	26.074***		
LM Sar		0.014	3.064**

[§] All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

[#] The patent variable used in this regression is based on predicted values obtained using elements of Table 5.

[@] The standard errors were computed based on 1000 iterations of the augmented spatial bootstrap method described in the appendix.

Table 4. Employment Growth - 2000-1984
Dependent Variable: ln (Non-farm $Employment_{2000}$/Non-farm $Employment_{1984}$)

Variable	OLS	Spatial Model	Spatial IV Model
Spatial Interaction			
Rho		0.295	0.295
		(5.495)***	(5.084)***
New Technology Created			
Total Patents - Sum 1985-2000	0.051	0.048	0.074
	(5.812)***	(5.723)***	(2.991)***
County Characteristics			
Wage 1985	-0.085	-0.076	-0.061
	(-1.385)	(-1.304)	(-1.020)
Employment 1985	-0.072	-0.066	-0.093
	(-5.342)***	(-5.107)***	(-3.472)***
SS Dependence 1985	-0.986	-0.932	-0.892
	(-3.886)***	(-3.814)***	(-3.215)***
Concentration Index 1985	0.182	0.166	0.172
	(7.109)***	(6.757)***	(6.710)***
Market Access			
log distance to a MSA 1968	-0.037	-0.021	-0.015
	(-3.772)***	(-2.261)**	(-1.398)
Presence of Interstate 1972	-0.011	-0.010	-0.013
	(-0.656)	(-0.657)	(-0.761)
State Effects			
Kansas	-0.057	-0.036	-0.027
	(-2.453)**	(-1.557)	(-1.042)
Minnesota	0.098	0.062	0.052
	(4.047)***	(2.623)***	(2.018)**
Missouri	0.102	0.082	0.093
	(4.357)***	(3.626)***	(3.617)***
Nebraska	-0.048	-0.036	-0.031
	(-1.923)*	(-1.483)	(-1.168)
North Dakota	-0.062	-0.039	-0.039
	(-2.114)**	(-1.357)	(-1.295)
South Dakota	0.092	0.074	0.084
	(3.299)***	(2.774)***	(2.856)***
Constant	-0.038	-0.135	-0.096
	(-0.197)	(-0.730)	(-0.505)

Table 4. (continued)

Diagnostics			
R-Square	0.367	0.404	0.382
R-Adj-Square	0.353	0.391	0.368
LR	16.153***		
LM	15.435***		
LM Sar		2.425	0.756

[§] All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.
[#] The patent variable used in this regression is based on predicted values obtained using elements of Table 5.
[@] The standard errors were computed based on 1000 iterations of the augmented spatial bootstrap method described in the appendix.

Table 5. IV Patent Equation

Dependent Variable: ln(Sum of first inventor patents (+1))

N=618 **Variable**[&]	75-2000[§]	75-84	85-2000
Instruments			
Spatial Interaction - rho	0.154	0.149	0.151
	(4.088)***	(3.476)***	(4.122)***
(log) Per-capita income	1.024	1.052	0.756
	(4.883)***	(4.859)***	(3.870)***
(log) Population	0.974	0.809	0.948
	(20.501)***	(16.639)***	(18.534)***
Percent with College degree	0.061	0.053	0.117
	(5.413)***	(4.594)***	(7.430)***
Other Variables			
County Characteristics			
Concentration Index	-0.405	-0.095	-0.147
	(-2.099)**	(-0.478)	(-1.345)
log distance to a MSA 1968	-0.148	-0.170	-0.107
	(-3.172)***	(-3.525)***	(-2.382)**
Presence of Interstate 1972	0.028	0.039	0.007
	(0.382)	(0.509)	(0.096)
Kansas	-0.056	0.091	-0.323
	(-0.503)	(0.794)	(-3.032)***
Minnesota	0.462	0.334	0.272
	(4.015)***	(2.831)***	(2.560)***
Missouri	-0.011	0.036	-0.206
	(-0.092)	(0.306)	(-1.996)**
Nebraska	0.007	0.032	-0.150
	(0.059)	(0.263)	(-1.344)
North Dakota	0.174	0.091	-0.043
	(1.257)	(0.639)	(-0.334)
South Dakota	-0.145	-0.000	-0.278
	(-1.063)	(-0.002)	(-2.164)**
Constant	-4.643	-6.147	-7.970
	(-2.823)***	(-3.631)***	(-9.516)***

Table 5 (cont'd)

Diagnostics			
R-Square	0.796	0.729	0.814
R-Adj-Square	0.792	0.724	0.811

[§] All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

[&]Except where noted, the independent variables are for the earliest year for the respective patent range. For example, the period 1975-2000 uses population in 1969 and 1985-2000 uses population in 1985.

Appendix

Bootstrapping is a method used to obtain sampling properties of empirical estimators using the data itself rather than theoretical properties (Efron and Tibshirani, 1993;Greene, 1997). For example, consider a given data set **X** whose matrix of estimated coefficients are $\hat{\boldsymbol{\beta}}$. If we sample from this data set with replacement we can construct a total of R pseudo data sets can be created $\mathbf{X}_1, \mathbf{X}_2, \ldots, \mathbf{X}_R$ and for each of these data sets an estimate of the coefficients of interest can be obtained $\hat{\boldsymbol{\beta}}_1, \hat{\boldsymbol{\beta}}_2, \ldots, \hat{\boldsymbol{\beta}}_R$ for any given model. Using these estimates we can compute bootstrap estimates of both the coefficients and the dispersion.

The bootstrap estimate of the parameter estimates are

$$\hat{\boldsymbol{\beta}}_b = \frac{1}{R}\sum_{r=1}^{R}\hat{\boldsymbol{\beta}}_i \tag{11}$$

The bootstrap estimate of the variance-covariance is:

$$Var\left[\hat{\boldsymbol{\beta}}_b\right] = \left[\frac{1}{1-R}\right]\sum_{r=1}^{R}\left(\hat{\boldsymbol{\beta}}_r - \hat{\boldsymbol{\beta}}_b\right)\left(\hat{\boldsymbol{\beta}}_r - \hat{\boldsymbol{\beta}}_b\right)' \tag{12}$$

Test statistics are then computed using the parameter estimates from the original data, $\hat{\boldsymbol{\beta}}$, and the variance-covariance structure above:

$$\mathbf{t} = \frac{\hat{\boldsymbol{\beta}}}{\left[\text{diag } Var\left[\hat{\boldsymbol{\beta}}_b\right]\right]^{\frac{1}{2}}}$$

The estimate from the original data is used instead of the bootstrap estimate as the bootstrap estimate may introduce bias (Efron, 1982). In standard applications the sampling with replacement does not pose any problems, the same does not hold for spatial problems. The most notable difference between standard econometrics and spatial econometrics is the inherent spatial structure of the data. The following represents the two stage model:

$$\begin{aligned} \mathbf{x} &= \rho_x \mathbf{W}\mathbf{x} + \mathbf{X}_x \boldsymbol{\beta}_x + \boldsymbol{\varepsilon}_x \\ \mathbf{y} &= \rho_y \mathbf{W}\mathbf{y} + \mathbf{X}_y \boldsymbol{\beta}_y + \boldsymbol{\varepsilon}_y \end{aligned} \tag{13}$$

Where $\mathbf{X}_y = \left[\hat{\mathbf{x}}\ \tilde{\mathbf{X}}_y \right]$ and $\hat{\mathbf{x}}$ are the fitted values from the first stage and $\tilde{\mathbf{X}}_y$ are the usual other variables. Denoting $\mathbf{Z} = \left[\mathbf{y}\ \mathbf{X}_y \right]$ we can see that random sampling with replacement from **Z** to create additional data sets will damage the spatial structure of the data and does not take into consideration any possible error in predicting the first stage. That is, by randomly selecting from the matrix **Z** we are not taking into consideration the place in space of each of the data points. This is especially problematic given how important this neighboring relationship is for spatial problems. To obtain bootstrap style estimates of the parameter precision thus one needs to maintain the spatial integrity of the data. This can be done by using what we call an "augmented spatial bootstrap method". For the IV approach used in this paper to fitted patents are used in place of actual patents in the employment growth equations. Using the standard routine we can obtain estimates of the parameters of interest in the first equation of (13), $\hat{\rho}_x$ and $\hat{\boldsymbol{\beta}}_x$. Using these parameter estimates we can compute the resulting residual $\mathbf{u}_x$:

$$\mathbf{u}_x = \mathbf{x} - \hat{\rho}_x \mathbf{W}\mathbf{x}_x - \mathbf{X}_x \hat{\boldsymbol{\beta}}_x \tag{14}$$

From (14) we can undertake sampling with replacement to obtain vectors of residuals $\mathbf{u}_{x,1}$, $\mathbf{u}_{x,2}$, …, $\mathbf{u}_{x,R}$. Using each vector of residuals one at a time, a vector of pseudo dependant variables can be computed in relation to each of these r = 1,2,…,R vectors of residuals:

$$\mathbf{x}_r = \left(\mathbf{I} - \hat{\rho}_x \mathbf{W} \right)^{-1} \left(\mathbf{X}_x \hat{\boldsymbol{\beta}}_x + \mathbf{u}_{x,r} \right) \tag{15}$$

The random assignment of the error term in (15) ensures the spatial structure of the data is maintained (Anselin, 1988). Using the newly created dependant variables from (15) we can estimate the following equation

$$\mathbf{x}_r = \hat{\rho}_{x,r} \mathbf{W}\mathbf{x}_r + \mathbf{X}_x \hat{\boldsymbol{\beta}}_{x,r} \tag{16}$$

Using the fitted values obtained from (16), $\hat{\mathbf{x}}_r$, these estimates are inserted into the dataset for the second stage regression $\hat{\mathbf{X}}_y = \left[\hat{\mathbf{x}}_r \ \tilde{\mathbf{X}}_y\right]$. Using this dataset we can construct a new set of second stage residuals using the parameter estimates from the second equation in (13):

$$\mathbf{u}_y = \mathbf{y} - \hat{\rho}_y \mathbf{W}\mathbf{y} - \hat{\mathbf{X}}_y \hat{\boldsymbol{\beta}}_y \quad (17)$$

Drawing with replacement from (17) we can construct an error vector $\mathbf{u}_{y,r}$ and use these errors to construct a pseudo vector of dependant variables using

$$\mathbf{y}_r = \left(\mathbf{I} - \hat{\rho}_y \mathbf{W}\right)^{-1} \left(\hat{\mathbf{X}}_y \hat{\boldsymbol{\beta}}_y + \mathbf{u}_{y,r}\right) \quad (18)$$

Using the pseudo vector of dependant variables from (18) we can estimate the following equation and compute estimates of $\hat{\rho}_{y,r}$ and $\hat{\boldsymbol{\beta}}_{y,r}$

$$\mathbf{y}_r = \hat{\rho}_{y,r} \mathbf{W}\mathbf{y}_r + \hat{\mathbf{X}}_y \hat{\boldsymbol{\beta}}_{y,r} \quad (19)$$

We can follow this process a large number of times to obtain a vector of parameter estimates and then compute estimates of dispersion and the accompanying t-statistics in the usual fashion. Since each iteration requires the estimation of two spatial models, iterating a very large number of times can be somewhat computer intensive.

CHAPTER 4 - THE ROLE OF AMENITIES ON EMPLOYMENT GROWTH IN THE U.S. HEARTLAND: A SPATIAL ANALYSIS EXAMINING THE ROLE OF RECREATIONAL AMENITIES IN SURROUNDING COUNTIES

A paper to be submitted to the
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Abstract

This study explains the role of recreational amenities on employment growth in rural areas using data from 618 counties in the U.S. rural Heartland. We consider a variety of recreational amenities as a factor underlying non-farm employment growth for counties in the Midwestern States of Iowa, Minnesota, Missouri, Kansas, Nebraska, South Dakota and North Dakota. Where the data cannot be grouped in a logical and orderly manner, principal component analysis is used to aggregate various types of recreational data to create specific recreational amenity indices. Using a wide range of amenity variables and using spatial econometric techniques, the results do indeed tend to suggest natural amenities have played a role in employment growth over the years 1969 to 2000. Further, our results also point to the importance of recreational amenities both within the county and in surrounding counties as having a positive impact on non-farm employment growth.

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Introduction

In general it is believed that, ceteris paribus, people and business are more likely to locate where there are more amenities than where there are fewer. In the last century this move has been quite obvious as employers and people alike have continued to move west to the mountains of Colorado or further on towards the West Coast where scenic and recreational amenities abound. These amenities clearly have value as any student renting a studio in Berkeley can tell you. The same is true for the ski instructor in Aspen who will work for minimum wage to enjoy the beautiful scenery and purchase a discounted ski pass. A number of studies have demonstrated that positive amenities may be capitalized into wages and higher housing values (Roback 1982, 1988) or land values (Cheshire and Sheppard, 1995). While capitalization of the amenity benefits into higher housing values and lower wages may occur, there is a growing literature which suggests amenities may be developed for economic policy purposes. The work of Gottlieb (1994) suggests amenities have potential to be used as an economic growth tool. Further work by Dissart and Dellar (2000), Halstead and Dellar (1997), and Rudzitis (1999) have shown quality of life plays an important role in economic growth at the community level. Using a relatively large set of recreational and natural amenity indicators, Dellar et al (2001) provide evidence that changes in the levels of population, employment, and income generally respond positively to a broad group of amenities.

While America is becoming increasingly urban, opportunities for recreational amenities, especially those of the camping and outdoor persuasion, are generally limited within well developed urban centers. This does not imply, however, that such areas cannot and do not benefit from outdoor recreation opportunities. A common weekend activity for families and individuals alike is to escape the city and head out to the lake or campground to spend the weekend. A half hour of driving or more is usually more than adequate to transport a family away from home, across county lines, and into an area with attractive camping, swimming, and hiking opportunities. So, in effect, when examining the overall effect of these recreational amenities on economic behavior it is apparent recreational amenities in proximity to the home county need to also be considered rather than just the amenities within the county itself. While few studies, if any, have examined the role of surrounding amenities on county economic activity, a few papers have explicitly considered the regional as well as local effects of economic activity. In a study on population growth by Kahn, Orazem, and Otto (2001) the authors found wage growth in geographically near counties complemented population growth in the home county. Additional studies giving attention to the relationships occurring regionally as opposed to locally include Blomquist, Berger, and Hoehn, 1988; Voith, 1991, 1993. Clearly any policy aimed at exploiting recreational amenities of the outdoor type, or any rural policy for that matter, needs to take into consideration the proximity effects as well. Many previous studies, especially at the county level, have ignored this spatial relationship and have incorrectly made the classical statistical assumption of independence between observations when conducting analysis. Since individuals and families are not confined to their county of residence on weekends it is unreasonable to consider only the recreational amenities in the home county. Rather it seems pertinent in this discussion to also consider what impacts amenities in surrounding counties have on the home county. To highlight recreational amenities in surrounding counties may be very important to employment growth in the home county. We can envision that while a county may be rich in employment growth and development opportunities, there may be a lack of amenities within the county itself. Therefore to look at the total impact of amenities (esp. those amenities which are recreational and pertain to the outdoors) we consider amenities in the surrounding counties as well.

In this paper we are primarily interested in the role of recreational and natural amenities on economic growth, i.e. non-farm employment growth. Examining the role of amenities in employment growth in Midwestern counties we also consider what are the impacts of amenities in surrounding counties as it is clear individuals are not confined to their home counties. However, to explain growth in a more complete growth framework in an effort to develop a more robust framework we formulate our model based on stylized macro economic growth principles, which includes technology, in addition to introducing a tradeoff between monetary wages and non-monetary amenity benefits. While there are a number of studies that examine and model rural economic growth with respect to amenities, such as those described above, these models are generally lacking in two very important respects: 1) omission of the role of technology as a factor in a more encompassing economic growth model, and 2) making the incorrect assumption of independence among counties. First, failure to include technology impacts, the fundamental building block of economic growth theory, may lead to missing variable bias in any growth model, especially if there are long periods of time. As an indicator of local technology we use patents filed within the county. In this paper will draw freely on the modern macroeconomic growth literature of countries and cities (Barro, 1991; Glaeser, et al. 1995; Glaeser, et al. 1992; Lucas, 1988; Romer, 1986) to develop hypotheses and insights to explain total employment growth patterns in rural counties in an effort to better understand why some rural counties grow and others continue to decline. Secondly, unlike with countries, economic agents within a county are restricted in movement across county lines only by their opportunity cost of about half an hour in their vehicle. It is unreasonable to believe that when we are examining the economic role of something as broad and spatially dependant as recreational amenities that we restrict in scope our economic agents to remain within the confines of their respective counties.

Realizing that there are limits in which recreational and natural amenities, can be developed, in no way are we arguing or advocating that all rural counties and areas should or will grow in employment and output. Rather, a few will grow, and we are attempting to identify the necessary endowments, location-specific characteristics and initial conditions needed to spur employment growth. It may be misallocating and wasting public resources to attempt to reverse the trend in many declining rural counties that are do not have available recreational and natural amenities, too isolated, lack the necessary initial conditions to support future employment growth. Using data from 618 counties in the U.S. Heartland states (Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota, and North Dakota), total non-farm employment growth is estimated and the factors explaining employment growth are identified. The Heartland counties present an interesting study area because over half the counties were declining in both population and employment, during the 1990's, while several counties posted significant growth. Third, given the empirical evidence, an attempt is made to draw policy implications for future rural development policy. Finally, the last section summarizes the analysis and discusses potential extensions of this analysis.

Analytical Framework

Modern economic growth literature is shifting emphasis from the traditional neoclassical framework to endogenous growth factors. Modern growth theories focus on the roles of ideas and technology embodied in human capital (Lucas, 1988), physical capital (Romer, 1986), natural capital (Castle, 1988), and initial conditions including infrastructure. Glaeser, et. al. (1992, 1995) have added cross-industry externalities and derived empirical estimates of total and sector employment growth in key industries for U.S. cities. Obviously, economic growth is far more complex than captured by these stylized macro models, but these models provide a useful starting point. These macro models ignore specific consideration of rural economic growth, but they do provide a useful starting point to building a more complete economic growth framework for our analysis.

The underlying theoretical model for this analysis follows Glaeser, et al (1992), which described employment growth in city-industries in the U.S. Firms are assumed to take prices, wages, w_t, and technology, A_t, as given and maximize a single input production function

$$A_t f(l_t) - w_t l_t \tag{1}$$

The firms choose labor input, l_t, such that the marginal product of labor is equal to the wage rate. Taking this derivative again with respect to labor in t+1 we can write the ratio of these two derivatives at two points in time:

$$\frac{A_{t+1}}{A_t}\frac{f'(l_{t+1})}{f'(l_t)} - \frac{w_{t+1}}{w_t} = 0 \tag{2}$$

Assuming a Cobb-Douglas functional form for the production technology of $f(l) = l^{\alpha}$, we can substitute into (2) and take logs to get an equation of labor growth shown in (3).

$$\ln\left(\frac{l_{t+1}}{l_t}\right) = \beta_1 \ln\left(\frac{A_{t+1}}{A_t}\right) + \beta_2 \ln\left(\frac{w_{t+1}}{w_t}\right) \tag{3}$$

where $\beta_1 = \left(\frac{1}{1-\alpha}\right)$, and $\beta_2 = \left(\frac{1}{\alpha - 1}\right)$.

We can draw loosely on the work of Roback (1982) for the relationship between workers actual wages and amenities. Ceteris paribus, a worker will be willing to locate in a region with a lower (higher) wage if the level of amenities are higher (lower). If w is the implicit wage paid to workers and takes into consideration location considerations, then w is a function of both actual wages paid, w_a, and amenities, s. If we assume utility is increasing in these amenities, then firms will be able to pay workers a smaller wage in areas with higher amenities. If we assume the trade off between actual and non-monetary amenities is given by the function $w = s^{\sigma} w_a^{\tau}$, where $\sigma<0$, and $\tau>0$, then equation (3) can be re-written to include both the implicit value of amenities and actual wage paid by firms.

$$\ln\left(\frac{l_{t+1}}{l_t}\right) = \beta_1 \ln\left(\frac{A_{t+1}}{A_t}\right) + \tilde{\beta}_2 \ln\left(\frac{w_{a,t+1}}{w_{a,t}}\right) + \tilde{\beta}_3 \ln\left(\frac{s_{t+1}}{s_t}\right) \tag{4}$$

where $\tilde{\beta}_2 = \left(\frac{\tau}{\alpha - 1}\right)$, and $\tilde{\beta}_3 = \left(\frac{\sigma}{\alpha - 1}\right)$.

These amenities yield utility to employees choosing to live in rural areas and may substitute for higher wages in metro areas. Note that we have not yet defined what an individual living and working in any given county defines as amenity benefits but will be discussed further when we specify the empirical model.

In equation (4) we are still left with a term for technology growth which we assume is a function of two components local (county) and regional. We describe this relationship using a Cobb-Douglas functional form, $A = R^{\delta} A_c^{\gamma}$ for t and t+1 where R is regional technology, and A_c is local technology. The parameters δ and γ represent the relative importance of such technology. Thus, we can express the growth in employment as a function of the growth in wages, regional technology growth and local technology growth or

$$\ln\left(\frac{l_{t+1}}{l_t}\right) = \tilde{\beta}_1 \ln\left(\frac{A_{c,t+1}}{A_{c,t}}\right) + \tilde{\beta}_4 \ln\left(\frac{R_{t+1}}{R_t}\right) + \tilde{\beta}_2 \ln\left(\frac{w_{a,t+1}}{w_{a,t}}\right) + \tilde{\beta}_3 \ln\left(\frac{s_{t+1}}{s_t}\right) \qquad (5)$$

$$\text{where } \tilde{\beta}_1 = \left(\frac{\gamma}{\alpha - 1}\right), \text{ and } \tilde{\beta}_4 = \left(\frac{\delta}{\alpha - 1}\right).$$

The above equation describes, at least conceptually, the factors which influence labor growth. While this is obviously a simplified model, it does underscore the importance of amenities and technology in determining employment growth. In the next section we discuss in greater detail the components of equation (5) and the data and methods used in the empirical analysis.

Econometric Model and Data Description

This section describes the data and the empirical relationships used to formulate and empirically estimate our conceptual model of employment growth. We consider county growth in employment over the periods 1969-2000 and the latter sub-period 1985-2000. Our sample includes 618 counties in the U.S. Midwestern States of Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota, and North Dakota. As stated earlier, this region is largely rural. The farm sector is struggling with low prices, the number of farms is slowly decreasing, the age distribution of farmers is shifting to the right (i.e., roughly 20 percent of the farms account for 80 percent of sales), and over half of the farm operators work off-farm. Relative earnings in the region, especially in rural counties are below the national average, but many rural people perceive this as a "quality-of- life" tradeoff that could be interpreted as an amenity value associate with rural living.

The change in value of natural amenities over time is believed to be a function of the natural amenity and recreational opportunities endowment. In an attempt to capture the importance of natural capital in the growth process (e.g., Castle, 1998), we use the potential flow of natural amenity and a variety of recreational amenities as a proxy.

$$\ln\left(\frac{s_{t+1,i}}{s_{t,i}}\right) = q\left(\mathrm{am}_i, r_{1,i}, r_{2,i}, r_{3,i}, \ldots, r_{R,i}\right) \qquad (6)$$

where am_i is the natural amenity scale, and $r_{r,i}$ is the recreational amenity for $r \in R_i$ where R_i is the set of recreational amenities available to county i and are those recreational amenities described in the previous section. Since q() is assumed to be a positive and monotonic function, we expect its arguments to have positive effects: i.e. $\frac{\partial q(.)}{\partial am_i} > 0$, and $\frac{\partial q(.)}{\partial r_{r,i}} > 0 \ \ \forall r \in R_i$.

The natural amenity scale (am) is used to control for local climatic and topographic conditions. As a proxy for the flow of natural amenity services in the county, we use an index of natural amenities including climatic factors as well as the type of land topography and percent of the county covered with water. These indices were constructed by the Economic Research Service (ERS) of USDA (McGranahan, 1999).

To compute indicators of recreational amenities we draw from the National Outdoor Recreation Supply Information System (NORSIS) dataset which was compiled for the 1998 Renewable Resources Planning Act. The strategies for constructing our different indicators for recreational amenities depend upon the makeup of the data. If the data can be easily combined and interpreted a simple sum is sufficient. However, if the recreational amenity in question is comprised of a number of different variables that are not directly combinable, then we use principal component analysis to derive county indicators for each amenity[2]. The recreational amenity indicators we have selected for this paper are: i) rails to trails miles, ii) National Resources Inventory (NRI) land available for recreation, iii) NRI water areas for recreational uses, iv) National Park Service (NPS) amenities, v) State Park Service amenities, vi) private campground amenities, vii) Forest Service amenities, and viii) amenities created by the US Army Corps of Engineers. Amenities i)-iii) were created based on a simple sum of the variables, and items iv)-viii) were created using factor analysis. Each of these is described in greater detail below.

The first three indicators, i)-iii), are constructed as simple sums within the county. The rails-to-trails amenity variable is the sum of rail beds converted to recreational trails for horseback, road biking, mountain biking, fishing access, skating, snowmobiling, and cross country skiing. NRI land available for recreation is the sum of acres available for municipal, county, State, Indian, and private recreational use. NRI land for water recreation is the sum of primary and secondary use recreation based water acres. Within our sample the data ranged significantly for each of these three variables[3].

The next set of recreational amenities, items iv)-vii), are created using factor analysis in a method similar to Deller, et al. (2001). Our recreational variable for State Park combined parks with camping, boating, fishing, hiking, primitive camping, picnicking, snowmobiling, and swimming. The new variable created was able to explain over 71% of the cumulative variation in state parks. The national park service amenity variable was able to explain 49.4% of the cumulative variation in NPS amenities. This variable included information on the number of NPS units with biking trails, fishing, horse back riding trails, hiking, swimming, and cross country skiing. The recreational variable for private campground amenities is created using both the number of private campgrounds and the number of campground sites. The variable created using factor analysis explained all of the variability in private campgrounds so estimates obtained using the variable here should be identical to that created if the two private campground indicators had been summed. The USDA forestry service amenity indicator is a combination of the numbers of boat ramps, picnic tables, developed swimming areas, trailheads, campgrounds, trailer sites, the number of miles open to the public, and total campground acres. This USDA forestry service indicator explains almost 68% of the variation in

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[2] The method we use here follows that of Dellar et al, 2001 who also uses principal components to create county level indicators of amenities. While we did try varying methods to compute aggregate variables, such as the iterated principal factor (ipf), the method chosen did not appear to have significant impacts on our estimates.
[3] We thus opt to augment the sample data with a "+1" and then take logs to allow the coefficient estimates to be interpreted directly as elasticities later in our estimation.

forestry amenities. The final recreational amenity is based on the US Army Corps of Engineers amenities. The index explains almost 78% of the cumulative variation and is comprised of total land and water recreational acres, total intensive use recreational acres, the numbers of individual campsites, individual picnic sites, boat ramps, designated swimming areas, trails, swimming pools, boat rentals, fishing docks, and miles of hiking trails, interpretive trails, bicycle trails, horseback trails, off-road trails, and other trails. A detailed view of the weighting factors are contained in tables 2-6.

Using the recreational amenity data above we go one step further to create an index based on all fifty of the individual indicators used to create our various different indices. This index was created using factor analysis since there was no obvious conventional means by which we could aggregate the various data into a single indicator. The index was created by summing the first four variables created by loading on the first four eigen values. These first four eigen values were somewhat of a natural break with 53% of variation in recreational amenities explained in this measure. A map showing the dispersion of this recreational amenity parameter is given in figure 1. As can be seen from the map in figure 1, Northern and Eastern regions of Minnosota, Southern regions of Missouri, and Western regions of South Dakota rank fairly high on this aggregate recreational amenity scale.

An alternative specification to (6) relates the flow of amenities in the home county to recreational amenities in surrounding counties. We define a recreational neighborhood for county i, J_i, as those counties within "close" proximity to the home county. Most counties in our Midwest sample can be reasonably described as having a "square" or "rectangular" geometric shape and occur on a fairly regular lattice. The neighboring recreational amenities are thus assumed to be drawn from the eight nearest counties. This follows the "King" coverage in relation to chess covering all spaces in the immediate proximity in both perpendicular and diagonal directions[4]. Since counties in the Midwest tend to occur in a fairly regular fashion like that of a chess board, the eight closest counties should give a fairly good indicator of the neighboring recreational pool[5]. This alternative specification of recreational amenity flows coming from the neighboring counties is represented by:

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[4] Thanks to Peter Orazem for pointing out this is a "King" style orientation rather than the "Queen" as is often referred to in the literature.

[5] Using the latitude and longitude coordinates for the county centroid a series of eight spatial matricies were created. The matricies $W_1, W_2, W_3, \ldots, W_8$ were constructed so the nth row of W_d contained a single "1" corresponding to the dth nearest county. For each of the counties we are able to create an indicator for each of

$$\ln\left(\frac{s_{t+1,i}}{s_{t,i}}\right)=\hat{q}\left(\text{am}_i,\sum_{j\in J_i} r_{1,j},\sum_{j\in J_i} r_{2,j},\sum_{j\in J_i} r_{3,j},\ldots,\sum_{j\in J_i} r_{R,j}\right) \quad (7)$$

As with the previous specification in (6), we assume that $\hat{q}$ is positive and monotonic. Equation (7) is increasing in its first argument, i.e. $\frac{\partial\hat{q}}{\partial am_i}>0$, as before. However, while we are postulating that $\frac{\partial q(.)}{\partial\sum_{j\in J_i} r_{r,j}}>0 \ \forall r\in R_i$, this may not always be the case. In situations where the amenity is contained within the county in very close proximity to a large city or a center of economic growth the proposed relationship may not only be insignificant but possibly even negative. This seemingly odd result may occur if the recreational amenity is within a county with economic growth such that the area is "sucking" employment from surrounding counties. Another possibility is the economy of the county itself is mature and, while in early stages may have benefited from the proximity to a particular recreational amenity, is no longer experiencing growth and possibly even decline. This could conceivably be the situation if the amenity itself is dated in such a manner as to no longer be providing a flow of recreational services.

In an attempt to estimate an economic growth model that incorporates some of the foundational growth forces we need to postulate functional relationships incorporating technology as well. Returning to our conceptual framework in (4) we notice employment growth is also believed to be a function of technology and wage growth. We believe local technology is a combination of explicit technology produced, i.e. patents, economic spillovers from surrounding counties, and factors related to market access.

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the recreation categories for the home county. For example, if r_1 is an nx1 vector of the rails-to-trails variable, then the neighboring rails-to-trails, r_{1,N_r}, would be computed by $r_{1,N_r}=r_1\left(W_1+W_2+W_3+\ldots+W_8\right)$. Since all the W matrices have zeros along the main diagonal and off diagonals are neighboring counties, the resulting variable r_{N_r} formed by the multiplication of the 1xn r_1 vector and the nxn $\left(W_1+W_2+W_3+\ldots+W_8\right)$ matrix results in the sum of the surrounding recreational amenities for the home counties.

$$\ln\left(\frac{A_{t+n,i}}{A_{t,i}}\right) = g\left(\sum_{j\in N_i}\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right), \sum_{k=t}^{t+n} pat_{k,i}, dist_i, Id_i\right) \tag{8}$$

Spatial externalities are believed to play a role in the new geographic economy (Fujita, Krugman, and Venables, 1999) and should be modeled explicitly. There is a growing literature that underlies the importance of interaction among economic agents (Glaeser et al., 1992; Akerlof, 1997). The realization that interaction among economic agents is an important part of the economic process as it facilitates in exchange of ideas observing competitors and emphasizes the need to consider the behavior of agents together rather than independently (Anselin, 2003). This physical interaction could also be indicative of a positive feedback (Arthur, 1999) which could associated with the clustering around a market or market network. These spatial externalities and local economic cluster effects are embodied in employment growth in geographically close counties as defined by some neighborhood N_i by the term $\sum_{j\in N_i}\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right)$. This relationship is expected to generate positive externalities a priori, i.e. $\frac{\partial g(.)}{\partial\sum_{j\in N_i}\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right)} > 0$. Consistent with the belief that new patents are a proxy for new knowledge and innovation (Jaffe 1989 and 1993; Hall, Jaffe, and Trajtenberg 2001; Anselin, Varga, and Acs 1997), this measure is expected to contribute positively to knowledge and technology growth i.e. $\frac{\partial g(.)}{\partial\sum_{k=t}^{t+n} pat_{k,i}} > 0$. The patent database created here was obtained by cross-referencing inventors' addresses obtained from the United States Patent and Trademark Office (USPTO) with a list of cities for each county based on Census county definitions. Using only the first inventor for each patent we were able to construct a list of patents by county for the years 1975-2000. Distance to a MSA ($dist_i$), and presence of an interstate within the county (Id_i), are assumed to play a role in the ability of economic agents to interact and act as an indicator for access to markets. Other things equal we would assume distance to play a negative and presence of an interstate to have a positive effect on technology growth within the county.

Regional technology growth is believed to be largely a function of the State where technology is taking place. Tax rates, State policies governing incentives for new technology, and general growth atmosphere within the respective state can be captured with the use of State dummies (sd_i) in which county i resides.

$$\ln\left(\frac{R_{t+n,i}}{R_{t,i}}\right) = h\left(\mathrm{sd}_i\right) \qquad (9)$$

In our sample of Midwestern counties the States of interest are Iowa, Minnesota, Missouri, Kansas, Nebraska, South Dakota, and North Dakota. However, without State specific information it is impossible to sign the h(.) with respect to any given State.

The final component of (5) we need to address is wage growth. For this paper we assume wage growth is a function of the initial wage ($wage_{t,i}$) and initial employment ($emp_{t,i}$) in county i.

$$\ln\left(\frac{w_{a,t+n,i}}{w_{a,t,i}}\right) = k\left(wage_{t,i}, emp_{t,i}\right) \qquad (10)$$

Initial wage should ceteris paribus have a negative impact on wage growth from a convergence point of view since if an area with a higher wage has attained a higher overall level of economic activity. This should translate into a positive impact on employment growth overall since $\tilde{\beta}_1 < 0$ in (4). In a sticky wage-model, initial employment will on the other hand have an indeterminate effect on wage growth since both wages and above and below equilibrium will have a positive impact on employment growth as the labor market adjusts. The employment and wage data used in this analysis comes from Bureau of Economic Analysis (BEA) data compiled on the Regional Economic Information System (REIS) dataset.

The relationships presented in (6) thru (10), can be substituted into the conceptual framework in (4). If we assign log-log functions to equations (6) thru (10), we are left with an estimable equation describing employment growth in terms of amenity flows, technology and economic spillovers, and a set of other initial conditions[6,7]:

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[6] All equations in this paper are estimated using spatial econometric techniques are take the general form of a spatially lagged dependant variable model: $Y = \rho WY + X\beta + \varepsilon$ where Y is a nx1 vector of dependant variables, W is a nxn spatial weights matrix created using a Deluanay Triangulation routine (Pace and LeSage

$$\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right) = \alpha + \rho \sum_{j \in N_i} \ln\left(\frac{emp_{t+n,j}}{emp_{t,j}}\right) + \beta_1 am_i + \sum_{r=1}^{R} \beta_{r+1} r_r + \beta_{10} Id_i + \beta_{11} \ln \sum_{k=t}^{t+n} pat_{k,i}$$
$$+ \beta_{12} \ln wage_{t,i} + \beta_{13} \ln emp_{t,i} + \beta_{14} \ln dist_{t,i} + \sum_{s=1}^{6} \beta_{s+14} Sd_i + \varepsilon_i \quad (11)$$

where the variables are as described above and α, ρ, and β_1 thru β_{20} are parameters to be estimated.

Since we are using the sum of patents filed within the county over the period there is good reason to believe we may have an endogeneity problem as there are obviously growth forces underlying employment and technology growth as represented by patents that are most likely not captured within the model. To correct for this we implement a two stage IV approach where equation (11) is estimated using predicted patents obtained with the following equation:

$$\ln \sum_{k=t}^{t+n} pat_{k,i} = \phi_0 + \rho_{pat} \sum_{j \in N_i} \ln \sum_{k=t}^{t+n} pat_{k,i} + \phi_1 \ln pci_{t,i} + \phi_2 \ln percol_{t,i} + \phi_3 \ln pop_{t,i}$$
$$+ \phi_4 \ln wage_{t,i} + \phi_5 Id_{t,i} + \phi_6 \ln emp_{t,i} + \sum_{s=1}^{6} \phi_{s+6} Sd_i + \varepsilon_{pat,i} \quad (12)$$

Where per capita income (pci), percent of the population over 25 with a college degree (percol), population (pop), and the spatial lag term $\sum_{k=t}^{t+n} pat_{k,i}$ have been introduced to identify the system. The use of the first three of these variables is straightforward. Note here that we also use the spatial lag as an instrument as well which is also an acceptable instrument for two stage spatial model (Anselin, 1988). As for the employment and wage data, income and population data were obtained from the REIS dataset. Percent of the population over the age of 25 with a college degree was gathered from Census data for the year 1970.

2003a and 2003b), X is the standard nxk matrix of explanatory variables, ρ is the spatial parameter to be estimated, β is a kx1 vector of parameters to be estimated, and ε is a disturbance term satisfying the standard classical assumptions.

[7] In this specification it was necessary to augment the patent sum, rails-to-trails, NRI acres of land, and NRI acres of water with a "+1" to facilitate with taking logs.

In what follows we postulate 5 models, identified by Roman numerals I-V, relating employment growth to various plausible relationships with recreational amenities both in the home and in surrounding counties. Specification I adopts the traditional view where home county employment growth is a function of only those recreational amenities in the home county. This specification, while it does include a spatial relationship embodied in ρ, does not account for the fact that individuals in one county can enjoy the recreational amenities offered in surrounding counties. The alternative specification to (11) relates employment growth not to the recreational amenities within the county but rather to the recreational amenities in surrounding counties. If we denote the recreational neighborhood by J_r we can express county employment growth as a function of recreational amenities from surrounding counties rather than from the within the county itself. This is captured in model (II). Further, we can postulate a model where employment growth is a function of recreational amenities both within and from surrounding counties as represented by model (III).

$$\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right) = \alpha + \rho\sum_{j\in N_i}\ln\left(\frac{emp_{t+n,j}}{emp_{t,j}}\right) + \beta_1 am_i + \sum_{r=1}^{R}\beta_{r+1}r_r + \beta_{10}Id_i + \beta_{11}\ln\sum_{k=t}^{t+n}\widehat{pat}_{k,i} + \beta_{12}\ln wage_{t,i} + \beta_{13}\ln emp_{t,i} + \beta_{14}\ln dist_{t,i} + \sum_{s=1}^{6}\beta_{s+14}Sd_i + \varepsilon_i \qquad \text{(I)}$$

$$\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right) = \alpha + \rho\sum_{j\in N_i}\ln\left(\frac{emp_{t+n,j}}{emp_{t,j}}\right) + \beta_1 am_i + \sum_{r=1}^{R}\sum_{j\in J_i}\beta_{r+1}r_{r,j} + \beta_{10}Id_i + \beta_{11}\ln\sum_{k=t}^{t+n}\widehat{pat}_{k,i} + \beta_{12}\ln wage_{t,i} + \beta_{13}\ln emp_{t,i} + \beta_{14}\ln dist_{t,i} + \sum_{s=1}^{6}\beta_{s+14}Sd_i + \varepsilon_i \qquad \text{(II)}$$

$$\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right) = \alpha + \rho\sum_{j\in N_i}\ln\left(\frac{emp_{t+n,j}}{emp_{t,j}}\right) + \beta_1 am_i + \sum_{r=1}^{R}\beta_{r+1}r_r + \sum_{r=1}^{R}\sum_{j\in J_i}\beta_{r+9}r_{r,j} + \beta_{17}Id_i + \beta_{18}\ln\sum_{k=t}^{t+n}\widehat{pat}_{k,i} + \beta_{19}\ln wage_{t,i} + \beta_{20}\ln emp_{t,i} + \beta_{21}\ln dist_{t,i} + \sum_{s=1}^{6}\beta_{s+21}Sd_i + \varepsilon_i \qquad \text{(III)}$$

where $\sum_{k=t}^{t+n} \widehat{pat}_{k,i}$ are predicted patents obtained from fitting (12). The above three equations represent the focus of our empirical work in the next section. To better understand the role of amenities requires us to take a hard look at how these amenities, both in the home county and surrounding, affects employment growth. A note of caution when estimating model (III) since there may exist a problem of spatial correlation with the independent variables which may lead to problems with heteroskedasticity.

In an attempt to better understand the role of recreational amenities in this employment growth framework we propose an additional two models as various a combinations of (6) and (7). The first is a composite measure of both home recreational amenities and recreational amenities in surrounding counties. The composite index created is the sum of the home county recreational amenity factor, plus those same recreational amenities in the surrounding counties. This composite variable would be an indicator of the recreational amenity of interest in immediate and almost immediate access. This relationship is described by model (IV) below:

$$\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right) = \alpha + \rho \sum_{j \in N_i} \ln\left(\frac{emp_{t+n,j}}{emp_{t,j}}\right) + \beta_1 am_i + \sum_{r=1}^{R} \beta_{r+1}\left(r_r + \sum_{j \in J_i} r_{r,j}\right) + \beta_{10} Id_i$$
$$+ \beta_{11} \ln \sum_{k=t}^{t+n} \widehat{pat}_{k,i} + \beta_{12} \ln wage_{t,i} \qquad \text{(IV)}$$
$$+ \beta_{13} \ln emp_{t,i} + \beta_{14} \ln dist_{t,i} + \sum_{s=1}^{6} \beta_{s+14} Sd_i + \varepsilon_i$$

In the second specification we specify a term to account for the interaction between home and neighboring counties. This model is described in the following model (V):

$$\ln\left(\frac{emp_{t+n,i}}{emp_{t,i}}\right) = \alpha + \rho \sum_{j \in N_i} \ln\left(\frac{emp_{t+n,j}}{emp_{t,j}}\right) + \beta_1 am_i + \beta_2 ar_i + \beta_3 \sum_{j \in J_i} ar_j + \beta_4\left(ar_i * \left(\sum_{j \in J_i} ar_j\right)\right) \qquad \text{(V)}$$
$$+ \beta_5 \ln wage_{t,i} + \beta_6 \ln emp_{t,i} + \beta_7 \ln dist_{t,i} + \sum_{s=1}^{6} \beta_{s+7} Sd_i + \varepsilon_i$$

Where ar is the aggregate recreational amenity variable created using factor analysis. When estimating above model with an interaction term between home and surrounding county amenities we do so using only the aggregate amenity index created using factor analysis instead of the entire set of individual recreational amenity indicators. The estimate for β_2 and β_3 represent are the coefficients to be estimated for the home and surrounding county aggregate recreational amenity impacts respectively and β_4 is the interaction coefficient between the home and surrounding counties.

Ordinary least squares as an estimation method for estimating any of the above equations with a spatially lagged dependant variable is not a viable estimation technique due to the spatially lagged dependant variable. Instead we rely on the use of maximum likelihood estimation to compute unbiased parameter estimates in the spatially specified spatial-autoregressive model (SAR). To derive estimates of the SAR specification we follow the algorithm outlined by Anselin (1988). In the spatially specified model we test for further presence of spatial autocorrelation using a Lagrange multiplier test (Anselin, 1988).

Results

In this section we present our empirical results of employment growth equations under different model specifications and different indicators of recreational amenities. In tables 7 and 8 a full set of recreational amenity indicators are used to estimate models I-IV. Models I-III are presented in table 7 and model IV is given in table 8. Tables 9 and 10 make use of our aggregate recreational amenity indicator to estimate the five models, I-III in table 9 and IV and V in table 10. These model headings referring to the models: (I) only own county recreational amenities are used as explanatory variables, (II) when only lagged recreational amenities are explanatory variables, (III) where both own and neighboring county recreational amenities are the right hand side variables, (IV) a composite amenity variable of the sum of home and surrounding county recreational amenities, and (V) a model relating employment growth to both home and neighboring county amenities plus an interaction term. For all equations presented herein we have adopted a two-stage spatial estimation procedure where we use only predicted values of patents as a dependant variable in the employment growth equations[8]. The

[8] When conducting exploratory analysis using OLS we found evidence of severe spatial auto correlation in the errors. Also, the results presented here are based only on the spatial model where use a two stage IV estimation due to the obvious potential endogenity between patents and employment growth. Results for both the OLS and basic spatial models may be obtained from the authors upon request.

final table, table 11, lists the estimated coefficients used to fit county patents used in our second stage employment growth equations.

First we discuss the results using a wide range of recreational amenity indicators in tables 7 and 8. Model (I) in table 7 contains the estimated coefficients for the growth equations when considering the restricted model with only home county recreational amenities. The adjusted R-square suggests this model is able to explain about 38% of the variation in employment growth over this period. The Lagrange Multiplier for the spatial auto regressive model (LM Sar) is computed to be 0.05 suggesting a spatial relationship does not exist within the model residuals[9]. In this specification we find the presence of campgrounds in the home county has had a positive and significant results on employment growth over the study period. In fact, the associated coefficient for the private campground indicator created using factor analysis was significantly different from zero with at least a 99% level of statistical confidence. Also found to be positive and significantly different from zero was the State Park indicator with a more modest level of statistical confidence of only 90% or more. Interestingly none of the other recreational amenities were found to be significant in the home county. If we focus on the set of results from model (II) in table 7 we do find that some recreational amenities in surrounding counties do appear to have played a significant role in employment growth. Model (II) for the growth period 1969-2000 explains about 38% of the variability in employment growth and the LM Sar test statistic of 4.48 suggests we can not rule out the possibility of a spatial relationship in the model residuals. In this set of results we do find the rails-to-trails, NRI water based recreational amenities, and the National Park Service amenities in neighboring counties have all had a positive and significant impact on employment growth. Rails-to-trails miles, and NRI water acres were both significantly different from zero with at least a 99% level of confidence and the NPS variable created using factor analysis was significantly different from zero with at least a 95% degree of confidence. These results would in part imply it was not the recreational amenities themselves in the home county that had a positive impact on employment growth but rather it was these amenities in the neighboring counties which had a positive impact on employment growth. In this specification we also find that the amenity scale parameter is positive and moderately significant from zero. The amenity scale is capturing a different group of amenities and here indicates the components of the amenity scale, primarily scenic and climatic attributes, has played a positive role in employment growth over this

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[9] The LM Sar test statistic is distributed χ^2 with one degree of freedom. The critical value at the 99%, 95% and 90% levels are 6.63, 3.84, and 2.71 respectively.

period. Interestingly, the variable for State Park amenities actually had a negative (and also statistically significant) impact on employment growth over the period 1969-2000. There are a few explanations that may be given for this seemingly odd result and will be discussed in greater detail later in this paper.

The third specification in table 7, model (III), considers both the recreational amenities in the home county as well as recreational amenities in surrounding counties together in the same model. This model has an adjusted r-square of 0.4 suggesting about 40% of the variation in employment growth has been explained by the model. With a LM Sar statistic of 3.1 we cannot rule out the possibility of a spatial relationship in the model residuals. In this specification we are able to examine the effects of the recreational amenities indicated in both the home and neighboring counties. As we can see from the estimated t-statistics for the home and neighboring counties (Lag) amenities, correlation among these variables does not appear to be a problem when viewed at a glance[10]. What we find is the effects from the first two models (I) and (II) persist in general in (III). These results taken together would imply State Parks and private campgrounds are important in the home county while rails-to-trails miles, NRI recreational water acres, and NPS recreational amenities are important in neighboring counties.

Table 8 contains the estimated parameters from model IV where the recreation parameters represent the sum of the home county recreational amenity plus the recreational amenity for the same factor in surrounding counties. In table 8 we find the adjusted r-square is 0.38 suggesting just over a third of the variation in employment growth is explained by this model. Of the recreational variables we find rails to trails miles, NRI recreational water acres, NPS, and private campgrounds all contributed in a positive and statistically significant manner to employment growth. However, we do find an unusual result here that State Park recreational amenities are found to have a negative and statistically significant impact on employment growth with at least a 95% degree of confidence.

The conceptual model we presented proposed a more encompassing growth model which also included technology and spatial externalities and growth cluster effects. The parameter on new technology created, or patents, was found to range from an elasticity of 0.20 to 0.26. In the most

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[10] If multicolinearity were truly a problem here we should expect the t-statistics in parentheses to differ greatly between (I) and (III), and (II) and (III). Since this does not appear to be occurring, multicolinearity is most likely not an important issue here.

optimistic of these cases this implies a 10% increase in the number of patents filed within the county will result in a 2.6% increase in employment growth in the most optimistic of these estimates and 2% in the most conservative. Further, the estimate for spatial externalities and cluster effects, “rho”, was estimated to lie in the 0.17 to 0.27 range. Since the dependant variable is in log-format this result can be taken to mean a 10% increase in the employment growth in surrounding counties as defined by the spatial weights matrix W will lead to a 2.7% increase in the home county *ceteris paribus*. The results from these two parameters do indeed tend to suggest that technology spillovers and locational spillovers do play an important role in non-farm employment growth.

Of our additional explanatory variables we find initial employment has a negative and statistically significant effect on non-farm employment growth. In model IV in table 8 the estimated coefficient for 1969 employment implies that a 10% increase in the number of non-farm employment will result in a 2.3% decrease in non-farm employment growth, and this result is statistically different from zero with at least a 99% level of statistical confidence. The other variables for initial wage, presence of an interstate and distance to a MSA in 1968 did not appear to have a significant impact on non-farm employment growth.

Table 9 and 10 estimate the same models as above, with the addition of model V in table 10 incorporating an interaction term, using our aggregate recreation amenity index which collapses all the recreational variables embodied in tables 7 and 8 into a single variable using principal component analysis. In models I-IV in tables 9 and 10 we find once again recreational amenities have had a positive impact on non-farm employment growth. This is true whether we consider only recreational amenities in the home county as in I in table 9, recreational amenities in surrounding counties as in II in table 9, or a combination of home and surrounding recreational amenities as in III and IV in tables 9 and 10 respectively. When we examine the relationship between home and surrounding recreational amenities with the addition of an interaction term in model V of table 10 we find some attention-grabbing results. First, it is interesting to note that all three of the recreational amenity parameters are significant. The estimated parameter coefficients for both home and surrounding counties are positive and significantly different from zero with a high degree of statistical confidence while the interaction term is negative and statistically different from zero with a high degree of statistical confidence. It is also interesting to point out the relative sizes of the estimated coefficients as well. A value of 0.008 is higher than the comparable estimate for surrounding counties recreational amenities which are estimated to be 0.0025 and both of these are larger than the interaction term of -0.0002. If we were to take the partial derivative of the employment function with respect to home recreational amenities we would have a potential indicator of the impact of recreational amenities on home county non-farm employment growth which has been adjusted by the competing or "sucking" impacts of recreational amenities in neighboring counties[11]. Only if neighboring counties amenities very large in comparison to home county recreational opportunities could this relationship be negative. The amenity scale parameter in tables 9 and 10 appears to have a much move favorable impact on employment growth as compared to the coefficient estimates in tables 7 and 8 when we consider a much wider range of individual recreational amenity characteristics. In fact, in all model specifications in I-V in tables 9 and 10 this parameter is significantly different from zero with a high statistical level of confidence. The amenity scale variable was likely found to be more significant in these later regressions as a number of the individual recreation variables in tables 7 and 8, such as NRI water and recreational land acres, are likely highly correlated with the USDA amenity indicator.

Conclusions and Extensions

In an attempt to compress a large amount of recreational amenity data into a few indicators we either 1) used the raw data itself where applicable to condense the data, or 2) or used principal component analysis in a manner similar to Deller et al. (2001), to create a set of recreational amenity variables from a larger, more diverse set of indicators. Our results generally suggest that recreational do contribute in a positive manner to employment growth in the home county. We also found during the growth period 1969-2000 specific recreational amenities in surrounding counties as indicated by rails-to-trails miles, NRI acres available for water recreation, and NPS recreational amenities appear to have had a positive and significant effect on employment growth in the home county. When we further introduce an interaction term we do indeed find both home and surrounding counties do play a positive and statistically significant role in explaining non-farm employment over the period 1969-

[11] For this equation the partial derivative of the growth equation with respect to home county amenities, ar would be: $\frac{\partial\left(\ln\frac{emp_{2000,i}}{emp_{1969,i}}\right)}{\partial ar_i} = 0.0081 - 0.0002 * \sum_{j\in J_i} ar_j$. This will be negative only if recreational amenities in surrounding counties are very large. Also, since the amenity variable was created using principal components and was then converted to a normal (0,1) it does not make much sense to evaluate this at the mean which is zero. However, one could evaluate this function at various different quantiles to gain additional insight.

2000. In addition, given the negative coefficient for the interaction term, home and surrounding recreational amenities may actually be substitutes rather than complements.

The main focus of this paper is those amenities which contribute in a positive manner to non-farm employment growth. This does not however limit the policy implications to employment growth alone as a number of studies have shown there is a positive relationship between population and employment growth (Greenwood, Hunt, and McDowell 1986, Boarnet 1994, Carlino and Mills 1987, and Clark and Murphy 1996). Thus it is likely many of the results derived from this study would likely apply to a broader class of economic development policies related to employment and population alike. The policy implications of the findings presented in this paper may be further reaching than one may perceive at first. Since we have found employment reacts in a positive manner to certain recreational amenities in surrounding counties, the question becomes how are such amenities properly funded and developed? Standard theory would suggest that since these amenities are public goods which are generally non-excludable, and non-rival, recreational amenities will be under invested in if the entire burden happens to fall on the shoulders of the county within which it resides. Many rural counties have debated consolidating counties and it seems, at least given the analysis here indicating externalities between counties, consolidation or at least regionalization of counties has merit. If there is an externality that does exist, benefits from amenities having positive economic impacts across county borders, such consolidation can internalize at least some externalities and increase overall efficiency. Of course the basis of recreational amenities being enjoyed by individuals in different counties is not the only reason for consolidation of counties but it may be a factor.

This paper has provided empirical evidence that suggests amenities do play an important role in promoting employment growth. However, the results tend to suggest recreational amenities in surrounding counties also play an important role. The recreational amenities examined in this paper tend to be land intensive and would likely not be located in counties which may have been traditionally or currently are centers for economic growth. In some instances, such as national parks, development may be limited by legal mandate and necessarily restricts further economic growth. This does not however, preclude neighboring counties from realizing increased economic activity due to their location advantages.

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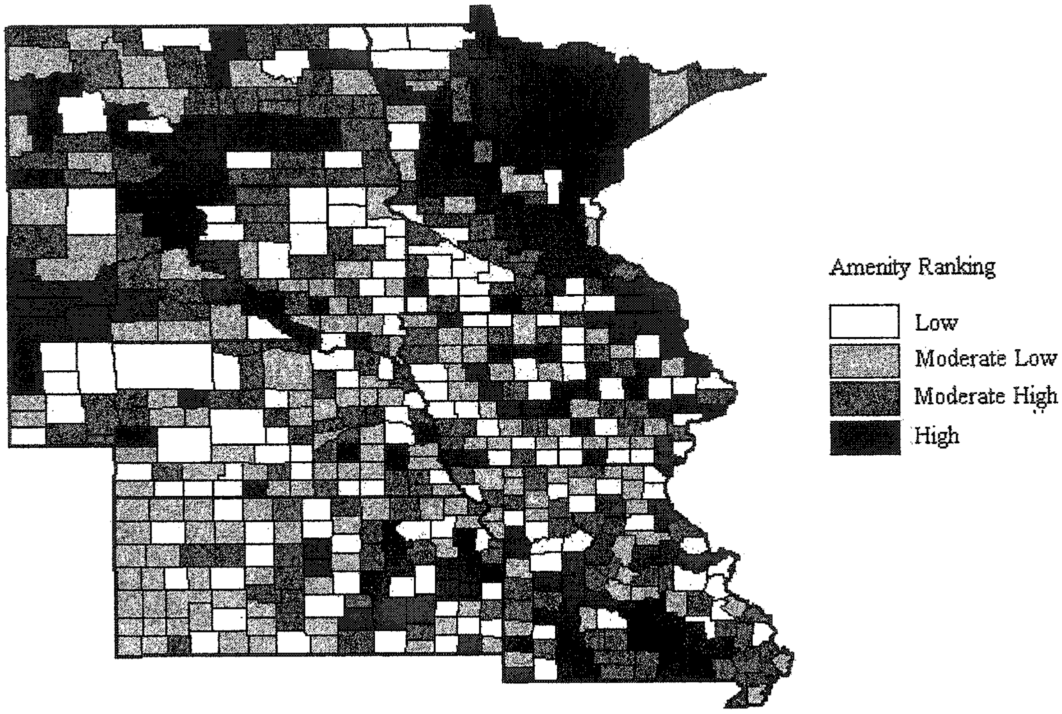

Figure 1. Aggregate Indicator of Recreational Amenities - Rankings

Table 1. Other Summary Statistics

Variable	Mean	Std. Dev.	Median	Minimum	Maximum	Count
Employment Growth 1969-2000	0.469	0.366	0.413	-0.504	2.07	
Climatic and Scenic Amenities						
Amenity Scale	-1.661	1.495	-1.705	-6.400	2.99	
Recreational Amenities						
NRI Land Acres	1664.89	5104.612	0	0	54000	
NRI Recreational Water Acres	10261.97	33467.79	2300	0	461400	
Rails to Trails Miles	16.49	73.725	0	0	1298.86	
Other Explanatory Data						
Total Patents Filed 1975-2000	125	666	14	0	12065	
Total Employment 1969	10876	40286	3431	105	544944	
Wage 1969	5.112	0.786	5.011	3.505	8.55	
Distance to a MSA 1968	109	68	97	359	0.5	
Interstate 1972						176
Instruments						
Percent College Degree 1970	6.562	3.343	5.890	0.463	30.02	
Population 1969	26217	73742	11657	624	967826	
Per capita income 1969	3.116	0.553	3.088	1.468	5.34	
State Counts						
Iowa						99
Kansas						105
Minnesota						87
Missouri						115
Nebraska						93
North Dakota						53
South Dakota						66

Table 2. Principal Component Eigenvectors: State Park

Variable	
# Parks with Camping	0.3678
# Parks with Boating	0.3757
# Parks with Fishing	0.3879
# Parks with Hiking	0.3417
# Parks with Primitive Camping	0.3060
# Parks with Picnicking	0.3960
# Parks with Snowmobiling	0.2912
# Parks with Swimming	0.3479
Cumulative Variation Explained	71.20%

Table 3. Principal Component Eigenvectors: National Park Service

Variable	
# Units with Biking Trails	0.3433
# Units with Fishing	0.5265
# Units with Horse Trails	0.1166
# Units with Hiking	0.5152
# Units with Swimming	0.3284
# Units with Cross-County Skiing	0.4671
Cumulative Variation Explained	49.40%

Table 4. Principal Component Eigenvectors: Private Campgrounds

Variable	
# Private Campground Sites	0.49969
# Private Campgrounds	0.49969
Cumulative Variation Explained	100%

Table 5. Principal Component Eigenvectors: USDA Forest Service

Variable	
# Boat Ramps	0.2657
# Picnic Areas	0.3739
# Developed Swimming Areas	0.3576
# Trailheads	0.2202
Miles of Road Open to Public	0.3742
# Campgrounds	0.4148
# Trailer Sites	0.4073
Campground Acres	0.3679
Cumulative Variation Explained	67.80%

Table 6. Principal Component Eigenvectors: US Army Core of Engineers

Variable	
Total Land and Water Recreational Acres	0.2298
Total Intensive Use Recreational Acres	0.3046
# Individual Campsites	0.3400
# Individual Picnic Sites	0.2912
# Boat Ramps	0.2408
# Designated Swimming Areas	0.2992
# Trails	0.3106
Miles of Hiking Trails	0.2349
Miles of Interpretive Trails	0.3018
Miles of Bicycle Trails	0.2154
Miles of Equestrian Trails	0.2046
Miles of Off-road Vehicle Trails	0.1520
Miles of Other Trails	0.1803
# Swimming Pools	0.1154
# Boat Rentals	0.2131
# Fishing Docks/Piers	0.2475
Cumulative Variation Explained	77.90%

Table 7. Employment Growth 1969-2000 – Recreational Amenities

Variable	Model Specification (I)[§,@]	(II)	(III)
Local Climatic and Scenic Amenities			
Amenity Scale	0.0135	0.0228	0.0075
	(1.2344)	(2.1437)**	(0.6752)
Recreational Amenities			
NRI Recreational Land Acres	0.0046		0.0046
	(1.3901)		(1.4291)
Rails to Trails	0.0073		-0.0018
	(0.8000)		(-0.1944)
NRI Recreational Water Acres	0.0026		0.0000
	(0.6415)		(-0.0093)
State Park	0.0098		0.0094
	(1.8194)*		(1.7396)*
NPS	-0.0019		-0.0056
	(-0.2720)		(-0.7338)
Private Campgrounds	0.0634		0.0586
	(4.3332)***		(3.9838)***
USDA Forest Service	-0.0043		-0.0052
	(-0.7163)		(-0.7873)
US Army COE	0.0070		0.0068
	(1.5718)		(1.5565)
Lag - NRI Recreational Land Acres		-0.0025	-0.0035
		(-0.5183)	(-0.7278)
Lag - Rails to Trails		0.0195	0.0160
		(2.4942)**	(2.0216)**
Lag - NRI Recreational Water Acres		0.0460	0.0431
		(3.3175)***	(3.0563)***
Lag - State Park		-0.0073	-0.0057
		(-3.5994)***	(-2.7924)***
Lag - NPS		0.0044	0.0052
		(2.2363)**	(2.5733)**
Lag - Private Campgrounds		0.0083	0.0082
		(1.5845)	(1.5227)
Lag - USDA Forest Service		-0.0007	-0.0014
		(-0.3360)	(-0.6408)
Lag - US Army COE		0.0013	0.0017

Table 7. (continued)

		(0.8331)	(1.0603)
Technology and Interaction			
Spatial Interaction "rho"	0.2762	0.1870	0.1708
	(4.8913)***	(3.1795)***	(2.8669)***
Predicted Total Patents[#] - Sum 1975-2000	0.2005	0.2557	0.2551
	(6.2907)***	(5.6062)***	(5.6629)***
County Characteristics			
Wage - 1969	-0.2822	0.1270	0.1888
	(1.7341)*	(1.0939)	(1.6409)*
Employment - 1969	0.0174	-0.2397	-0.2584
	(-6.8764)***	(-5.6088)***	(-6.1579)***
log distance to a MSA - 1968	0.0153	0.0182	0.0234
	(0.8470)	(0.8632**	(1.1138)
Presence of Interstate - 1972	0.0462	0.0586	0.0362
	(0.5226)	(1.9903)*	(1.2349)
State Effects			
Kansas	0.0527	0.0605	0.0681
	(0.9962)	(1.1427)	(1.2926)
Minnesota	0.2424	-0.0336	-0.0543
	(0.9995)	(-0.5410)	(-0.8673)
Missouri	0.0513	0.1755	0.2087
	(4.6952)***	(3.2166)***	(3.7231)
Nebraska	0.0489	0.0460	0.0464
	(1.0864)	(0.8915)	(0.9010)
North Dakota	0.1791	-0.0365	-0.0465
	(0.8453)	(-0.5211)	(-0.6531)
South Dakota	0.2708	0.1311	0.1168
	(3.2463)***	(2.0973)**	(1.8824)*
Constant	1.3601	0.7931	0.8477
	(4.6351)***	(2.3894)**	(2.6031)***
Diagnostics			
R-Square	0.4043	0.4038	0.4297
R-Adj-Square	0.3844	0.3839	0.4026
LM Sar	0.0529	4.4734**	3.1414**

[§] All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.
[#] The patent variable used in this regression is based on predicted values obtained using elements of Table 13.
[@] The standard errors were computed based on 1000 iterations of an augmented spatial bootstrap method.

Table 8. Employment Growth 1969-2000 – Total Recreational Amenities: Composite

Variable	Model Specification (IV) §,@
Local Climatic and Scenic Amenities	
Amenity Scale	0.0005
	(0.2623)
Recreational Amenities	
Composite Indices:	
(Home plus Surrounding)	
NRI Recreational Land Acres	-0.0032
	(-0.6201)
Rails to Trails	0.0151
	(1.9517)*
NRI Recreational Water Acres	0.0441
	(3.1242)***
State Park	-0.0046
	(-2.2919)**
NPS	0.0041
	(2.2514)**
Private Campgrounds	0.0155
	(3.0898)***
USDA Forest Service	-0.0020
	(-1.1224)
US Army COE	0.0021
	(1.3819)
Technology and Interaction	
Spatial Interaction "rho"	0.1739
	(2.9084)***
Total Patents# - Sum 1975-2000	0.2461
	(5.3640)***

Table 8. (continued)

County Characteristics	
Wage	0.1606
	(1.3635)
Employment	-0.2309
	(-5.4318)***
log distance to a MSA	0.0288
	(1.3473)
Presence of Interstate	0.0519
	(1.7559)*
State Effects	
Kansas	0.0767
	(1.3705)
Minnesota	-0.0493
	(-0.7670)
Missouri	0.2109
	(3.4820)***
Nebraska	0.0613
	(1.1421)
North Dakota	-0.0348
	(-0.4908)
South Dakota	0.1266
	(2.0137)**
Constant	0.6471
	(1.9099)*
Diagnostics	
R-Square	0.4037
R-Adj-Square	0.3838
LM Sar	7.3159***

[$] All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.
[#] The patent variable used in this regression is based on predicted values obtained using elements of Table 13.
[@] The standard errors were computed based on 1000 iterations of an augmented spatial bootstrap method.

Table 9. Employment Growth 1969-2000 – Recreation Index

Variable	Model Specification (I)[§,@]	(II)	(III)
Local Climatic and Scenic Amenities			
Amenity Scale	0.0303	0.0303	0.0278
	(2.9411)***	(2.9523)***	(2.6829)***
Recreational Amenities			
Total Recreation Amenity Indicator	0.0052		0.0042
	(2.1865)**		(1.7631)*
Lag - Total Recreation Indicator		0.0018	0.0016
		(2.6193)***	(2.2649)**
Technology and Interaction			
Spatial Interaction "rho"	0.2908	0.2681	0.2656
	(5.2373)***	(4.7396)***	(4.6767)***
Predicted Total Patents[#] - Sum 1975-2000	0.2773	0.2728	0.2764
	(6.2839)***	(6.1963)***	(6.2901)***
County Characteristics			
Wage - 1969	0.1430	0.1200	0.1234
	(1.2366)	(1.0368)	(1.0684)
Employment - 1969	-0.2616	-0.2521	-0.2575
	(-6.3038)***	(-6.0912)***	(-6.2242)***
log distance to a MSA - 1968	0.0139	0.0164	0.0198
	(0.6738)	(0.7904)	(0.9498)
Presence of Interstate - 1972	0.0310	0.0363	0.0336
	(1.0473)	(1.2272)	(1.1385)
State Effects			
Kansas	0.0152	0.0104	0.0113
	(0.3419)	(0.2328)	(0.2547)
Minnesota	0.0919	0.0855	0.0772
	(1.8763)*	(1.7313)*	(1.5609)
Missouri	0.2061	0.2032	0.2077
	(4.2233)***	(4.1716)***	(4.2664)***
Nebraska	0.0420	0.0498	0.0516
	(0.9194)	(1.0845)	(1.1272)
North Dakota	0.0623	0.0643	0.0590
	(1.1857)	(1.2255)	(1.1269)
South Dakota	0.1909	0.1873	0.1874
	(3.5450)***	(3.4785)***	(3.4893)***
Constant	1.3511	1.3224	1.3348
	(4.5845)***	(4.4811)***	(4.5375)***

Table 9. (continued)

Diagnostics			
R-Square	0.3759	0.3764	0.3794
R-Adj-Square	0.3625	0.3630	0.3650
LM Sar	1.1160	2.0170	2.6650

[§] All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.
[#] The patent variable used in this regression is based on predicted values obtained using elements of Table 13.
[@] The standard errors were computed based on 1000 iterations of an augmented spatial bootstrap method.

Table 10. Employment Growth 1969-2000 – Recreation Index: Composite and Interaction

Variable	Model Specification (IV) §,@	(V)
Local Climatic and Scenic Amenities		
Amenity Scale	0.0288	0.0260
	(2.7885)***	(2.5209)**
Recreational Amenities		
Composite - Home plus Surrounding	0.0019	
	(2.9858)***	
Total Recreation Amenity Indicator		0.0081
		(3.0134)***
Lag - Total Recreation Indicator		-0.0002
		(-3.1015)***
Amenity Interaction		0.0025
		(3.2293)***
Technology and Interaction		
Spatial Interaction "rho"	0.2651	0.2489
	(4.6740)***	(4.3704)***
Predicted Total Patents# - Sum 1975-2000	0.2742	0.2718
	(6.2408)***	(6.2120)***
County Characteristics		
Wage	0.1195	0.1259
	(1.0345)	(1.0976)
Employment	-0.2540	-0.2493
	(-6.1542)***	(-6.0472)***
log distance to a MSA	0.0188	0.0291
	(0.9028)	(1.3927)
Presence of Interstate	0.0353	0.0381
	(1.1974)	(1.2962)

Table 10. (continued)

State Effects		
Kansas	0.0104	0.0070
	(0.2332)	(0.1597)
Minnesota	0.0794	0.0891
	(1.6058)	(1.8109)*
Missouri	0.2053	0.2027
	(4.2189)***	(4.1846)***
Nebraska	0.0518	0.0579
	(1.1302)	(1.2714)
North Dakota	0.0613	0.0488
	(1.1700)	(0.9359)
South Dakota	0.1868	0.1795
	(3.4755)***	(3.3590)***
Constant	1.3243	1.2454
	(4.4986)***	(4.2263)***
Diagnostics		
R-Square	0.378	0.388
R-Adj-Square	0.365	0.373
LM Sar	2.378*	2.520*

[§] All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.
[#] The patent variable used in this regression is based on predicted values obtained using elements of Table 13.
[@] The standard errors were computed based on 1000 iterations of an augmented spatial bootstrap method.

Table 11. Patent Equations
(dependant variable – log(period sum of patents 1975-2000 +1)

Variable	1975-2000§
Instruments	
Spatial Interaction - "rho"	0.157
	(4.032)***
Per capita income - 1969	0.990
	(4.170)***
Population with a College Degree - 1970	0.365
	(4.081)***
Population - 1969	1.100
	(5.480)***
Other Variables	
Wage - 1969	0.452
	(1.557)
Employment -1969	-0.117
	(-0.691)
Presence of Interstate - 1972	0.043
	(0.577)
log distance to a MSA - 1968	-0.136
	(-2.856)***
State Effects	
Kansas	-0.022
	(-0.191)
Minnesota	0.389
	(3.264)***
Missouri	-0.006
	(-0.055)
Nebraska	0.014
	(0.119)
North Dakota	0.166
	(1.184)
South Dakota	-0.113
	(-0.825)
Constant	-8.926
	(-10.284)***
Diagnostics	
R-Square	0.793
R-Adj-Square	0.789
LM Sar	5.420**

§ All values in parentheses are t-statistics reflecting the test if the given coefficient is equal to zero, ***= significant at the 1% level, **= significant at the 5% level, *= significant at the 10% level.

GENERAL CONCLUSIONS

This dissertation has presented and tested a number of different theories related to economic growth as applied to predominantly rural regions. In the first section a two-period overlapping generations model with endogenous rural-urban migration is developed to examine the roles of technology and knowledge spillovers, and rural amenities on labor migration behavior. The major theoretical conclusions reached in this section suggests: 1) if technology spillovers exist in a market then high skill individuals will seek employment in these areas where they earn superior urban wage returns relative to engaging in agricultural production in the rural area; and 2) the usefulness of rural amenities as a means to attract individuals is not apparent since the trade-off between higher urban wages and rural amenities will depend to a large extent on what type of equilibrium, i.e. high vs. low steady state equilibrium, the economy is in currently. While difficult to draw definite conclusions from the stylized model presented, it does provide a useful general framework from which can be examined a variety of rural issues. Further, the theoretical framework does motivate to a large degree the applied work in section II.

The empirical applications contained in the second section of the dissertation examined three major areas. These are: 1) the role of spatial externalities brought about by physical proximity of other inventors in explaining new knowledge creation (i.e. patents); 2) the impact of new technology and location externalities on non-farm employment growth in the US Midwest; and 3) the influence of recreational amenities on non-farm employment growth in the US Midwest. In all three of the above instances the unit of observation is at the county level. The realization counties are clearly not independent units necessitates the use of spatial econometric methods. In chapter two are identified the variables which have significant impacts on new knowledge and technology creation as measured by patents and finds impressive evidence of spatial knowledge spillins. That is, the patenting behavior in close, neighboring proximity tends to have a positive impact on patenting activity in the home county. This is consistent with the hypothesis the exchange of ideas and thoughts by economic agents in physical contact, both in a formal and informal network, benefits from an interaction externality that is often omitted from empirical analysis. This is a particularly important result as it provides evidence for both the existence of such knowledge externalities but also the size and relative magnitude of these knowledge spillins. While few would doubt such externalities exist, there has been little empirical evidence supporting their existence. Additional factors having a strong positive effect on new knowledge creation were measures of human capital, per capita incomes, and previous patenting activity within the county. The estimated results were quite similar for different time periods analyzed and imply the size and relative magnitudes of many of the factors influencing new knowledge and technology are relatively constant over time.

Chapter three examines the role of local technology and knowledge embodied in patents on employment growth in the US Midwest over the period 1969-2000 in addition to two sub-periods within this time frame. Again a spatial model is used to capture the spatial externalities, i.e. economic and technology, existing between counties. The results from the empirical analysis overwhelmingly suggest that when patent counts within the county are used as an indicator for new knowledge and technology, then this variable has a strong positive impact on non-farm employment growth within the county. The spatial interaction term was also found to play an important positive role in explaining employment growth within the county implying spatial externalities play an important role in explaining employment growth. The results for both the direct technology parameter and the spatial parameter were quite similar for all periods studied. This has interesting implications for rural counties since a county should be better able to realize the economic spillovers via employment growth if neighboring counties are experiencing non-farm employment growth. Unfortunately there exists an alternative interpretation which suggests if neighboring counties are experiencing very little or even negative employment growth, this will have a negative impact on the home county.

The final chapter, four, builds on the conceptual model given in the preceding chapter and exploits the tradeoff relationship between wages and non-monetary amenity benefits. In this new model of employment growth is believed to be a function of recreational and natural amenities, wages, technology, and spatial interaction. The types of amenities given the greatest amount of attention in the empirical analysis are recreational amenities which tend to be largely land and wilderness intensive. The recreational amenity indicators used are created by condensing a much larger data set of recreational variables into single categories using principal component analysis. When empirically estimating the effects of these amenities on non-farm employment growth considered are the role of amenities in the home county in addition to the effect of these same amenities in surrounding counties. The time frame is from 1969-2000. The results tend to imply that recreational amenities in the surrounding county as well as the home county are important factors in explaining non-farm employment growth over this period. Realizing that there are limits in which recreational and natural amenities, can be developed, in no way is it argued or advocated that all rural counties and areas should or will grow in employment and output. Rather, a few will grow, and this research attempts to identify the necessary endowments, location-specific characteristics and initial conditions needed to spur employment growth. It may be misallocating and wasting public resources to attempt to reverse the trend in many declining rural counties that are do not have available recreational and natural amenities, too isolated, lack the necessary initial conditions to support future employment growth.

The research presented in this dissertation highlights some important aspects related to economic growth as applied to rural areas, and, in the case of technology, to economic growth in general. The theory and empirical estimation presented within are definitely not exhaustive on the topic of rural economic growth. On the contrary, the areas studied are but a subset. However, with the previous caveat stated, the analysis does draw some interesting conclusions related to economic growth in primarily rural areas. The topics discussed herein are those which are either in the foreground of the rural policy debate, as in the case of employment growth, spatial externalities, and amenities, or in the background as a generally unseen, pivotal force underlying economic growth as in the case of technology. With these areas of interest in mind, this research has been cautiously successful in developing both a theoretical framework and applying empirical techniques to better evaluate and understand economic behavior as applied to issues facing rural regions given the dependence of rural counties on economic forces and markets outside county boundaries.

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