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Estimating the Impact of Highways on Economic Activity: Evidence from Appalachian Development Corridor G

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Abstract. This paper analyzes the economic impact of an Appalachian Development Highway (Corridor G) on small business activity using two modeling approaches. The first model evaluates aggregate economic growth along Corridor G and in the surrounding counties. This estimate provides no evidence of increased economic activity in adjacent counties due to completion of Corridor G. In order to account for the imprecision of an aggregate estimate, a second study of over 7,000 firms in the region was performed. This firm-level analysis indicates that proximity to the roadway improves productivity by roughly 1 percent per mile, but only in rural areas. This result suggests that a discrete public infrastructure investment may improve productivity in rural firms.

1. Introduction

The effect of highway infrastructure on regional economic activity and firm productivity remains an enduring public policy question. While many studies have examined the effect of highway spending (Aschauer, 1989) or the completion of a network (Chandra and Thompson, 2004), examinations of firm level effects of infrastructure have yet to convincingly answer aggregate productivity questions (Datta, 2010). This study responds to these concerns and performs more disaggregated research into the impacts of highway construction. The purpose of this inquiry is to provide two different approaches to modeling economic growth which may affect our findings. In particular, I examine regional effects in a traditional growth model and by using firm-level productivity effects.

The paper proceeds as follows: a review of existing research, a brief review of the study area, and the regional growth and firm-level productivity models of highway impacts. Each model is tested in turn, which is followed by summary and conclusions. The appendices include specific data on the sampled area – Corridor G, from Charleston, West Virginia, to Pikeville, Kentucky.

2. Literature review

There is abundant existing research into the aggregate effects of highway infrastructure on productivity. Aschauer (1989) fostered a long discussion of the role of infrastructure investments and output growth, with Holtz-Eakin (1994), Munnell (1990), Rubin (1991), and Morrison and Schwartz (1996) estimating positive impacts of highway investments. Shatz et al. (2011) offers a particularly thorough review and meta-analysis of these studies. The conclusion from these works is simply that there is evidence of at least modest and persistent benefits to regions of aggregate public capital investment. However, the evidence is not wholly one sided. There have been a number of other studies which fail to find a link between highway investment and productivity. Hulten and Schwab (1991) and Tatom (1993) are among those who find no effect from aggregate highway infrastructure investment.

This variance in research conclusions has not yet been resolved in in the literature, though some causes may be apparent in the transmission of output impacts. The explanation of the output transmission mechanism for highway infrastructure as suggested by Munnell (1992) offers two counteracting effects. First, the presence and quality of public capital boosts private productivity, hence incentivizing additional private investment. Second, government expenditures on public capital may "crowd out" private capital investment. This implies that variability in estimated effects could result from regional differences in capital accumulation.

Later estimates of highway output effects (Chandra and Thompson, 2004) provide evidence that geographic scope of analysis may play a role in the divergence of estimates. Chandra and Thompson report that virtually all regional economic growth associated with the completion of elements of the Interstate Highway System could be attributed to the relocation of economic activity from counties not directly serviced by the highway system. So, any modeling of geographic effects of a specific highway investment which does not include cross-border effects may overreport the output impacts of infrastructure investments.

Evidence from cost functions also offers insight into the impacts of aggregate public capital effects. Studies which examine firm-level costs include Dalenberg and Eberts (1992), Morrison and Schwartz (1996), and Nadiri and Mamuneas (1996), all of whom report that aggregate public capital investments reduce firm costs. Further analysis of new highway construction or large-scale upgrade is warranted, not least because data on the impacts of such new construction in the U.S. is relatively rare.

3. Methods and data

With the West Virginia portion completed in 1997, Corridor G is one of 26 roads in the Appalachian Development Highway System. The region comprises the northern part of the West Virginia/Kentucky coalfields. As the road is completed through Kentucky it will comprise a four-lane, limited-access road from Pikeville, Kentucky, to Charleston, West Virginia. Figure 1 shows the West Virginia portion of Corridor G, which runs from Williamson to Charleston. This stretch will be the focus of the firm-level analysis.

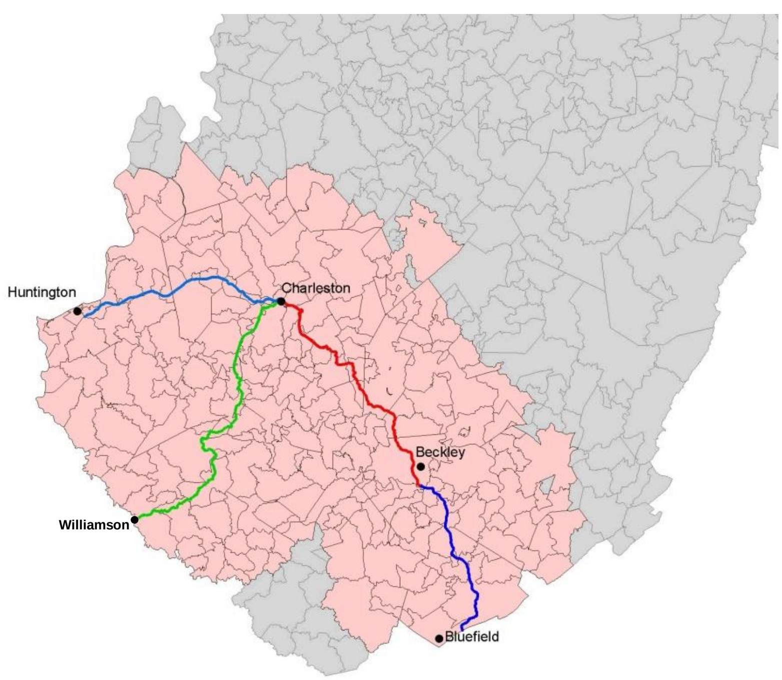

Figure 1. The Corridor G Region, Charleston to Williamson, West Virginia.

The area has experienced considerable economic turbulence in the past two decades. The halving of coal prices that led to rapid loss of coal-related jobs from 1984 through the mid-1990s had a profound effect on the coal-mining counties in the region (Burton, Hicks, and Kent, 2000). Population declines have continued, and several counties in the region were below 50 percent of 1950 levels by 2010.

The ill effects of the lost mining employment continued to impact the region in the years since. This region served as an ideal example of the type of location intended to benefit from the construction of an Appalachian Development Highway. However, while it is good example for rural areas, the region is not an ideal location from which to extrapolate estimates of the productivity effects of highways to urban areas throughout the United States.

Extending previous research (Hicks, 2006b) on the output effects of highway infrastructure, a regional production function model is employed in this analysis. The traditional extension of a Cobb-Douglas production function is matched with spatial and temporal corrections for autoregression, trend changes to per capita income (the proxy for regional output) over time, and a dummy variable for the year in which the Appalachian Development Corridor (HWY 119) was completed. So, the model presented is a pooled spatial vector autoregression with exogenous variables. The model in matrix form is **Y=BZ+E** with individual stationary first-differenced [I(1)] variables. An example equation for per capita income is:

$$\frac{Inc_{i,t}}{Pop_{i,t}} = \propto + \beta_{1\ldots n}\left(\frac{Inc_{i,t-n}}{Pop_{i,t-n}}\right) + \emptyset_{1\ldots n}\left(\frac{Edu_{i,t-n}}{Pop_{i,t-n}}\right) + \gamma_{1\ldots n}\sum\left(coninc_{i,t-n}\right) + \delta_{1\ldots n}\left(\frac{Emp_{i,t-n}}{Pop_{i,t-n}}\right) + TN + \theta(HWY119) + e_{i,t} \quad (1)$$

In this form per capita income is a function of lagged dependent variables, exogenous variables, and a spatial autocorrelation component regressed on panel data. The dependent variables are the components of a basic growth model: income growth, human capital, and physical capital. The exogenous variables are the trend and highway presence dummy. We will refer to the spatial autocorrelation variable in a separate category for technical reasons.[1]

4. Results

In order to fully populate this model with data, the use of a number of common proxies and econometric adjustments is helpful. All variables are for each of the West Virginia and Kentucky counties contiguous to Hwy 119 (Corridor G), the highway under investigation in this study. The data are from 1978 through 2000, which eliminates the need to perform an SIC to NAICS bridge but is sufficient to capture the effects of the infrastructure. The dependent variables are years of education per capita, as a proxy for human capital, and real construction income, as a proxy for physical capital. The independent variables are time/presence dummies for the construction and completion of the West Virginia segment of the highway.

A few comments are warranted for using total years of education to proxy for human capital, as is commonly done. Human capital measurements are difficult to make across regions that suffer great variability in culture, educational attainment, or health care access. But, for this region (rural West Virginia and Kentucky) more simple measures are likely to provide sufficient variability to reflect actual human capital differences.[2] That is the goal of employing a proxy variable in this type of model. This approach is justifiable since this study is not intended to directly estimate human capital impacts, only control for their differing presence.

The model includes a trend component that provides for a correction necessary for observing changes over time in a model that does not include random or time-varying effects (Baltagi, 1996). The use of a common intercept is appropriate due to the necessity of including spatial interaction terms. This differs from earlier studies of this type that used a fixed-effects model (Holtz-Eakin and Schwartz, 1995). The selection of the appropriate panel model has been subject to much debate in the literature beyond even the spatial and autoregressive issues of the estimators (see Baltagi, 1996). A panel model with a common intercept appeared to be the most appropriate specification. This specification permits both cross-sectional and time-varying components to be estimated. A longer set of observations will

[1]A loose definition of exogeneity is used in this specification, which fails to preclude statistical bias in a few applications. It is unlikely this presents qualitative problems in this model. More clearly, the spatial autocorrelation function and construction income may well not be strictly exogenous (though construction income has been omitted from the per capita income measure).

[2] Within the observed region there are very few differences in regional human capital components unrelated to education. In particular, regional differences in health care outcomes are quite similar and likely experience high covariance with education, making their omission appropriate due both to theory and the problem of collinearity in an estimation model.

likely be necessary for alternative models to be fruitfully employed. These choices were rather easy in this instance since a fixed-effects model may be incompatible with spatial interaction terms (Anselin, 2001). Standard errors were White-washed with White's (1980) heteroscedasticity invariant variance-covariance matrix.

A comment on the spatial autocorrelation function is also warranted. This spatial component, a Spatial Durbin Model, is a common technique in regional analysis (Anselin, 2001). The estimation of a spatial component involves the use of a weighted and normalized set of observations of the dependent variable in contiguous counties in time *t*. This accounts for the regional impact of contiguous counties in the model. The interpretation of this component is the impact of adjacent counties on the dependent variable (per capita income). Its inclusion corrects for the very real problem of spatial autocorrelation (Anselin, 2001).

The choice of appropriate lag lengths is also a much debated point in the literature. The use of a vector autoregressive model is recommended when the theoretical structure of the model contains doubt as to the timing of impacts. This is a clear case where that is appropriate. The model is not sensitive to variation in lag length, and, indeed, the Akaike Information Criterion is minimized with one lag. This leaves a single lag as the appropriate selection, though it seems to matter little in terms of magnitude or significance of the estimates.

The choice of pooling the estimates or permitting them to vary by individual cross section is another choice in panel models that has not received consensus opinion in the econometric literature. In this case, permitting at least the highway construction impacts to vary at the individual cross section seemed warranted. The magnitudes and significance of the other variables were unaffected by pooling or allowing for cross-sectional variation. The first differences of the variables were used, and these variables are all stationary at I(1) using common tests.[3] These reduce the explanatory power of the model and would oftentimes lead to the use of a cointegrating equation, which is not feasible here for a variety of reasons primarily related to sample size. The only real concern that motivated the use of first differences is the failure to reject at high levels of significance stationarity in many of the variables in levels in common unit root tests. Again, the choice here is made on the side of caution, trading an excessive amount of explanatory power for assuredness that a spurious regression is not the result.

Interpretation of the results (Table 1) for the first of these models is straightforward. First, the education coefficients, the human capital proxies, are consistent with other studies in its direction and magnitude. These results hold also for the construction income coefficient, the proxy for physical capital. Neither non-construction income (the lagged dependent variable illustrated here) nor the spatial matrix is important in terms of interpretation for the purposes of this research, so they are treated here as controls.

The second model, which includes the highway presence dummy and trend within the growth model, tells much the same story. The difference of note is the absence of statistical significance of the first lag of the construction income. This is likely due to the use of the highway presence dummy that sweeps construction income changes from the model. In this model, the highway presence dummy resulted in reduced incomes in Kanawha County (the urban terminus of the highway). No other counties experienced impacts that were of statistical significance in either of these two models.

The magnitude of the highway contribution was small in every instance. The Kanawha County growth impact was a roughly 5 percent reduction in the growth rate, and growth effects on other counties were too small to be of economic significance. These findings are consistent with earlier work (Holtz-Eakin and Schwartz, 1994; Chandra and Thompson, 2000) in finding little specific support for infrastructure types. It does, however, suggest that human and private capital play a significant role in growth, verifying that the choice of proxies is appropriate.

Though this modeling effort directly addresses spatial autocorrelation, a problem not fully addressed in earlier research, it still fails to address some of the key concerns of these earlier studies, specifically that the level of aggregation remains quite high. In essence, this model does not get at the basic questions regarding firm-level productivity changes attributable to highway construction. This necessitates another approach to modeling highway impact at the firm level.

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[3] I employed the traditional Dickey-Fuller test, and concerns over the power of the test over a data break (such as the NAICS, SIC changeover in 2000) motivate the sample period.

Table 1. County-level growth models (change in non-construction per capita income is dependent variable).

Variable	Spatial VAR-Growth model	Spatial VAR-Growth w/ highway presence dummy
Intercept	-0.0234** (-2.27)	-0.03396*** (-2.56)
Δ non-construction income, t-1	-1.819 (-1.14)	-2.861* (-1.73)
Δ education per capita, t-1	4.2474** (2.43)	2.657* (1.80)
Δ construction income, t-1	3.62E-07* (1.69)	-4.98E-07 (-1.49)
Δ spatial matrix, t-1	-1.495 (-1.49)	-2.5345 (-1.54)
Δ non-construction income, t-2	-0.7185 (-0.57)	-1.1058 (-0.96)
Δ education per capita, t-2	1.1465 (0.62)	0.7362 (0.399)
Δ construction income, t-2	5.46E-07*** (2.755)	4.96E-07*** (2.98)
Δ spatial matrix, t-2	4.0088** (2.003)	3.0696* (1.81)
Adjusted R-squared	0.30	0.43
F-statistic	2.800	3.27

Notes: t-statistics in parenthesis. County fixed effects, trends and treatment model not reported, n=161.
* Denotes statistical significance at the 0.10 level, using a standard t-statistic, ** significance at the 0.05 level and *** at the 0.01 level.

4.1. A model of the productivity impact of infrastructure

The direction of formal modeling of New Growth Theory reflects more recent interest concerning research and development and human capital. One direction of interest in this research is to evaluate the productivity-enhancing value of public infrastructure. A full treatment of New Growth Theory, while outside the scope of this study, would include a formal treatment of technological change and increasing returns to investment. The exploratory analysis offered in this study will present an ambitious modeling effort that addresses empirical questions of interest. The basic growth model offered here is a production function:

$$Y = f(K, G, L) \tag{2}$$

where output per worker is a function of exogenously-determined infrastructure and firm capital. The exogeneity of public infrastructure rests on the assumption that the marginal cost of providing local infrastructure is largely unnoticed by firms.

Assuming an explicit functional form of this production function is fraught with challenges. However, for flexibility and ease of exposition, and with an eye towards empirical specification, we will assume of a constant elasticity of substitution function of the form:

$$Y_{i,j} = G^{\propto}\left[w_{L,i,j}L_{i,j}^{\rho} + w_{k,i,j}K_{i,j}^{\rho}\right]^{\frac{1}{\rho}} \tag{3}$$

where i is an individual firm in industry j, L is labor, K is capital, and each w is a share parameter.

The CES parameter, ρ, will vary by industry in an empirical specification and provides justification for industry control variables that will be included in the several empirical specifications. For simplicity we normalize $\rho = 1$. Similarly, the form of substitution of capital for labor will vary significantly by industry. This permits the adoption of linear substitution technology of the form $K_i = \rho L_i$. Normalizing ρ permits the reduction of the CES function to:

$$\frac{Y}{L} = G^{\theta} \tag{4}$$

In modified logarithmic form[4] this is:

$$ln\left(\frac{Y}{L}\right) = \theta lnG \tag{5}$$

[4] Note that per capita production (Y/L) is treated as an integer in this and most economic analysis, which explains the treatment of this variable when performing the log transformation.

This clearly lends itself to estimation of the sensitivity of output per worker in individual firms to public infrastructure investment. These types of specifications are commonly employed (e.g., Hall and Jones, 1999). A benefit of a generalized specification is that it permits empirical controls for industry specific variation in the CES and substitution parameters. We examine the specification (dropping logarithmic notation) of:

$$\frac{Y}{L} = a + b\emptyset + e \quad (6)$$

$$\text{where } \emptyset = \delta Z + \beta\pi + u_i \quad (7)$$

The specification of this empirical model permits the estimation of the average product of labor for firm *i* in industry *j* from a matrix of control variables **Z** and public infrastructure **π**. This process permits an evaluation of the robustness of the assumptions underlying equations (2) and (3), as well as the all-important parametric evaluation of infrastructure. This model presents only a basic framework for firm-level response to infrastructure. Of additional interest is the regional response.

4.2. Empirical estimation

This econometric specification will be tested on a novel set of data from The Robert C. Byrd Appalachian Development Corridor G (US Route 119), which offers a useful area for examining the impact of a development corridor. We will examine firms located in zip codes that are within five miles of the corridor, the West Virginia portion of which is illustrated in Figure 2. This permits the examination of roughly 7,500 firms. Data includes revenues, employment, 6-digit SIC classification, ownership type, and tenure of firm. Roughly 15 percent of firms lack the full set of necessary data (primarily employment) and so are omitted from the testing. To these data we add regional demographic data at the zip code level as well as a number of count variables for particular amenities in six classifications (e.g., number of hospitals, number or retails centers, etc., in the zip code). These are treated as controls for other types of infrastructure.

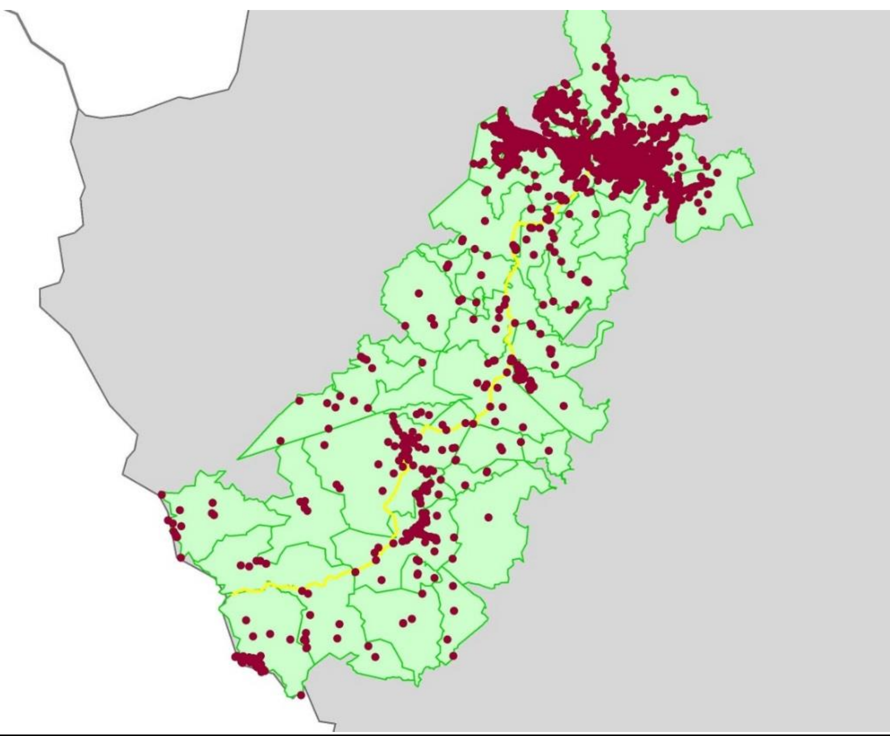

Figure 2. Corridor G and associated firms in West Virginia.

These data populate a standard production empirical specification outlined in equations (5) and (6) above. To this we add two measures of the proximity of firms to the highway, Euclidian and road distance to Corridor G. These variables serve as a proxy of efficiency of public infrastructure. These latter data were estimated using a GIS-T algorithm on latitude and longitude estimates of firm location provided by the Dun and Bradstreet Marketplace database. The standard Mercator projection was employed. The process for estimating these travel distances involves overlaying the firm spatially on a digital commercial map. These maps are similar to those used by the logistics and delivery industries. They include nodes that distinguish changes in road characteristics such as intersections, curbs, pavement types, and additional lanes in public roadways. The routing algorithm measures the distance from the firm to the nearest node, and subsequently the distance to Corridor G by the shortest route.

Omissions due to obvious errors in these data were under 2 percent. Summary statistics for selected data appear in Table 2. Empirical results on selected rural zip codes and industries appear in Tables 3 and 4, respectively.

Table 2. Summary statistics of sample firms (7,062 observations).

	Employees	**Sales ($1,000)**	**Average Product of Labor ($1,000's)**	**Euclidean Distance (feet)**	**Road Distance (feet)**
Mean	11.61	735.54	89.82	15,977	26,710
Median	3	100.00	50.00	10,820	18,429
Maximum	1,800	668,600	1,181.49	60,591	137,127
Standard Deviation	45.07	9,960.5	88.33	13,457	25,049
Skewness	20.8	47.46	62.98	0.314	1.03
Kurtosis	647	2,866	4,495	2.42	3.64

Table 3. Spatial Productivity Model results: rural counties, Euclidean distance.

Variable	**Rural, 1 Emp**	**Rural, < 5 Emp**	**Rural, < 10 Emp**	**Rural, < 25 Emp**	**Rural, < 50 Emp**	**Rural, < 500 Emp**
Intercept	12.8	11.6	11.59	11.73	11.78	11.76
	(11.16)	(25.12)	(26.65)	(28.25)	(28.21)	(28.41)
Log of distance in feet	-0.13	-0.057	-0.0058	-0.07*	-0.078*	-0.07*
	(-1.12)	(-1.18)	(-1.28)	(-1.63)	(-1.79)	(-1.74)
Square of log distance	1.05E-10	1.47E-10*	1.46E-10*	1.26E-10*	1.52E-10**	1.45E-10**
	(0.93)	(1.88)	(1.98)	(1.79)	(2.16)	(2.06)
Branch binary	0.012	0.02	0.011	-0.004	-0.03	-0.04
	(0.25)	(0.24)	(0.15)	(-0.06)	(-0.53)	(-0.60)
Cemeteries	0.00015	-0.0072	-0.009	-0.01	-0.009	-0.0088
	(0.068)	(-1.49)	(-2.05)	(-2.36)	(-2.03)	(-1.97)
Churches	-0.014	0.017	0.01	0.01	0.01	0.01
	(-1.78)	(1.95)	(2.11)	(2.11)	(1.94)	(1.74)
Hospitals	0.027	-0.18	-0.18	-0.16	-0.144	-0.11
	(0.56)	(-1.88)	(-2.01)	(2.11)	(-1.62)	(-1.26)
Malls	0.28	-0.28	-0.28	-0.31	-0.30	-0.33
	(1.30)	(-1.43)	(-2.10)	(-1.83)	(-1.82)	(-2.02)
Schools	0.011	0.004	0.008	0.014	0.011	0.01
	(1.14)	(0.40)	(-1.54)	(1.17)	(1.12)	(1.27)
Adj-R^2	0.04	0.009	0.019	0.09	0.01	0.01
F-Statistic	2.15	1.82	2.12	2.05	2.2	2.24
Observations	194	663	815	900	929	948

Notes: t-statistics in parenthesis. * denotes statistical significance at the 0.10 level, ** denotes statistical significance at the 0.05 level and *** denotes statistical significance at the 0.01 level

Table 4. Selected industry regressions, rural counties only, Euclidean distance.

Variable	Rural Gasoline Stations	Rural Retail (multi-type)	Rural Manufacturing
Intercept	21.78***	11.733***	7238634***
	(6.14)	(32.00)	(1.23)
Log of distance in feet	-1.319***	-8.75E-05***	-768135
	(-3.14)	(-2.38)	(-1.22)
Square of distance	-3.22E-11	1.68E-09**	0.000711
	(-0.02)	(2.30)	(1.24)
Branch binary	0.97	0.15	-807609
	(2.95)	(0.67)	(-1.10)
Cemeteries	-0.06	-0.004	-422
	(-1.44)	(-0.32)	(-0.10)
Churches	0.46**	-0.002	-1747
	(2.31)	(-0.10)	(-0.14)
Hospitals	4.00	0.15	-131656
	(1.23)	(0.62)	(-0.76)
Malls	-20.82*	-0.516	144603
	(-1.72)	(-1.52)	(0.57)
Schools	0.06	0.02	-12590.75
	(0.63)	(0.65)	(-0.823)
Adj-R^2	0.70	0.06	0.18
F-Statistic	4.53**	1.98*	4.95***
Observations	13	110	137

Notes: t-statistics in parenthesis. *denotes statistical significance at the 0.10 level, **denotes statistical significance at the 0.05 level, and *** denotes statistical significance at the 0.01 level

Interpretation of these models is also straightforward but warrants some discussion. In the first estimation (not shown) a sample of over 7,100 West Virginia firms including a relatively urban Kanawha County finds no statistical significance of the highway. The estimation does not provide support for increasing returns to infrastructure in an urban area. The subsequent estimations, those shown in the tables, remove Kanawha County from the estimation (though it is partially rural). In these models, the estimations for different firm sizes show increasing statistical significance as the size of firm increases. However, the magnitude of the parameter estimates is not statistically significant across firm size. Similarly, this disaggregated model strongly supports an interpretation of increasing returns as exhibited by the significance of the squared term. This provides support for the hypothesis that public infrastructure enjoys increasing returns in a rural setting. These results are very similar to estimated effects of highway construction on retail agglomerations as reported by Hicks (2006), in which only rural effects were observed.

The industry-specific regressions are illustrated here to present information on the range of results obtained when smaller, industry-specific analysis is performed. There are a few observations worth noting in these estimates. First, in each of these sectors, in rural counties, distance played an important role in firm productivity. This confirms the aggregate effects reported earlier for more specific industries, which are reported here for illustration of two points of consequence. First, as we note, the source of productivity benefits may be either supply or demand side. By choosing industries that would plausibly be at the extreme of both benefits, the overall results are clarified. For gasoline states and retail stores in rural settings, it is likely that the benefits would be primarily on the demand side, as proximity to the main road enables higher levels of visits at locations closer to the interstate. For the manufacturing firm, no such demand-side benefits appear likely to explain productivity increases, yet firms closer to the road have higher levels of productivity. Again, this exercise does not try to decompose the relative magnitude of both effects, simply posit their existence. With selected firms operating at both extremes of causes, we can have more confidence in the underlying notion that the highway itself is increasing firm productivity and that these results are not simply the result of underlying patterns in regional industrial structure.

Analysis performed on the estimates of actual road distance serves as an alternative measure of infrastructure quality. There is no implied preference for the road distance or Euclidean distance measure. In a practical sense, it would appear that road distance would be a preferential measure; however, since we have placed no restrictions upon the source of benefits (supply or demand) there are plausible conditions where both would apply. While actual travel costs should be reflected in road distance, making the travel distance preferred, there are conceivable instances where both costs and demand could be better represented by Euclidean distance. For example, advertising costs may be lower for firms that are more proximal to the road and can thus use on-site signage which might be visible from the highway.

In these estimates, distance played no role in the productivity of firms when using the entire sample. As with the earlier estimates, this changed in rural areas (Table 5). When assessing the impact of infrastructure in rural areas only, the distance variable was statistically significant.

Table 5. Aggregate regression, rural counties, road distance as infrastructure variable.

Variable	Coefficient
Intercept	598,884.1***
	(6.08)
Road Distance (miles)	-4,073.885*
	(-1.70)
Per Capita Income	-8.530441
	(-1.16)
Number of SICS in Firm	4110.79
	(0.16)
Number of Employees	-452.9382
	(0.31)
Households in Zip Code	3.914701
	(0.78)
West Virginia	-400,563.8***
	(-5.28)
Adjusted R-squared	0.034
Observations	1,072

*denotes statistical significance at the 0.10 level,
**denotes statistical significance at the 0.05 level, and
*** denotes statistical significance at the 0.01 level.

Interpreting the findings in this portion of the study provides some support for the hypothesis that a positive productivity impact related to the physical proximity of infrastructure may result. This impact varies across industries and is apparent only in rural regions. In considering all possible interpretations of these results, we also examined the possibility that increased rents adjacent to the highway led to the displacement of low productivity firms with high productivity firms. As part of our preliminary analysis we estimated firm age, which was uncorrelated with productivity in all our aggregate models (p-value = 0.64 in the strongest case). This is not surprising, since only 135 out of more than 7,500 firms in the sample were newer than the completion of the highway (the non-response rate was just over 7 percent). Still, it is safe to conclude that the movement of higher productivity firms to the region cannot account for the productivity effect reported here.

Employing the point estimates of the distance parameters provides some scale of the impacts. Using the Euclidean distance, we find that a roughly 1.3 foot decrease in the distance from the firm to Corridor G raised worker productivity by roughly one dollar a year. Using the road distance, the impact increases to a one dollar increase for every 0.77 feet the firm is closer to Corridor G. This means that halving the average distance to Corridor G would increase the average output of a worker by roughly $10,010 (Euclidean) or by $10,250 (road). Notably this is a point estimate. This finding suggests a nontrivial impact of infrastructure on firm productivity in rural regions, but there is much that remains unknown regarding the contribution of infrastructure to economic activity.

The specific question outlined above provides the basis for estimation that should answer a wide variety of questions related to development policy. These include the impact of related amenities on firm productivity, concentration, and market power potential by industry in small regions, the impact of various factors on regional unemployment, and a host of others. The direction of causality also remains a concern.

The infrastructure model outlined above cannot capture the dynamic spatial impact of infrastructure. To understand the time impact of the infrastructure, and its impact across broad space and time, we will have to rely on different data sets and different modeling approaches.

5. Summary and conclusions

The findings presented in this paper offer different techniques of infrastructure analysis. The first, a cross-county growth regression, extended the methods of earlier research by Holtz-Eakin and Schwartz (1994) and Chandra and Thompson (2000). This model yields estimates which reject a finding that Corridor G's construction has added net economic activity to the region. However, the potentially obscuring factors of aggregation warranted more detailed research. This was performed in the second model. The second approach used cross-sectional data in a production function to test the impact of highway presence on individual firm productivity. These results were startling. In rural counties firms with more than one employee experienced a significant and positive increase in productivity due to proximity to Corridor G. This spatial measure was accomplished by measuring the Euclidean distance from each firm to the highway using GIS-T methods. The results were more profound in industries where transportation and time costs were present for either producers or consumers. This is a finding similar to that of Hicks (2006) in Indiana's rural counties. The results were important since they imply a non-trivial impact, but one which should be interpreted with caution.

This research helps answer an important question regarding highway productivity impacts. Several other factors remain unknown. Among these are the impact of other types of infrastructure such as water, sewer, gas, and electricity on regional growth. This has important implications for follow-on road construction in regions.

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