Jiwattanakulpaisarn et al (2006) Highway Infrastructure Investment and Regional Employment Growth: A Dynamic Panel Regression Analysis, paper submitted to the 46th Congress of the European Regional Science Association (ERSA)

Highway Infrastructure Investment and Regional Employment Growth: A Dynamic Panel Regression Analysis

Piyapong Jiwattanakulpaisarn; Robert B. Noland; Daniel J. Graham; John W. Polak

Department of Civil and Environmental Engineering, Centre for Transport Studies, Imperial College London, London SW7 2AZ, United Kingdom

Abstract

As a measure of the economic development impact stemming from transport infrastructure, the employment impact of transport investment has been a subject of considerable interest within academic research and practitioner communities for decades. Yet, conflicting evidence has emerged in the literature, which generally relies on simple regression analysis and may suffer from several basic methodological problems. Focusing on the actual impacts after the construction phase, this paper empirically investigates whether and the extent to which investments in highways contribute to aggregate county-level employment in the private sector of the State of North Carolina, United States. Given the potential for unobserved regional heterogeneity and lagged responses of the labour market to any exogenous shock, we estimate dynamic panel models with the density of highway lane-miles representing the extent and coverage of the highway network as an independent variable, using panel data for all 100 North Carolina counties over the period 1985-1997. Estimation problems of endogeneity and weak instruments have been explicitly addressed by means of a system Generalized Method of Moments (GMM) estimator. Our main results are that the employment effect of highway infrastructure depends critically on the model specification considered, and it is essential to account for the dynamics of employment adjustment and potential endogeneity of highway infrastructure to avoid biases in the estimated effect of highways.

1. Introduction

A number of macro-level studies attempting to establish the statistical link between transport infrastructure investment and employment have applied econometric techniques to estimate the effect of transport infrastructure while controlling for the effects associated with other factors. Among several research questions that have been addressed in the previous literature is the impact of highway infrastructure investments on overall employment in the economy. Previous studies were conducted at various levels of aggregation, using a variety of modelling approaches. Four basic measures have been applied for measuring highway infrastructure. Some researchers use monetary units of highway capital stock, primarily based on the perpetual inventory technique, while others employ some physical measures of highway capital stock, such as length or density of highways. Many studies have been devoted to analysing the effect of highway infrastructure expenditures, while some have tested the hypothesis that the presence of major highways, represented by dummy variables, has implications for the location of employment.

Unfortunately, direct use of empirical findings from historic and recent studies, in shaping transport policy and supporting particular investment decisions, has been rather limited by mixed and inconclusive evidence in the literature. Many studies find that overall employment is positively and significantly related to the stock of highway infrastructure (Lombard et al, 1992; Dalenberg et al, 1998; Haughwout, 1999; Carlino and Mills, 1987; Clark and Murphy, 1996), government expenditures on highways (Crane et al, 1991; Jones, 1990; Carroll and Wasylenko, 1994; Islam, 2003; and Bollinger and Ihlanfeldt, 2003), and the availability of major highway access (Luce, 1994; and Boarnet, 1994). Recent evidence also shows that highway capital tends to reduce the demand for employment (Pereira, 2000), while public highway spending is also found to have a negative impact on overall job growth (Lombard et al, 1992; and Dalenberg and Partridge, 1995). In addition, insignificant evidence regarding the employment effect of highway infrastructure stock (Thompson et al, 1993; and Duffy-Deno, 1998) and highway expenditures (Eagle and Stephanedes, 1987; Stephanedes, 1990; Clark and Murphy, 1996) has also been reported.

Apart from the common differences among these studies in scope and methodology, another possible reason for the contradictory evidence is that much of the previous work has generally suffered from several methodological drawbacks. In many studies, for instance, several important determinants of employment growth are omitted, and the choices of control variables included in the estimated equations generally are not based on theory. Those studies based solely on cross-sectional data also typically do not account for unobserved regional heterogeneity that may explain spatial differences in employment changes. More importantly, the possibility that the causal relationship between transportation investment and employment growth could work in both directions is generally ignored.

The reverse causation may potentially arise in several ways. High-employment-growth economies could have a large tax base, and they can afford further development of transportation systems. Government policy might also be oriented towards additional investments in transport infrastructure for regions with concentrations of jobs and people in order to tackle congestion problems. In other cases, public policy with the objective of stimulating certain declining regions may involve increases in spending on transport infrastructure supply. Moreover, provision of transport infrastructure is likely to be a response to forecast demand for transportation services. That is, in the case of effective transportation planning, transport investment may be considered as the effect of employment growth.

This paper attempts to shed some light on this controversy by analysing the effect of highway investment on aggregate county-level employment in the State of North Carolina. In particular, we examine whether expansions of highway capacity contribute towards county employment growth. As it is important to consider that due to the complexity of economic systems highway infrastructure is only one of numerous factors contributing to changes in employment, we derive a reduced form model of equilibrium employment that considers the effects of highways and other potential factors on the supply and demand for labour. Given the potential for lagged responses of the labour market to any exogenous shock or disturbance, our empirical implementation is based on a simple dynamic panel specification for the employment model. A panel data set for 100 North Carolina counties from 1985 to 1997 is used in order to account for unobserved county and time specific effects. The density of highway lane-miles is employed to capture the extent and coverage of the highway network. We estimate several dynamic employment models using a Generalized Method of Moments (GMM) technique that allows us to control for the endogeneity of lagged employment as well as that of highway and some independent variables, which could bias the coefficients estimated. In addition to the dynamic panel estimation, static employment models are estimated by conventional panel regression methods for comparisons.

The remainder of this paper is organised as follows. The next section describes our theoretical framework. A theoretical foundation to establish the potential linkage between highway infrastructure investment and employment by distinguishing the effect on labour demand and supply is developed. This is followed by a simple theoretical model that serves as the basis of our empirical analysis. Section 3 describes econometric models and briefly discusses the GMM estimation techniques used to estimate the dynamic panel models. We then describe county-level data used for the analysis in Section 4. Estimation results from dynamic and static panel data models of employment are presented in Section 5. The final section summarises and concludes the paper.

2. Theoretical Framework

2.1 Underlying Mechanisms through which Transport Infrastructure Investment Affects Employment

Theoretically, it has been hypothesised that provision of transport infrastructure can generate employment opportunities throughout an economy. Apart from the direct economic impact on jobs generated from construction works of transportation projects that is generally thought to be a short-term nature, the potential long-term effects on employment resulting from the provision of transport infrastructure can be discussed within the framework of labour market theory. The basic principle of the theory maintains that the interaction between the demand for labour and the supply of labour determines the equilibrium level of wages and employment in the local labour market. The equilibrium state of the labour market would remain unchanged unless it is disturbed by any economic disturbance or shock to the market. As explicitly pointed out by Eberts and Stone (1992), public infrastructure investment can be thought of as a shock to the labour market. It could lead to the enhancement of a region's attractiveness, thereby affecting the decisions of firms and households in several ways. Therefore, if transport infrastructure investment leads to adjustments in labour demand and/or labour supply, the current equilibrium of the labor market will move toward a new position that subsequently results in changes in the levels of local wages and/or employment. The section contains a short discussion on the potential effects of transportation investment on the supply of and the demand for labour.

The supply side of the labour market can be influenced by transport infrastructure in two major ways. With a given population, improved access to jobs caused by investments in transportation can lead to adjustments in local labour supply in the short run through changes in the geographical size of the labour market and amount of labour force participation. Labour markets will tend to increase in geographical size because of a commuting response. As noted by SACTRA (1999), a reduction in commuting costs due to transport improvements would enable workers to increase the areas of job search and make longer journeys for a given amount of generalized costs. In certain cases, if improved transport services allow workers to commute across the jurisdictional boundary between two regions, the supply of the labour force available to firms will not be limited to the region in which commuting costs and times decline. Rather, the additional source of labour supply may come from the adjacent region. Moreover, the provision of transport facilities may also encourage people to participate in the labour force. Improved transport infrastructure can provide better access to employment opportunities. This will facilitate people in seeking a job that offers wages higher than or equal to their reservation wage.[1] Furthermore, as formally discussed in Borjas (1996), commuting costs could affect individuals' decisions on labour force supply on the grounds that commuting costs raise the reservation wage, which in turn lowers the probability of entering the labour force. Reduced travel time and costs associated with transportation improvements could thus remove this significant barrier to labour-market participation.[2]

In the long run, improved transport infrastructure, in certain circumstances, could cause the overall population base of a region to increase beyond what it would otherwise be by attracting in-migrations or halting out-migration. Good transportation services can directly serve as a household amenity. The provision of transport infrastructure in the region can also stimulate employment opportunities, which are bound to attract households. Therefore, it is possible that investments in transportation infrastructure could result in an increase in population size, all else being equal, which in turn increases the number of persons who will be available to supply labour to the market. The increase in population would be less significant if the provision of transportation facilities cause negative externalities (i.e. traffic and pollution) and/or raises housing prices, which may act as a disincentive for living in that region.[3,4] Indeed, improvements in transportation may put negative pressure on the supply side of the local labour market as urban economic theory suggests that a decline in transport costs in a central area could lead to the decentralization of population. Accordingly, the long-run effect on labour supply with respect to potential changes in the population base can be positive, negative, or neutral.

The effects of transport infrastructure investment on the demand side of the labour market are relatively more complicated. The additional provision of transport infrastructure can improve production technology. Better transportation systems increase the productivity of firms within a region primarily by facilitating the efficient movement of people and goods, providing lower costs of transporting inputs and outputs, and making the expansion of market areas more profitable.[5] Furthermore, overall productivity growth may arise because transport infrastructure investment can be directly responsible for augmenting the productivity of production inputs. Improvements in transportation services can have a direct impact on labour productivity by lowering commuting time spent getting to and from work (SACTRA, 1999; OECD, 2002).[6] As the result of the influences of transport improvements on the availability of the labour supply, an increase in labour productivity in the production process is probably due to a better match between the supply of jobs and skilled workers.

As additional investments in transport infrastructure can be considered as an increase in production technology and hence in total factor productivity, the theory of production

---

[1] A reservation wage represents the lowest wage that people are willing to supply their labour force. The economic theory of labour supply suggests that in principle people decide whether to work by comparing their reservation wage and the level of wages offered in the job market.

[2] Berechmann and Passwell (2001) provide empirical evidence indicating that a reduction in travel times and costs has led to an increase in the labour market participation for people in economically distressed areas.

[3] Many studies have found a positive relationship between transport infrastructure investment and the prices of land or housing (e.g. McDonald and Osuji, 1995; Haughwout, 1997; Boarnet and Chalermpong, 2001; Stethoff and Kockelman, 2002).

[4] Empirical evidence on the induced travel demand from transport investment has been provided in many econometric studies. See Noland (2001) for examples of recent estimates of induced travel effects at state level; Noland and Cowart (2000), Fulton et al (2000), Cervero and Hansen (2002) for county level estimates. Noland and Lem (2002) provide a comprehensive review of literature on this aspect.

[5] Empirical evidence on the positive link between the provision of transport infrastructure and labour productivity has emerged in the literature. Aschauer (1989) finds a positive correlation between the stock of highway capital and labour productivity by estimating national time-series data for the United States. Some regional studies also obtain similar results (e.g. Bergman and Sun (1996) for North Carolina counties; Fritsch and Prud'homme (1997) for French regions).

[6] For example, exhausted workers may be less productive if they have to spend more time commuting. An empirical study by Prud'homme and Lee (1999) find that average speed for journey-to-work trips in 23 cities in France is positively related to the productivity of labour.

suggests that this could lead to an upward shift of the production function. It is therefore possible for firms to employ a smaller quantity of labour inputs to produce a given volume of outputs. This implies that if market demand and hence output requirements remain unchanged, the quantity of labour demanded may decline. This is known as the substitution effect. However, a complementary effect may also exist because productivity growth due to transport improvements could lead to a rise in labour demand. In particular, affected firms may respond to the productivity gains in order to increase revenues and profit. For instance, firms may take advantage of a reduction in generalized transport costs and production costs to expand their markets, either through lowering price or through serving a larger market from which it was not previously profitable due to high shipping costs. As a result, the demand by such firms for employment will increase to meet the rise in output. The provision of transport infrastructure can enhance a region's productivity, which in turn induces more businesses to enter a region. Therefore, to the extent that transport investments induce a number of businesses into a region, this could simply lead to increases in the region's demand for labour.

Nevertheless, there is the possibility that improved transport infrastructure would tend to reduce the attractiveness of the region as a location for doing business. The provision of transportation facilities may induce more vehicle traffic, leading to congestion and environmental effects. In some cases, the prices of land and property in particular locations could increase in response to transport improvements. In addition, firms may have some incentives to locate outside the region with improved transportation. Decreases in transport costs of serving the local market may allow firms to be closer to markets in neighbouring regions where the prices of their products remain competitive in both markets. In other words, improved transport facilities would tend to encourage some firms in one region to move outwards to another region in order to gain spatial competitive advantages.[7] Thus, the relocation of firms away from the region will also have a direct and negative impact on the volume of businesses and hence employment.

2.2 A Simple Structural Model of the Labour Market

As previously mentioned, a basic weakness of several previous studies is that the regression models estimated are not formulated on any coherent theoretical basis. In particular, the choice of variables thought to be relevant to the level or change in employment in local and regional economies seems to be made in an ad-hoc fashion. In the present research, we draw upon standard economic theory in deriving a reduced-form employment model that accounts for the effects of highway infrastructure and other potential factors on the supply and demand for labour. This model is based on a simple structural model of labour market equilibrium as illustrated graphically in Figure 2-1.

[7] This spatial concern, based on the Hotelling (1929) model, is the so-called 'two-way road effect' in the literature. See SACTRA (1999) and Goodwin (2002) for detailed discussions.

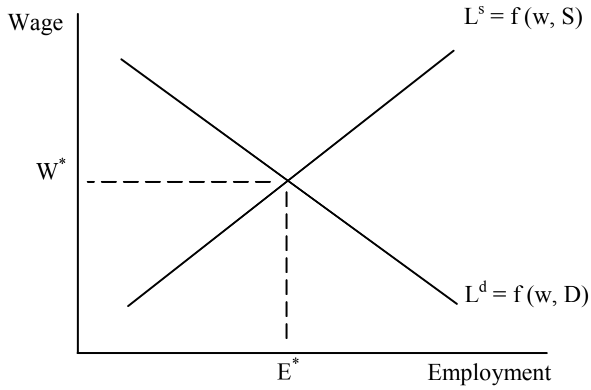

Figure 2-1: Equilibrium in the competitive labour market

The structural model consists of three equations, one each for aggregate labour demand, aggregate labour supply, and the equilibrium condition:

$$L^d = f(w, D),\ \partial L^d / \partial \mathrm{w} < 0 \qquad (2\text{-}1)$$
$$L^s = f(w, S),\ \partial L^s / \partial \mathrm{w} > 0 \qquad (2\text{-}2)$$
$$L^d = L^s \qquad (2\text{-}3)$$

where L^d and L^s denote the demand for labour and the supply of labour, w is the wage rate for labour. D and S represent the vectors of factors that determine the position of the demand curve and the supply curve, respectively. The slope of the demand curve is downward since an increase in wages can have (1) *a substitution effect* as firms might substitute other factor inputs for labour and (2) *an output effect* as a rise in production costs due to increased wages may increase the price of output, decreasing production and hence labour demand. The labour supply curve is upward-sloping with respect to the wage rate. This is because, for a given size of working-age population, higher wages generally have two distinct effects on work incentives. The first is to make individuals choose between working and not working, increasing the probability that they enter the labour market. The second is to encourage individuals to consume less leisure and increase the number of working hours. [8] The assumption of the labour market-clearing condition (2-3) yields the equilibrium level of wages and employment determined by the intersection of the labour supply and labour demand curves. Factors that shift either the aggregate demand curve or the aggregate supply curve affect both the equilibrium wage and employment levels in the labour market. The derivation of the reduced-form model of employment is shown below.

2.2.1 Aggregate Labour Demand Model

To derive the aggregate labour demand model, we begin by considering the production possibilities of a region as an aggregate production function:

$$Q = A\, f(K, L) \qquad (2\text{-}4)$$

where Q is aggregate output of the private sector, K is the stock of private capital services, and L is labour input. A denotes a technical efficiency parameter in a Hicks-neutral form. It is

[8] This inference is known as the substitution effect of a higher wage rate on labour supply. Yet, it is worth noting that an increase in the wage rate can also generate the income effect in the sense that higher wages could make individuals become wealthier and supply less labour. In particular, the conventional theory of labour supply suggests that there may be a backward-bending portion of the labour supply curve. However, in the context of the aggregate supply of labour, we assume that the substitution effect dominates.

specified to capture regional differences in productivity which we will discuss later. We assume that firms operating in a competitive market minimise the private production costs:

$$C = wL + rK \tag{2-5}$$

subject to the production (2-4). w and r are the exogenous prices of labour and capital services respectively. For a formal derivation of the labour demand function, it is necessary to specify a functional form for the aggregate production function (2-4). We assume for simplicity that each region produces output using capital and labour with the Cobb-Douglas production technology.

$$Q = AK^{\alpha} L^{\beta} \tag{2-6}$$

where α and β are parameters. Employing the usual Lagrange multiplier method and taking the logarithmic transformation, we obtain the labour demand equation in the following form:

$$\ln L^d = \delta_0 + \delta_1 \ln w + \delta_2 \ln r + \delta_3 \ln Q + \delta_4 \ln A \tag{2-7}$$

where $\delta_0 = a\gamma(\ln\beta - \ln\alpha)$, $\delta_1 = -a\gamma$, $\delta_2 = a\gamma$, $\delta_3 = \gamma$, $\delta_4 = -\gamma$, and $\gamma = 1/(\alpha + \beta)$. A final issue regarding the aggregate model of labour demand sketched above is the specification of the Hicks-neutral production function shifter (A). As discussed in Section 2.1, investments in transport infrastructure can be thought of as increases in the level of production technology, thereby enhancing the total factor productivity of firms. Following the studies by Carlino and Voith (1992), Lobo and Rantisi (1999), and Graham (2000), we also consider that regional variation in productivity may also depend on differences in several location-specific characteristics such as industry composition, government investments in local public services, labour force characteristics, and agglomeration economies and diseconomies. We therefore hypothesise that the production function shifter encompasses the effect of highway infrastructure (H) and other local characteristics (T) on productivity:

$$A = H^{\phi} \prod_i T_i^{\chi_i} \tag{2-8}$$

where i indexes the number of proxy variables for T. The aggregate labour demand model (2-7) can now be rewritten as:

$$\ln L^d = \delta_0 + \delta_1 \ln w + \delta_2 \ln r + \delta_3 \ln Q + \phi\delta_4 \ln H + \sum_i \chi_i \delta_4 \ln T_i \tag{2-9}$$

According to which the aggregate demand for labour is determined by the wage rate, the price of capital, the level of output, the availability of highway infrastructure, and other area-specific characteristics that affect productivity.

2.2.2 Aggregate Labour Supply Model

The theoretical model of the aggregate supply of labour is derived in a relatively simplified way. We briefly review the labour economics literature on labour supply in an attempt to identify major factors influencing the supply side of the aggregate labour market. We then simply postulate an aggregate model of labour supply that is capable of distinguishing the effects of highway infrastructure from those of other labour supply determinants.

Considering labour supply in aggregate generally requires attention to two aspects: the size of the working-age population in an economy and their labour supply decisions. All else being equal, population evolution, for example, due to births, deaths, and migration will alter the total size of the potential labour force. An immense literature in regional science and related disciplines on the determinants of population size exists.[9] Theoretically, it is assumed that the location decision of individuals or households is affected by a variety of factors influencing their utility. In particular, the relative attractiveness of a region has been suggested as depending upon several local attributes, for example, local taxes, other living costs, employment opportunities, availability of local public services (e.g. transportation access, health, education), climate, recreation opportunities, other aspects of the quality of life, and proximity to urbanized areas, among others.

Taking the size of the working-age population as given, the conventional theory of labour supply maintains that the quantity of labour supplied relates to individuals' labour supply decisions about whether to participate in the labour force and about how many hours to work. When making the decision whether to work or not to work, a person is concerned with his/her reservation wage, which is the minimum wage at which an individual is willing to accept an offer of employment. To the extent that the market wage is greater than the reservation wage, the person would be better off working. Individuals' decision on the supply of hours to provide is based on the income-leisure trade-off. In particular, they maximize utility by choosing among income-leisure opportunities, given a budget or income constraint. The literature has suggested several important determinants of labour supply decisions. As mentioned previously, the higher the wage rate, other things constant, the more people are willing to work and the greater the number of hours of work supplied. Factors other than the wage rate that alter the amount of labour supplied at a given level of population can potentially lead to shifts in the labour supply curve. For example, attention has been given to differences in non-labour income and preferences between leisure and income in explaining variations in labour supply. The availability of transfer payment income (i.e. public aid and social security benefits) is thought to discourage persons from labour market entry and job search. The relation between labour force participation and the extent of employment opportunities in the labour market has been the subject of considerable debate through two competing hypotheses: the added-worker hypothesis and the discouraged-worker hypothesis.[10]

Based on the above arguments together with the discussion on the potential effect of transport infrastructure on labour supply in Section 2.1, we assume the straightforward model of aggregate labour supply in the labour market using a log-linear form

$$\ln L^s = \gamma_0 + \gamma_1 \ln w + \gamma_2 \ln H + \sum_j \tau_j \ln S_j + \sum_k \rho_k \ln R_k + \sum_l \nu_l \ln D_l \qquad (2\text{-}10)$$

where L^s denotes the supply of labour, w represents the wage rate, H is a measure of highway infrastructure that can have impacts on job accessibility and the size of population, D is the

[9] For example, see Carlino and Mills (1987), Boarnet (1994), Luce (1994), Clark and Murphy (1996), Duffy-Deno (1998), Mark et al (2000), and Henry et al (1997; 1999; 2001).

[10] The former contends that unemployment of one household member may cause other household members to enter the labour force in order to maintain family income. In contrast, proponents of the latter hypothesis argue that some individuals may not be actively seeking employment during a high unemployment period because the probability of finding a satisfactory job is low.

vector of demographic variables capturing regional variations in the age structure of population, and *S* and *R* are the vectors of other location-specific factors that might affect individuals' labour supply decisions and residential location choice, respectively.

2.2.3 Reduced-Form Model of Employment

The reduced form model for the equilibrium employment level can be obtained by solving the aggregate models of labour demand (2-9) and labour supply (2-10) with the market clearing assumption ($L^d = L^s$). In doing this, we first equate (2-9) and (2-10), and rearrange terms to derive the reduced-form wage model

$$\ln W^* = \beta_0 + \beta_1 \ln r + \beta_2 \ln Q + \beta_3 \ln H + \sum_i \lambda_i \ln T_i + \sum_i \xi_i \ln S_i + \sum_k \psi_k \ln R_k + \sum_l \vartheta_l \ln D_l \qquad (2\text{-}11)$$

where all independent variables are as described previously. By substituting (2-11) into either (2-9) or (2-10), and rearranging terms, we can write the reduced-form model for the equilibrium level of employment (E^*) in the following form

$$\ln L^d \ or\ \ln L^s = \ln E^* = \alpha_0 + \alpha_1 \ln r + \alpha_2 \ln Q + \alpha_3 \ln H + \sum_i \varphi_i \ln T_i + \sum_j \zeta_j \ln S_j + \sum_k \mu_k \ln R_k + \sum_l \kappa_l \ln D_l \qquad (2\text{-}12)$$

This reduced-form employment model provides an initial theoretical underpinning for our empirical specifications presented in the next section.

3. Empirical Models and Econometric Methods

The principal focus of this research is on the effect of highway infrastructure investment on employment. The reduced-form model (2-12) allows one to examine the contemporaneous relationship between highway infrastructure and the equilibrium employment level, controlling for other factors that influence labour demand and labour supply. We can specify an empirical version for the linear reduced form model of the equilibrium employment level (2-12) taking the general form

$$\ln E_{it}^* = \alpha + \beta \ln H_{it} + \gamma' \ln Z_{it} + \mu_i + \tau_t + \varepsilon_{it} \qquad (3\text{-}1)$$

where *H* is a measure of highway infrastructure available, Z represents, for brevity, a vector of other determinants of labour demand and labour supply as previously discussed, ε is an i.i.d. error term, and *i* and *t* index regions and years respectively. Owing to difficulties of controlling for all relevant factors that could be important in explaining differences in employment across regions, we include the time-invariant region-specific component (μ) to account for unobserved or omitted heterogeneity across regions that does not vary over time (e.g. climate, topography, local land-use policy, geographical location, and initial technological differences) and the region-invariant time-specific component (τ) to account for any shocks to the labour market that are common to all regions but vary across time (e.g. the rate of technological change, business cycle effects, and fiscal policy of central government).

While specification (3-1) is static, it is essential to consider the potential for lagged responses of the labour market to any exogenous shock or disturbance when analysing the extent to which improvements in highway infrastructure affect employment. That is, employment may not adjust instantaneously and/or fully towards its equilibrium or desired level during a single year. Rather, it is plausible to suppose that the adjustment process exhibits considerable time lags. This could be the case for several reasons. As the labour economics literature commonly emphasises, slow adjustment of employment may be due to the fact that firms usually incur non-recurring fixed costs associated with either upward or downward adjustments to their desired workforce size, for example, hiring, training and firing costs. Due to relocation costs, input factors (e.g. labour and capital) may not be freely mobile across regions in the short run. In addition to the adjustment costs, imperfect information on changed circumstances also contributes to lags. Accordingly, assuming a correspondence between the observed level of employment and the equilibrium level of employment is unrealistic.[11]

To account for this issue, we consider a simple dynamic specification for our employment equation of the form

$$\ln E_{it} = \alpha + \delta \ln E_{it-1} + \beta_0 \ln H_{it} + \beta_1 \ln H_{it-1} + \theta' \ln Z_{it} + \sigma' \ln Z_{it-1} + \mu_i + \tau_t + \varepsilon_{it} \qquad (3\text{-}2)$$

This dynamic panel equation, which is called an autoregressive distributed lag (ARDL) model, explicitly takes into account dynamic responses of employment to changes in highway infrastructure and other factors. The inclusion of the lagged level of employment also allows for potential persistence in the process of adjustment towards an equilibrium, which is reflected by the parameter δ. Regarding the employment effect of highway investments, specification (3-2) shows that the current availability of highways could affect the *current* and *future* levels of employment. The coefficient on the highway variable for the contemporaneous period (β_0) measures the short-run effect of highways on employment, while the long run effect can be calculated as $(\beta_0 + \beta_1)/(1 - \delta)$.

In estimating dynamic panel regression models, it is well known that the presence of the lagged dependent variable induces substantial complications. The ordinary least squares (OLS) estimator produces biased and inconsistent estimates because of the correlation between the lagged dependent variable and time-invariant individual specific effects, which are ignored, in the disturbance term. In the case of dynamic panel models with fixed effects, the within-group or least-squares dummy variables (LSDV) estimator is problematic because of the correlation between the demeaned lagged dependent variable and the demeaned error term unless the time dimension of the panel is large. The correlation between the lagged dependent variable and the compound disturbance also renders the random effects estimator biased and inconsistent.[12]

There have been a variety of dynamic panel estimators developed in the literature. A general approach to deal with the endogeneity of the lagged dependent variable in dynamic panel

---

[11] Some empirical evidence suggests that population and employment only gradually adjust towards equilibrium (e.g. Carlino and Mills, 1987; Clark and Murphy, 1996; and Duffy-Deno, 1998). In addition, Evans (1990), in a survey of research evidence on the role of interregional differences in migration, concludes that regional economies are not in equilibrium.

[12] See Hsiao (2003; chapter 4) and Baltagi (2005; pp. 135-136) for comprehensive discussion on estimations issues of dynamic panel data models

models is to remove the individual-specific effects by the first difference transformation, and then employ instrumental variables for the lagged dependent variable in the first differenced equation to purge the constructed correlation between the transformed lagged dependent variable and the transformed disturbance term. Consider a simple dynamic panel model below

$$y_{it} = \alpha\, y_{it-1} + \omega' x_{it} + \mu_i + \varepsilon_{it} \qquad (3\text{-}3)$$

By taking first differences to eliminate the individual-specific effects from equation (3-3), we obtain

$$y_{it} - y_{it-1} = \zeta\,(y_{it-1} - y_{it-2}) + \omega'(x_{it} - x_{it-1}) + \varepsilon_{it} - \varepsilon_{it-1} \qquad (3\text{-}4)$$

As the model in first differences is still complicated by the correlation between the lagged dependent variable y_{it-1} - y_{it-2} and the disturbance ε_{it} - ε_{it-1}, Anderson and Hsiao (1981) suggest using either y_{it-2} or y_{it-2} - y_{it-3} as instruments for y_{it-1} - y_{it-2} in a two-stage least squares (2SLS) framework. This instrumental variable (IV) estimation approach yields consistent estimates but is inefficient because it does not use all the available moment conditions (for example, see Arellano and Bond, 1991).

Our empirical analysis relies on the Generalized Method of Moments (GMM) techniques for dynamic panel estimation suggested by Arellano and Bond (1991) as well as Arellano and Bover (1995) and Blundell and Bond (1998). A key feature of the GMM framework, which has increasingly been applied in dynamic panel analysis, is that it exploits the panel structure of the data to employ all available instruments that satisfy a larger set of relevant moment conditions, and applies the GMM methodology to obtain consistent estimates. Furthermore, estimating a dynamic panel data model in the GMM framework allows us to relax the restrictive assumption of x_{it} being strictly exogenous.

Arellano and Bond (1991) building upon the IV estimation suggested by Anderson and Hsiao (1981) propose applying a GMM estimator to a dynamic panel regression in first differences. It involves eliminating the individual effects by first differencing and using all possible lags of y_{it} in time period *t-2* and earlier (y_{it-2}, y_{it-3}, y_{it-4},…,y_{i1}) as instruments. The same strategy is applied to form instruments for the generic x_{it} variable that is allowed to be endogenous in the sense that x_{it} is correlated with contemporaneous and earlier shocks, $E(x_{it}\varepsilon_{is}) \neq 0$ for $t \geq s$. If the variable is assumed to be predetermined in the sense that x_{it} is correlated with earlier shocks only, $E(x_{it}\varepsilon_{is}) \neq 0$ for $t > s$, Arellano and Bond suggest using the values of x_{it} lagged one or more periods as instruments. Hence, treating the variables x_{it} as endogenous exploits the moment conditions $E(x_{it-s}\Delta\varepsilon_{it}) = 0$ for $s \geq 2$ and $E(y_{it-s}\Delta\varepsilon_{it}) = 0$ for $s \geq 2$.

However, the Arellano and Bond estimator, which is the so-called first-differenced GMM estimator, may suffer from a weak instruments problem when series are highly persistent (e.g. close to random walk processes) or the variance of the individual specific effects (μ_i) is relatively large compared to that of the transitory shocks (ε_{it}) (Blundell and Bond, 1998). In such a case, only weak correlation may exist between the lagged levels of the series and their subsequent first differences, implying that the available instruments used in the GMM estimator in first differences are less informative. Using Monte Carlo simulations, Blundell and Bond (1998) demonstrate that weak instruments can result in large finite-sample biases when using the first-difference GMM procedure to estimate autoregressive models for moderately persistent series from moderately short panels.

The "system GMM" estimator subsequently developed by Arellano and Bover (1995) and Blundell and Bond (1998) is preferable to the first-differenced GMM estimator when estimating dynamic models with persistent panel data. Providing that $E(\Delta y_{it}\mu_i) = 0$ and $E(\Delta x_{it}\mu_i) = 0$, lagged first differences of the variables (y_{it} and x_{it}) can be used as instruments in the levels equations, in addition to the instruments that are available after first-differencing. That is, for example, Δy_{it-1} is valid to be an instrument for y_{it-1} in levels equations like (3-3). This exploits additional moment conditions for equations in levels, $E(\Delta y_{it-1}(\mu_i+\varepsilon_{it})) = 0$ for $t \geq 3$, that are combined with the moment conditions for equations in first differences exploited in the first-differenced GMM estimator. The system GMM thus estimates regressions in differences and regressions in levels simultaneously. Blundell and Bond (1998, 2000) show that the use of the system GMM estimator provides dramatic gains in efficiency and reduces the biases of the GMM estimator in first differences if the series is short in time and highly autoregressive.

To assess the validity of instruments adopted in GMM estimations, we need to perform specification tests for autocorrelation and overidentified restrictions. The consistency of a GMM estimator depends crucially on the assumption of absence of serial correlation. If the errors are not serially correlated in levels, there should be no evidence of second order autocorrelation in differenced residuals. For the GMM estimator in first differences, for instance, the presence of second order autocorrelation implies that y_{it-2} is an invalid instrument as it is correlated with ε_{it-2} in the differenced error term (but y_{it} lagged three periods and earlier may be a valid instrument).[13] Arellano and Bond (1991) derive a test for autocorrelation of order *m* in the first differenced errors. Failure to reject the null hypothesis of no second order serial correlation gives support to the model. Alternatively, the test for overidentified restrictions can help to verify the overall validity of the instruments. This is done by examining the set of instruments and the need to satisfy the orthogonality conditions. If the test fails to reject the null hypothesis of no correlation between instruments and the error, we can reasonably conclude that the instruments used in the GMM estimator are valid.

4. Data and Variable Description

The data consist of annual observations from 1985 through 1997 for all 100 counties of the State of North Carolina. Table 4-1 lists the definitions and sources of all variables. Most data are available for the entire period of our analysis except for data from the US Bureau of the Census, which have usually been available every 10 years. Interpolation is performed to obtain data for non-census years.

[13] Similarly, Δy_{it-1} is not a valid instrument for y_{it-1} in levels equations when using the system GMM estimator.

Table 4-1: Description of variables and data sources

Variables	Definition	Years of data	Data Sources
Employment	Aggregate private sector employment by place of work	1985-1997	Regional Economic Information System (REIS), U.S. Bureau of Economic Analysis (BEA)
Highway Density	Lane-miles of highways per square miles of county area	1985-1997	U.S. Energy and Environmental Analysis (EEA)
Output	Gross county product in the overall private sector	1985-1997	The Department of Commerce, U.S. Bureau of Economic Analysis (BEA). See text for the methodology applied to estimate gross county product.
Property Tax	Effective property tax rates (the total property tax levy for all jurisdictions in the county as a percentage of the total property valuation)	1985-1997	North Carolina Department of Revenue
Human Services expenditure	Per capita public expenditures for human services such as health, mental health, legal aid, subsidies paid to hospitals, social service administration, and assistance programs	1985-1997	North Carolina Department of State Treasure
Public Safety Expenditure	Per capita public expenditures for public safety such as police and communications, emergency communications, emergency management, fire, inspectors, rescue units, animal control	1985-1997	North Carolina Department of State Treasure
Cultural and Recreation Expenditure	Per capita public expenditures on recreation, parks, coliseums, museums, libraries, and any other culture and recreation projects	1985-1997	North Carolina Department of State Treasure
Education Expenditure	Per capita public expenditures on capital outlay and current operations for public schools and community colleges	1985-1997	North Carolina Department of State Treasure
Environmental Protection Expenditure	Per capita public expenditures for garbage and landfills, drainage and watersheds, cemeteries, and other environmental protection projects	1985-1997	North Carolina Department of State Treasure
Transportation and Public Utility Expenditure	Per capita public expenditures on public utilities (e.g. water and sewer services, electric power, and national gas) and for improvements to streets, parking facilities, airports, mass transit, and other transportation	1985-1997	North Carolina Department of State Treasure
Unemployment	County annual unemployment rates	1985-1997	U.S. Bureau of Labour Statistics
High School	The percentage of the population over 25 years of age who are high school graduates	1980, 1990, 2000	U.S. Census Bureau
College	The percentage of the population over 25 years of age who are college graduates	1980, 1990, 2000	U.S. Census Bureau
Under 18	The percentage of the population that is under 18 years old	1980, 1990, 2000	U.S. Census Bureau
Over 65	The percentage of the population that is over 65 years old	1980, 1990, 2000	U.S. Census Bureau
Public Aid	The percentage of the county population who receive public aid assistance	1985-1997	North Carolina Department of Health and Human Services
Social Security	The percentage of the county population who receive social security benefits	1985-1997	North Carolina Department of Health and Human Services
Urban	1 if a county is a central county of a metropolitan statistical area (MSA), 0 otherwise	1983, 1990, 1993	U.S. Census Bureau
Suburban	1 if a county is an outlying county of a metropolitan statistical area (MSA), 0 otherwise	1983, 1990, 1993	U.S. Census Bureau
Adjacent to Urban	1 if a county is a rural county bordering central county, 0 otherwise	1983, 1990, 1993	U.S. Census Bureau
Adjacent to Suburban	1 if a county is a rural county bordering outlying county, 0 otherwise	1983, 1990, 1993	U.S. Census Bureau

County-level employment data come from the Regional Economic Information System (REIS) compiled by the Department of Commerce, U.S. Bureau of Economic Analysis (BEA). These data measure employment by place of work for the entire private sector. This enables us to analyse the effect of highway investments on private sector employment in aggregate.

The density of highway lane-miles is proposed to capture the availability of highway infrastructure within each county. Lane-mile data for all counties are from Fulton et al (2000). The data were compiled by Energy and Environmental Analysis, Inc. (EEA) for the US Environmental Protection Agency (EPA) and contain the lane-miles of all interstate highways, all state highways, many other primary roads, and some secondary roads. A number of studies to date have empirically investigated the linkage between county employment and the density of highways (e.g. Carlino and Mills, 1987; Lombard et al, 1992; Clark and Murphy, 1996; and Duffy-Deno, 1998). In most of these studies, however, highway density is measured in terms of the total length of highways per unit area of the region. Unfortunately, that highway measure is not capable of accounting for regional differences in area-wide roadway capacity (e.g. the number of lanes associated with highways). The use of highway lane-mile density in the present study is far more desirable in capturing the extent and coverage of the highway network.

In order that the employment impact associated with highway infrastructure can be statistically distinguished, the theoretical model derived suggests that we also require data and proxy variables for the level of output, the price of capital, the age structure of population, and other county characteristics that may affect productivity, individuals' labour supply decisions, and the location decisions of households. Each of these independent variables will be discussed in turn.

County-level data for output are generally unavailable. However, we follow the methodology applied by Boarnet (1995 and 1998) in estimating gross county product using readily available data.[14] In this regard, gross state product in North Carolina in each year is apportioned to counties based on each county's share of total state personal income in that year.

$$Gross\ county\ product_{c,t} = \frac{County\ personal\ income_{c,t}}{State\ personal\ income_{c,t}} \times Gross\ state\ product_{t} \qquad (4\text{-}1)$$

where *c* and *t* index counties and years respectively. We obtain data for North Carolina gross state product in private industries and total state personal income from the Department of Commerce, U.S. Bureau of Economic Analysis (BEA). Data for total personal income for each county are taken from the same source.

No measure of the price of private capital can be included in the empirical models because the data are unavailable. Yet, we assume that significant variations in the net price of capital are less likely to be observed within the state. Rather, the after-tax price (or gross price) of capital should vary among counties by differences in local property tax rates. Therefore, the effective rate of property taxes, based on data from the North Carolina Department of State Revenue, is employed to measure variations in the price of capital across counties.

No *a priori* expected signs can be given to the property tax variable, however. This is due to the potentially conflicting effects of taxes on employment. For example, property tax burdens on firms may deter growth in labour demand. One reason for this is straightforward. An increase in property tax rates may be seen as an investment disincentive because they raise business costs. This could in turn retard expansion of firms and discourage new establishments. With regard to the supply side of the labour market, one may also expect that high local property taxes borne by residents is a deterrent to the location of households and hence growth in labour supply. However, property taxes can also have a positive effect. As a proxy for the price of capital incurred by firms, property taxes can have an input mix effect. That is, private production in counties with a relatively high property tax may be more labour

[14] According to Boarnet (1995; Appendix A), this technique is originally used by the Southern California Association of Governments (SCAG) to apportion state gross product to their member counties.

intensive in producing a given level of output because affected firms might substitute labour for other inputs that are subject to high property taxes. In addition, higher property taxes paid by local residents and firms may be fully capitalized into lower property prices and values, presumably attracting private investment and in-migration of households. Accordingly, we are uncertain about the expected relationship between property tax rates and county employment.

The role of local government expenditures on public services in determining local economic growth has been well documented in the literature.[15] Higher public expenditures could reduce firms' production costs through providing or improving public services that would otherwise need to be purchased by firms and enhancing the productivity of certain production inputs. In addition, to the extent that government spending on local public services maintains and improves residential amenity and the quality of life, households may be more attracted to counties with relatively high public expenditures. Based on data from the North Carolina Department of State Treasurer, six variables for real public expenditures on several categories of public services (i.e. education, health and human services, cultural and recreation, public safety, transportation and public utility, and environmental protection) are thus included to control for county-to-county differences in productivity and locational attractiveness as a place of residence. We express all expenditure variables as percentages of population and posit that these variables are positively related to county employment.

To a large extent, spatial variation in productivity from county to county may be partly due to differences in human capital characteristics. In particular, the education level of population can be an indicator of the quality of the labour force, directly affecting the inherent productivity of human resources. We thus use the percentage of adult population who are high school graduates and the percentage of adult population who are college graduates to control for regional differences in the human capital of the labour force. These data are obtained from the *Census of Population* (U.S. Bureau of the Census) for 1980, 1990, and 2000; and interpolation is performed to obtain data for non-census years. We expect that each of these educational attainment variables and employment is positively related.

In addition to the above variables, five other variables are included to capture other locational attributes that can influence the local supply of labour. We include the percentage of the population under 18 years of age and the percentage of the population over 65 years of age, which are available from the *Census of Population*, U.S. Bureau of the Census, to control for the age structure of the population. The expected signs of these two variables are negative as they partly represent the non-working age population. To control for the negative effect of the availability of direct income transfers for labour force participation rates and hence labour supply, we include the percentage of the county population who receive public aid payments or who receive social security benefits using data obtained from the North Carolina Department of Health and Human Services. The availability of data on unemployment rates from the US Bureau of Labour Statistics also enables us to capture the possibility that high unemployment may affect labour force participation by increasing either discouraged workers or additional workers.

Finally, four dummy variables for (i) central city counties within metropolitan areas, (ii) metropolitan suburban counties, (iii) rural counties that border central city counties, and (iv) rural counties that border suburban counties are included to account for any unspecified

[15] See for example Helms (1985), Wasylenko and McGuire (1985), Quan and Beck (1987), Fox and Murray (1990), Modifi and Stone (1990), Carroll and Wasylenko (1994), and Dalenberg and Partridge (1995)

county characteristics that vary among urban and rural counties within the state.[16] These dummy variables are expected to capture systematic differences in amenities and local circumstances with respect to urbanization status, for example, agglomeration economies; congestion and environmental quality; costs of living, land use regulations; diffusion of economic benefits from urbanised areas to their neighbouring communities; and the exploitation of resources in less developed areas adjacent to metropolitan regions.

5. Estimation Results

5.1 Estimation of the dynamic employment model

Table 5-1 presents results from several alternative specifications for the dynamic panel employment model based on equation (3-2) using the pooled sample of 100 North Carolina counties. In columns 1 and 2, we report, respectively, OLS and LSDV estimates of the employment model in levels. Although both estimators are biased and inconsistent, it is useful as a comparison to GMM estimates. Due to the presence of the lagged dependent variable in a dynamic panel model, the OLS estimator tends to bias the coefficient of the lagged dependent variable upwards, while the LSDV estimator produces a downwards-biased estimate of the autoregressive coefficient (e.g. Arellano and Bond, 1991; Hsiao, 2003). Thus, one may expect the OLS and LSDV estimates to form an approximate upper and lower bound, respectively, for the true parameter of the lagged dependent variable. In addition to the specification tests, we therefore use this knowledge on the direction of the bias in the OLS and LSDV estimates to evaluate the performance of the GMM estimators, from which the results are presented in columns 3 to 6.[17]

Column 3 presents parameter estimates using the first differenced GMM estimator, assuming that all regressors except the lagged level of employment are strictly exogenous. An application of the Hansen's J test of overidentifying restrictions provides evidence that the instruments used are valid, and the test for serial correlation suggests that we cannot reject the null hypothesis of no second-order serial correlation in the first differenced residuals, implying no misspecification. Most explanatory variables expected to influence county employment in the private sector are not statistically significant from zero. Exceptions are coefficients for the level of output and unemployment rate, which are significant with expected signs. The statistical significance of the lagged employment variable indicates the presence of adjustment processes towards equilibrium in the North Carolina labour market. However, the first order autoregressive coefficient is much smaller than the lower bound provided by the LSDV estimator. Although this downward bias in the coefficient of the lagged employment variable could be a sign of the weak instruments problem due to persistent series (e.g. Blundell and Bond, 1998 and 2000), the comparison between the LSDV estimate and the GMM estimate in this case is likely to be concealed by possible endogeneity of highway and some other control variables.

[16] Rural counties not adjacent to metropolitan areas are the base case.

[17] The results reported are for one-step GMM estimators, which are consistent with possible heteroscedasticity. For inference on the coefficients, one-step GMM estimates have been considered to be more reliable than GMM estimates in the two-step version (see Arellano and Bond, 1991; Blundell and Bond, 1998, 2000).

Table 5-1: Estimation results for the dynamic models of employment

Dependent variable: Employment	(1) OLS	(2) LSDV	(3) Differenced GMM (with strictly exogenous explanatory variables)	(4) Differenced GMM (with endogenous explanatory variables)	(5) System GMM (with strictly exogenous explanatory variables)	(6) System GMM (with endogenous explanatory variables)
Employment (-1)	0.987*** (207.59)	0.782*** (29.71)	0.427** (2.37)	0.697*** (21.41)	0.996*** (25.72)	0.986*** (160.24)
Highway Density	- 0.002 (-0.07)	- 0.035 (-1.07)	- 0.067 (-1.26)	- 0.022 (-0.57)	0.235** (2.02)	0.005 (0.16)
Highway Density (-1)	0.003 (0.10)	0.020 (0.58)	- 0.100 (-0.74)	0.017 (0.47)	- 0.244** (-2.08)	- 0.005 (-0.14)
Output	0.277*** (5.14)	0.271*** (4.58)	0.210** (2.33)	0.227*** (3.39)	0.234 (1.27)	0.232*** (3.39)
Output (-1)	- 0.266*** (-4.93)	- 0.136** (-2.31)	0.253 (1.21)	- 0.037 (-0.54)	- 0.237 (-1.46)	- 0.220*** (-3.17)
Property Tax	- 0.007 (-1.02)	- 0.006 (-0.89)	- 0.014 (-0.48)	- 0.003 (-0.44)	- 0.011 (-0.97)	- 0.007 (-1.05)
Property Tax (-1)	0.005 (0.79)	0.005 (0.61)	- 0.018 (-0.29)	0.007 (0.78)	- 0.007 (-0.20)	0.003 (-0.44)
Human Services Expenditure	0.0002 (0.05)	0.002 (0.39)	0.002 (0.26)	0.005 (0.96)	0.005 (0.30)	0.001 (0.11)
Human Service Expenditure (-1)	0.001 (0.23)	0.002 (0.51)	0.019 (0.53)	0.0002 (0.04)	- 0.005 (-0.16)	0.001 (0.16)
Public Safety Expenditure	0.007 (1.26)	0.005 (0.94)	- 0.005 (-0.50)	0.005 (0.66)	0.017 (0.88)	0.012* (1.95)
Public Safety Expenditure (-1)	- 0.003 (-0.50)	0.0003 (0.06)	- 0.027 (-0.74)	- 0.003 (-0.59)	- 0.019 (-0.71)	- 0.007 (-1.22)
Cultural and Recreation Expenditure	- 0.001 (-1.12)	- 0.001 (-0.93)	- 0.001 (-0.75)	- 0.001* (-1.76)	0.001 (0.46)	- 0.002** (-2.07)
Cult and Recreation Expenditure (-1)	0.001 (1.09)	0.001 (0.86)	0.004 (0.66)	0.001 (0.94)	- 0.003 (-0.50)	0.001* (1.76)
Education Expenditure	0.002 (1.61)	0.002 (1.05)	0.016 (1.10)	0.003 (1.42)	0.003 (1.64)	0.003 (1.07)
Education Expenditure (-1)	0.001 (0.67)	0.001 (0.84)	0.018 (1.08)	0.001 (0.33)	0.010 (1.06)	0.001 (0.45)
Environmental Protection Expenditure	0.0004 (0.47)	0.001 (0.53)	0.001 (0.56)	0.001 (0.68)	0.001 (0.71)	0.001 (0.65)
Environmental Protection Expenditure (-1)	0.00001 (-0.01)	- 0.0003 (-0.45)	0.003 (0.67)	- 0.0002 (-0.45)	- 0.004 (-0.83)	0.0002 (0.48)
Transportation and Public Utility Expenditure	0.0001 (0.48)	0.0002 (0.75)	0.001 (1.35)	0.00001 (0.02)	- 0.0001 (-0.06)	- 0.0002 (-0.62)
Transportation and Public Utility Expenditure (-1)	- 0.0004 (-1.31)	- 0.0003 (-1.02)	0.002 (0.96)	- 0.00003 (-0.10)	0.0003 (0.17)	- 0.0001 (-0.32)
Unemployment	- 0.048*** (-7.22)	- 0.066*** (-9.55)	- 0.059*** (-4.71)	- 0.068** (-8.47)	- 0.030 (-1.41)	- 0.050*** (-6.78)
Unemployment (-1)	0.043*** (6.53)	0.011* (1.77)	0.030 (0.50)	0.002 (0.31)	0.019 (0.95)	0.040*** (5.51)

Table 5-1: Estimation results for the dynamic models of employment (cont'd)

Dependent variable: Employment	(1) OLS	(2) LSDV	(3) Differenced GMM (with strictly exogenous explanatory variables)	(4) Differenced GMM (with endogenous explanatory variables)	(5) System GMM (with strictly exogenous explanatory variables)	(6) System GMM (with endogenous explanatory variables)
High School	0.236 (1.09)	0.486* (1.81)	- 2.362 (-0.93)	0.318 (0.81)	- 0.854 (-0.40)	0.443* (1.93)
High School (-1)	- 0.202 (-0.95)	- 0.526* (-1.95)	2.334 (0.85)	- 0.395 (-1.00)	0.892 (0.43)	- 0.340* (-1.75)
College	0.020 (0.19)	- 0.269** (-2.00)	1.039 (0.75)	- 0.275* (-1.71)	0.334 (0.46)	- 0.003 (-0.03)
College (-1)	- 0.020 (-0.19)	0.330** (2.39)	- 1.035 (-0.69)	0.362** (2.25)	- 0.351 (-0.48)	0.002 (0.02)
Under 18	- 0.320** (-2.08)	- 0.503** (-2.59)	- 0.382 (-0.28)	- 0.252 (-0.85)	0.549 (0.51)	- 0.434** (-2.58)
Under 18 (-1)	0.314** (1.97)	0.454** (2.17)	0.256 (0.16)	0.085 (-0.27)	- 0.632 (-0.56)	0.428** (2.41)
Over 65	- 0.250** (-2.45)	0.175 (1.14)	1.871 (0.98)	0.259 (1.21)	0.020 (0.02)	- 0.239* (-1.91)
Over 65 (-1)	0.210** (2.16)	- 0.070 (-0.45)	- 1.870 (-0.95)	- 0.212 (-0.92)	- 0.108 (-0.10)	0.198 (1.62)
Public Aid	- 0.038*** (-2.66)	- 0.025* (-1.83)	- 0.018 (-0.38)	- 0.012 (-0.65)	- 0.127** (-2.02)	- 0.036** (-2.03)
Public Aid (-1)	0.034** (2.40)	0.017 (1.28)	- 0.002 (-0.02)	- 0.0001 (-0.00)	0.134 (1.94)	0.034* (1.85)
Social Security	0.004 (0.13)	- 0.024 (-0.70)	0.040 (0.51)	0.002 (0.06)	- 0.101 (-1.06)	0.005 (0.14)
Social Security (-1)	0.014 (0.44)	- 0.024 (-0.74)	- 0.108 (-0.77)	- 0.024 (-0.93)	0.162 (1.47)	0.014 (0.43)
Urban	- 0.007* (-1.96)	- 0.010 (-1.30)	- 0.015 (-0.93)	- 0.002 (-0.18)	- 0.004 (-0.35)	- 0.006* (-1.66)
Suburban	- 0.005 (-1.47)	0.006 (0.68)	0.002 (0.11)	0.005 (0.40)	0.004 (0.31)	- 0.005 (-1.27)
Adjacent to Urban	- 0.004* (-1.66)	- 0.004 (-0.76)	- 0.016 (-1.41)	- 0.008 (-1.10)	0.001 (0.16)	- 0.004 (-1.56)
Adjacent to Suburban	- 0.007** (-2.26)	- 0.005 (-0.63)	- 0.014 (-0.73)	- 0.012 (-1.04)	- 0.008 (-1.51)	- 0.006 (-1.47)
Observations	1200	1200	1100	1100	1200	1200
Hansen Test of over-identifying restrictions (p-value)	-	-	0.255	1.000	0.336	1.000
Second order serial correlation (p-value)	-	-	0.209	0.098	0.117	0.213

Notes

1) Year specific constants are omitted for brevity. In all specifications, the Wald statistics suggest that we can reject the null hypothesis that all the coefficients of year dummies are zero.
2) Numbers in parentheses below the coefficients are t-statistics, which are heteroscedasticity consistent. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.
3) In columns 3 to 6, we report the GMM estimates from the xtabond2 module for dynamic panel data models in *STATA*. For GMM estimations in differenced equations, we do not use any lagged value of endogenous regressors dated further back than t-7 as instruments because of the limited size of the instrument matrix in *STATA*. However, this approach helps us to avoid potential overfitting biases due to the use of too many instruments.
4) The Hansen test of over-identifying restrictions is asymptotically distributed as χ^2 under the null hypothesis of instrument validity.
5) The Arellano and Bond test for first- and second-order autocorrelation of residuals is distributed as N(0,1).

There is the possibility that potential endogeneity of the density of highway lane-miles, government expenditures for public services, output, unemployment rate, and the proportion of adult population who are high school or college graduates could influence the estimation results. As discussed in Section 1, the two-way causation of the relationship between transportation investment and employment growth implies that provision of highway infrastructure could be endogenous to the economy. Similarly, economic activity could also influence fiscal policy on public services (e.g. high-economic-growth economies could have a large tax base, and they can afford to provide more and better schools, hospitals, and public parks, etc.). Treating the level of output as being exogenous is clearly unrealistic since employment and output are simultaneously determined. The typically inverse correlation between unemployment and employment does not imply causality. Finally, counties with greater opportunities for jobs and income could attract more workers with a high educational qualification.[18]

The results using the first-differenced GMM estimator that allows such variables to be endogenous are presented in Column 4. Despite taking into account the potential endogeneity, the coefficient of the lagged employment variable, though being higher than that reported in Column 3, is still lower than the corresponding LSDV estimate. Moreover, the test for second order serial correlation indicates misspecification. Most of the remaining coefficients are basically unchanged, with the exception of the proportion of the adult population who are college graduates and per capita expenditures on cultural and recreation projects. Yet, the estimated coefficients of both have unexpected signs. In addition, the test statistic for the null of no second order autocorrelation suggests that the estimates are inconsistent.

These results raise concerns regarding the problem of weak instruments when using the standard GMM estimator in first differences with persistent series. Column 1 has shown that employment is highly persistent since the OLS estimate for the autoregressive parameter is positively significant and close to unity. The strong persistence of panel data used in this analysis is likely to result in the poor performance of the first differenced GMM estimator. The specification test also indicates that the instruments used by the differenced estimator are invalid. Therefore, the system GMM framework, which exploits additional moment conditions, is more appropriate in our context. The coefficients estimated from the system GMM estimator are presented in columns 5 and 6.

The use of the system GMM estimator, although under the assumption that all explanatory variables are strictly exogenous, provides evidence that lend support to the work by Blundell and Bond (1998 and 2000) who suggest that due to weak instruments one can expect first-differenced GMM estimates to be biased in the direction of the LSDV. As reported in column 5, the system GMM estimate of the first-order autoregressive coefficient (0.996) is considerably higher than the differenced GMM results (0.427 and 0.697). However, the coefficient falls outside of the lower-upper bound (0.782-0.987). We suspect that this is partly reflecting the influence of exogeneity restrictions on the regressors. Also changed is the significance of the coefficient estimates for the remaining variables. Whereas the results are consistent with the notion that the availability of direct income transfers negatively affect the labour market (i.e. a negative and significant coefficient on the proportion of the population that receive public aid assistance), the failure of output and unemployment rate to influence aggregate private employment in this specification is counter to theoretical expectations.

[18] This concern relates to a prominent argument in a substantial body of empirical research on the location determinants of employment and population, for example see Carlino and Mills (1987), Boarnet (1994), Henry et al (2001). The basic premise of this literature is that the location decisions of firms and households are simultaneous. In this case, we can argue that people follows jobs.

Of particular importance to us is the employment effect of the density of highway lane-miles. Unlike before, the system GMM estimates indicate that the highway density variable is statistically significant as an explanatory variable for employment. The short run coefficient is positive and statistically significant in this specification, and the estimates also show that the effects of highway infrastructure persist over time. In particular, the long run elasticity with respect to the highway variable is about -0.01, implying that a 1% increase in the density of highway lane-miles will marginally reduce overall county employment in the private sector by 0.01% in the long run. One possibility for this is that first differencing the equations, which is carried out in the differenced GMM framework, may diminish the influence of time invariant regressors in the models. This could be the case for the highway density variable in which the time series variation is limited. Adding the equations in levels, the system GMM estimator could possibly reveal the statistical relationship between highway density and county employment. Nonetheless, the strict exogeneity assumption for highways precludes us from drawing the conclusion that expanding capacity of highway infrastructure affects a county's employment in the entire private sector of North Carolina.

The last column of Table 5-1 reports the results from our preferred specification. It relies on the system GMM framework in which the density of highway lane-mile and several other regressors discussed above are treated as endogenous. The reliability of this specification is suggested by the first-order autoregressive coefficient of lagged employment that lies in the interval between the OLS and LSDV estimates. Moreover, the two specification tests for the validity of the GMM estimator indicate neither the presence of serial correlation nor the joint invalidity of the instruments.

In contrast to the system GMM estimates in column 5, the positive and significant relationship between the density of highway lane-miles and aggregate private employment virtually disappears, suggesting that the extent and coverage of a county's highway network does not have effects on employment for the entire private sector in North Carolina. This conflicting result possibly reflects the failure of the strict exogeneity restrictions on the highway density variable and other key regressors imposed in the previous GMM estimation. Compared to the GMM results in column 5, the relaxation of the strict exogeneity assumption has also dramatically altered the coefficient estimates for several other variables, many of which are consistent with our expectations. The results in column 6 indicate that the aggregate level of output in private industries is positively related to employment, whereas the coefficient on unemployment rates becomes negative and significant. As also expected, the percentages of the population under the age of 18 and over 65 years of age have negative effects on employment since a greater share of young and senior persons could be associated with a lower share of working-age population. In addition, the positive relationship between employment and the share of the population above the age of 25 who have completed four or more years of high school tends to support the notion that the quality of labour force plays an important role in generating economic growth. Note, however, that the negative coefficient on the share of the adult population who are college graduates is surprising, but it is fairly small and not statistically significant. Likewise, the coefficient on property tax is also negative and insignificant. Turning to the fiscal variables, the negative coefficients for government expenditures on cultural and recreation activities as well as transportation and public utilities contrast sharply with *a priori* expectations. Nevertheless, the results show that public expenditures on health and human services, education, environmental protection, and public safety contribute positively, though slightly in magnitude, towards county employment growth. Note that it is only the positive effect of public safety expenditures that is significant in the short run.

5.2 Estimation of the static employment model

Given that the dynamic panel estimates in the preferred GMM specification indicate no discernible effect of highway capacity expansions on county employment in the private sector, it is interesting to compare this result with estimates of a corresponding static model. We estimate the static version of the employment model (3-1) that does not include any lagged variables as regressors by means of the OLS estimator and conventional panel regression techniques. In the static employment specification, the underlying assumption is that all variables have only contemporaneous effects on employment. Moreover, it is assumed that the observed employment level is at its desired or equilibrium level. Given the positive and significant coefficient of lagged employment specification as well as the statistical significance of the long-term effects from several explanatory variables in the employment specification with dynamics, we would expect the parameter estimates of the static employment function to be biased. This is because they may partially pick up the effects of lagged employment, and the static model is not capable of capturing time lags of the effects. The results are presented in Table 5-2.

The first three columns of Table 5-2 present the OLS, fixed effects and random effects estimation results for the static employment model. Focusing on the highway density variable, all of these estimators provide evidence suggesting that the density of highway lane-miles has a positive and significant impact on overall private employment. Based on this, one may generally argue that roadway expansions have important payoffs in terms of private sector employment growth across North Carolina counties. Nevertheless, these estimated results have relied on very restrictive assumptions that the disturbance in equation (3-1) is assumed to be nonautocorrelated and that all independent variables are strictly exogenous in the model. Therefore, we relax these assumptions by considering two alternative fixed effects specifications of equation (3-1).[19] First, we estimate the fixed effects model in which the error term exhibits first-order autocorrelation:

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + v_{it} \qquad (5\text{-}1)$$

where ρ is the first-order coefficient of autocorrelation and v_{it} is the stochastic disturbance term. Note that this approach introduces error dynamics in a static panel regression through the errors of equation (3-1), and we can simply derive an autoregressive distributed lag model of the form similar to equation (3-2) using equation (5-1). To some extent, estimating the static employment model with first-order autocorrelated errors allows us to *partially* account for lagged responses of employment through the unobservable error dynamics induced by ε_{it-1}. Second, we address the potential endogeneity of highways using a two-stage least squares (2SLS) estimator with an instrumental variable.

[19] Although fixed county effects in column 2 could be the preferred specification as we include the entire set of North Carolina counties in our sample, we performed the Hausman specification test of the null hypothesis that the individual-specific effects are uncorrelated with one or more of the included regressors. The Hausman test yields the chi-square of 97.86 (32 degree freedom), which is far larger than a 1% critical value of 53.47, thereby rejecting the null hypothesis. This suggests that in this case the model with fixed county effects is preferable to one with random county effects.

Table 5-2: Estimation results for the static models of employment

Dependent variable: Employment	(1) OLS	(2) Fixed Effects	(3) Random Effects	(4) Fixed Effects / AR(1)	(5) Fixed Effects / 2SLS	(6) Fixed Effects / 2SLS
Highway Density	0.091*** (3.45)	0.084** (1.86)	0.135*** (2.98)	- 0.020 (-0.62)	- 0.359 (-0.40)	- 0.639 (-0.61)
Output	1.150*** (105.99)	0.494*** (11.06)	0.926** (37.48)	0.301*** (8.65)	0.560*** (4.05)	0.601*** (3.78)
Property Tax	- 0.043 (-1.37)	- 0.020** (-2.18)	- 0.014 (-1.33)	- 0.005 (-1.10)	- 0.016 (-1.34)	- 0.014 (-1.05)
Human Services Expenditure	- 0.005 (-0.32)	- 0.004 (-0.50)	- 0.005 (-0.58)	0.001 (0.33)	- 0.006 (-0.75)	- 0.007 (-0.81)
Public Safety Expenditure	0.094*** (4.82)	- 0.003 (-0.33)	- 0.011 (-1.06)	0.004 (0.70)	0.009 (0.34)	0.016 (0.55)
Cultural and Recreation Expenditure	- 0.006** (-2.05)	0.001 (0.98)	0.001 (0.50)	- 0.001 (-0.71)	0.001 (0.75)	0.001 (0.61)
Education Expenditure	0.015** (2.07)	0.003 (1.10)	0.003 (0.92)	0.0003 (0.35)	0.003 (1.15)	0.002 (0.98)
Environmental Protection Expenditure	0.011 (1.77)	0.0001 (0.12)	0.001 (0.58)	0.0005 (0.68)	- 0.001 (-0.35)	- 0.002 (-0.54)
Transportation and Public Utility Expenditure	- 0.001 (-0.55)	0.001 (1.67)	0.001 (1.16)	0.0002 (0.89)	0.001* (1.73)	0.001 (1.66)
Unemployment	0.325*** (15.68)	- 0.073*** (-7.08)	- 0.042*** (-3.91)	- 0.052*** (-8.97)	- 0.063*** (-3.05)	- 0.058** (-2.42)
High School	- 1.360*** (-13.81)	- 0.416*** (-4.88)	- 0.202** (-2.34)	- 0.031 (-0.20)	- 0.450*** (-4.43)	- 0.472*** (-4.14)
College	0.416*** (11.66)	0.386*** (5.85)	0.262*** (4.63)	- 0.004 (-0.04)	0.364*** (5.85)	0.350*** (5.00)
Under 18	- 1.041*** (8.96)	- 0.251** (-2.42)	- 0.114 (-1.15)	- 0.116 (-1.03)	- 0.037 (-0.08)	0.098 (0.19)
Over 65	- 0.302*** (-3.21)	0.056 (0.65)	0.175** (1.96)	- 0.050 (-0.51)	0.058 (0.89)	0.060 (0.84)
Public Aid	- 0.234*** (-12.30)	0.010 (0.89)	0.028** (2.29)	- 0.049*** (-4.28)	0.005 (0.32)	0.002 (0.09)
Social Security	0.724*** (8.65)	0.021 (0.42)	0.004 (0.07)	- 0.007 (-0.30)	0.0002 (0.00)	- 0.013 (-0.20)
Urban	- 0.201*** (-7.82)	0.003 (0.21)	0.021* (1.67)	- 0.018 (-1.08)	- 0.002 (-0.08)	- 0.005 (-0.22)
Suburban	- 0.227*** (-10.09)	0.023 (1.74)	0.016 (1.06)	0.010 (0.77)	0.040 (1.09)	0.050 (-1.20)
Adjacent to Urban	- 0.118*** (-7.24)	0.002 (0.20)	0.014 (1.53)	- 0.006 (-0.73)	0.005 (0.43)	0.007 (0.55)
Adjacent to Suburban	0.067*** (3.58)	0.056*** (3.56)	0.063*** (3.96)	0.018 (1.35)	0.061*** (3.30)	0.065 (3.13)
Constant	2.935 (13.16)	6.920*** (20.33)	4.415*** (16.02)	7.293*** (126.01)	6.419*** (6.08)	6.102* (5.02)
Observation	1300	1300	1300	1200	1300	1300
Year dummies	No	Yes	Yes	Yes	Yes	Yes
County dummies	No	Yes	No	Yes	Yes	Yes
R^2	0.977	0.917	0.949	0.917	0.842	0.897
AR(1) coefficient	-	-	-	0.826	-	-

Notes
1) County and year specific constants are omitted for brevity.
2) Numbers in parentheses below the coefficients are t-statistics; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

An important concern when using this method is the use of appropriate instruments. Recent evidence in the U.S. literature consistently suggests that road infrastructure improvements, which are usually thought of a strategy for reducing road accident and casualties, are in fact associated with increased road crashes and casualties. For example, Karlaftis and Tarko (1998) using county-level data for Indiana provide evidence suggesting that increased highway mileage could lead to more traffic accidents. Milton and Mannering (1998) obtain similar results when analysing the effect of increases in the number of lanes on a given road section. Likewise, the more recent work by Noland and Oh (2004), estimating county-level time-series data for the State of Illinois, finds that expanding roadway capacity by increasing the number of lanes are associated with increased road accidents and fatalities. Analysis of state level data by Noland (2003) also reports consistent results. Given these empirical findings and the fact that we have no reason to suspect any strong correlation between employment and losses and injuries from road traffic accidents in each region, it is possible to use data for road accident fatalities and injuries to proxy for the coverage of the highway infrastructure network. Accordingly, we use the number of injuries and overall casualties per square miles of county area as instruments for the highway density variable.

The empirical findings from such alternative specifications are reported in the remaining three columns. Taking into account potential autocorrelation in the disturbance, the results change considerably. The coefficient of the highway variable shown in Column 4 is substantially smaller than those reported in the first three columns and, more importantly, becomes statistically insignificant with a negative sign. The two-stage least squares estimations in which the highway density variable is treated as endogenous also produce similar results. Columns 5 and 6, in which road injuries and casualties are respectively used as the instruments, consistently show no significant relationship between the density of highway lane-miles and county employment.

Our estimations suggest that the basic specification for the static employment model seems to overestimate the importance of highway infrastructure investments. When taking into account unobservable dynamic processes and the potential endogeneity of highways, the static model estimates show that the positive and significant effect of the highway density variable disappears. This is consistent with the estimates of the system GMM estimator for the dynamic panel model in which the nature and the timing of the impact of highway infrastructure as well as its possible endogeneity are taken into consideration. In addition, the system GMM estimation reveals that the coefficient of the lagged employment variable is strongly significant and very large (0.986), implying very slow adjustment. Given these results, the assumptions underlying the static employment model (3-1) seem to be problematic. As such, it is essential to recognise dynamic behaviours of employment changes and the potential reverse causation between highway infrastructure and economic growth when examining the employment impact of highway infrastructure investment. Failure to account for both issues could be an important source of misspecification of previous analyses.

6. Conclusions

This paper uses recent advances in dynamic panel econometrics to examine the employment impact from expanding highway capacity using a panel dataset for all 100 counties of the state of North Carolina. Allowing for possibly lagged adjustment of employment in response to any disturbance or shock to the labour market, we estimate the first-order autoregressive distributed lag model of employment using the system Generalized Method of Moments (GMM) technique. This estimation method is appropriate for our analysis that relies on persistent panel data. In the preferred specification taking into account possible endogeneity of highway and several other variables, the system GMM estimates provide little support to the notion of highway infrastructure as an instrument for employment growth. In particular, the density of highway lane-miles is found to have no discernible effect on overall private sector employment at the county level. The very large coefficient of lagged employment also indicates a non-negligible role of very slow adjustment processes. These findings suggest that controlling for the dynamic adjustment of employment and the possibility that highways are endogenous to the economy are of importance. Our estimations reveal that highway infrastructure tends to have a positive and strongly significant impact on employment when either or both of these issues are ignored; possibly indicating that previous work in this area came to incorrect conclusions.

The models estimated in this paper have a restrictive assumption that the disturbances are uncorrelated across spatial observations. Since we employ aggregate data for contiguous regions, there is a possibility that spatial dependence (i.e. the lack of independence among cross-sectional observations in a spatial dataset) may exist between observations. For instance, there may be measurement errors in observations of contiguous spatial units. This could result from the arbitrary delineation of spatial units of observations and a lack of correspondence between the spatial extent of the phenomenon of interest and the administrative boundaries for which data are collected. In addition, the importance of location and distance in explaining several forms of spatial interdependencies (e.g. spatial interaction, diffusion processes, and spatial hierarchies of place) also suggests the need to expect spatial dependence. To ensure the validity of the empirical findings reported in this paper, the potential existence of spatial dependence is therefore another econometric issue that will be explicitly taken into account in our further work.

References

Anderson, T. W. & Hsiao, C. (1981). Estimation of dynamic models with error components. Journal of the American Statistical Association 76, 598-606.

Arellano, M. & Bond, S. (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. Review of Economic Studies 58, 277-297.

Arellano, M. & Bover, O. (1995). Another look at the instrumental variables estimation of error-components models. Journal of Econometrics 68[1], 29-51.

Aschauer, D. A. (1989). Is public expenditure productive? Journal of Monetary Economics 23, 177-200.

Berechman, J. & Paaswell, R. (2001). Accessibility improvements and local employment: An empirical analysis. Journal of Transportation and Statistics [September/December], 49-66.

Bergman, E. M. & Sun, D. (1996). Infrastructure and manufacturing productivity: Regional accessibility and development level effects. In D.F.Batten & C. Karlsson (Eds.), *Infrastructure and the Complexity of Economic Development* (pp. 17-35). Heidelberg: Springer-Verlag Berlin.

Blundell, R. & Bond, S. (2000). GMM estimation with persistent panel data: an application to production functions. Econometric Reviews 19, 321-340.

Blundell, R. & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics 87[1], 115-143.

Boarnet, M. G. (1994). An empirical model of intrametropolitan population and employment growth. Papers in Regional Science 73[2], 135-152.

Boarnet, M. G. (1998). Spillovers and the locational effects of public infrastructure. Journal of Regional Science 38[3], 381-400.

Boarnet, M. G. (1995). Transport infrastructure, economic productivity, and geographic scale: Aggregate growth versus spatial redistribution, Working Paper No.255, University of California Transportation Center, Berkeley, California

Boarnet, M. G. & Chalermpong, S. (2001). New highways, house prices, and urban development: A case study of toll roads in Orange County, CA. Housing Policy Debate 12[3], 575-605.

Bollinger, C. R. & Ihlanfeldt, K. R. (2003). The intraurban spatial distribution of employment: which government interventions make a difference? Journal of Urban Economics 53[3], 396-412.

Borjas, G. J. (1996). *Labor Economics*. (1 ed.) McGraw-Hill.

Carlino, G. A. & Mills, E. S. (1987). The determinants of county growth. Journal of Regional Science 27[1], 39-54.

Carlino, G. A. & Voith, R. (1992). Accounting for differences in aggregate state productivity. Regional Science and Urban Economics 22, 597-617.

Carroll, R. & Wasylenko, M. (1994). Do state business climates still matter? Evidence of a structural change. National Tax Journal 47[1], 19-37.

Cervero, R. & Hansen, M. (2002). Induced travel demand and induced road investment: A simultaneous equation analysis. Journal of Transport Economics and Policy 36[3], 469-490.

Clark, D. E. & Murphy, C. A. (1996). Countywide employment and population growth: An analysis of the 1980s. Journal of Regional Science 36[2], 235-256.

Crane, L. M., Burke, D., & Hanks, C. (1991). Highway district and economic sector employment effects of transportation expenditures. Transportation Research Record 1305, 190-200.

Dalenberg, D. R. & Partridge, M. D. (1995). The effects of taxes, expenditures, and public infrastructure on metropolitan area employment. Journal of Regional Science 35[4], 617-640.

Dalenberg, D. R., Partridge, M. D., & Rickman, D. S. (1998). Public infrastructure: Pork or jobs creator? Public Finance Review 26[1], 24-52.

Duffy-Deno, K. T. (1998). The effect of federal wilderness on county growth in the intermountain western United States. Journal of Regional Science 38[1], 109-136.

Eagle, D. & Stephanedes, Y. J. (1987). Dynamic highway impacts on economic development. Transportation Research Record 1116, 56-62.

Eberts, R. W. & Stone, J. A. (1992). *Wage and employment adjustment in local labor markets*. Michigan: W.E. Upjohn Institute for Employment Research.

Evans, A. W. (1990). The assumption of equilibrium in the analysis of migration and interregional differences: A review of some recent research. Journal of Regional Science 30[4], 515-531.

Fox, W. F. & Murray, M. N. (1990). Local public policies and interregional business development. Southern Journal of Economics 22, 413-427.

Fritsh, B. & Prud'homme, R. (1997). Measuring the contribution of road infrastructure to economic development in France. In Emile Quinet & Roger Vickerman (Eds.), *The Econometrics of Major Transport Infrastructures* (First ed., pp. 45-67). London: MACMILLAN PRESS LTD.

Fulton, L. M., Noland, R. B., Meszler, D. J., & Thomas, J. V. (2000). A statistical analysis of induced travel effects in the U.S. Mid-Atlantic region. Journal of Transportation and Statistics April, 1-14.

Goodwin, P. B. (2002). Wider economic effects of transport investment, the UK story. In Erasmus Expo-& Congrescentrum Rotterdam.: Twee Jaar Ervaring Met Oeei: De Discussie Over Indirecte Effecten.

Graham, D. J. (2000). Spatial variation in labour productivity in British manufacturing. International Review of Applied Economics 14[3], 323-341.

Haughwout, A. F. (1999). State infrastructure and the geography of employment. Growth and Change 30[Fall], 549-566.

Haughwout, A. F. (1997). Central city infrastructure investment and suburban house values. Regional Science and Urban Economics 27[199], 215.

Helms, L. J. (1985). The effect of state and local taxes on economic growth: A time series-cross section approach. The Review of Economics and Statistics 67[4], 574-582.

Henry, M. S., Barkley, D. L., & Bao, S. (1997). The hinterland's stake in metropolitan growth: Evidence from selected southern regions. Journal of Regional Science 37[3], 479-501.

Henry, M. S., Schmitt, B., Kristensen, K., Barkley, D. L., & Bao, S. (1999). Extending Carlino-Mills models to examine urban size and growth impacts on proximate rural areas. Growth and Change 30[Fall], 526-548.

Henry, M. S., Schmitt, B., & Piguet, V. (2001). Spatial econometric models for simultaneous systems: Application to rural community growth in France. International Regional Science Review 24[2], 171-193.

Hotelling, H. (1929). Stability in competition. Economic Journal 39, 41-57.

Hsiao, C. (2003). *Analysis of Panel Data*. (2 ed.) United Kingdom: Cambridge University Press.

Islam, S. (2003). Distance decay in employment and spatial spillovers of highways in Appalachia. Paper presented at the Annual Meeting of the North American Regional Science Association, Philadelphia, PA, November 20-22, 2003

Jones, B. D. (1990). Public policies and economic growth in the American States. The Journal of Politics 52[1], 219-233.

Karlaftis, M. G. & Tarko, A. P. (1998). Heterogeneity considerations in accident modeling. Accident Analysis and Prevention 30, 425-433.

Lobo, J. & Rantisi, N. M. (1999). Investment in infrastructure as determinant of metropolitan productivity. Growth and Change 30[Winter], 106-127.

Lombard, P. C., Sinha, K. C., & Brown, D. J. (1992). Investigation of the relationship between highway infrastructure and economic development in Indiana. Transportation Research Record 1359*,* 76-81.

Luce, T. F. (1994). Local taxes, public services, and the intrametropolitan location of firms and households. Public Finance Quarterly 22[2], 139-167.

Mark, S. T., McGuire, T. J., & Papke, L. E. (2000). The influence of taxes on employment and population growth: Evidence from the Washington, D.C. metropolitan area. National Tax Journal 53[1], 105-123.

McDonald, J. F. & Osuji, C. I. (1995). The effect of anticipated transportation improvement on residential land values. Regional Science and Urban Economics 25, 261-278.

Milton, J. & Mannering, F. (1998). The relationship among highway geometric design relationships. Transportation 25, 395-413.

Modifi, A. & Stone, J. A. (1990). Do state and local taxes affect economic growth? The Review of Economics and Statistics 72[4], 686-691.

Noland, R. B. & Cowart, W. A. (2000). Analysis of metropolitan highway capacity and the growth in vehicle miles of travel. Transportation 27[4], 363-390.

Noland, R. B. (2003). Traffic fatalities and injuries: the effect of changes in infrastructure and other trends. Accident Analysis and Prevention [35], 599-611.

Noland, R. B. (2001). Relationships between highway capacity and induced vehicle travel. Transportation Research Part A 35, 47-72.

Noland, R. B. & Lem, L. L. (2002). A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. Transport Research Part D 7, 1-26.

Noland, R. B. & Oh, L. (2004). The effect of infrastructure and demographic change on traffic-related fatalities and crashes: a case study of Illinois county-level data. Accident Analysis and Prevention 36, 525-532.

OECD (2002). *Impact of transport infrastructure investment on regional development*. Organisation for Economic Co-operation and Development.

Pereira, A. M. (2000). Is all public capital created equal? The Review of Economics and Statistics 82[3], 513-518.

Prud'homme, R. & Lee, C.-W. (1999). Size, sprawl, speed and the efficiency of cities. Urban Studies 36[11], 1849-1859.

Quan, N. T. & Beck, J. H. (1987). Public education expenditures and state economic growth: Northeast and Sunbelt regions. Southern Economic Journal 54[2], 361-376.

SACTRA (1999). *Transport and the economy: Full Report,* The Standing Advisory Committee on Trunk Road Assessment (SACTRA).

Siethoff, B. T. & Kockelman, K. M. (2002). Property values and highway expansion: Timing, size, location, and use Effects. Transportation Research Record 1812, 191-200.

Stephanedes, Y. J. (1990). Distributional effects of state highway investment on local and regional development. Transportation Research Record 1274, 156-164.

Thompson, G. L., Weller, B., & Terrie, E. W. (1993). New perspectives on highway investment and economic growth. Transportation Research Record 1395, 81-87.

Wasylenko, M. & McGuire, T. (1985). Jobs and Taxes: The effect of business climate on states' employment growth rates. National Tax Journal 38[4], 497-511.