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Economic Returns to Rural Infrastructure Investment

Farm Foundation

1301 West 22nd Street
Suite 906
Oak Brook, IL 60523
Tel 630.571.9393
Fax 630.571.9580
farmfoundation.org

facebook.com/thefarmfoundation
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Productivity and Quality-of-Life Benefits to Rural Infrastructure

This paper is one of six commissioned as part of the workshop, *Economic Returns to Rural Infrastructure Investment*, organized by Farm Foundation and USDA's Economic Research Service (ERS). The workshop took place April 10–11, 2018, in Washington, D.C. A seventh paper, which had already been published, was also presented at the workshop because of its high relevance to the topic.

Authors David Albouy, Ph.D., of the University of Illinois, Arash Farahani, Ph.D., of the Independent Budget Office of New York City, and Heejin Kim of the University of Illinois, examine how each $1 of investment in infrastructure correlates to productivity and quality-of-life benefits in rural and urban counties.

To read the complete paper, or any of the other six papers, visit the Farm Foundation website, https://farmfoundation.org.

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PRODUCTIVITY AND QUALITY-OF-LIFE BENEFITS TO RURAL INFRASTRUCTURE

David Albouy, University of Illinois & NBER

Arash Farahani, Independent Budget Office of New York City*

Heejin Kim, University of Illinois

* The views expressed in this paper are the authors' and should not be interpreted as IBO's.

Introduction

The benefits of infrastructure can take on many forms. Most analyses – e.g. (Aschauer, 1989) and (Holtz-Eakin, 1994) – emphasize the effect of infrastructure on measures of output, or income, such as the dollar value of goods sold. These market-oriented impacts are associated with the "economy" by the public and are labeled by economists as productivity effects.

Yet infrastructure may have important quality-of-life benefits involving no market transactions. If a new school saves a family 20 minutes a day in travel time, that may not lead to higher output if the saved time is spent in leisure. Similarly, beautiful artwork may make locals happier without boosting their income. Public projects may also create nuisance effects, such as noise or pollution, which lower locals' quality-of-life. Fortunately, economists have indirect methods of inferring these quality-of-life effects.

Below, we consider the productivity and quality-of-life benefits of public infrastructure investments to rural counties using a newly constructed dataset and a rich economic framework. This dataset allows us to consider the impact of public infrastructure on various local outcomes, including income, employment, housing prices, and agricultural land values. The economic framework then interprets those estimates into various productivity and quality-of-life benefits. Our estimates indicate that, on average, infrastructure has economically significant quality-of-life benefits about as large as the productivity benefits. However, the total benefits to infrastructure are not the same everywhere and may be more worthwhile in some places over others.

In particular, we consider how counties differ in natural amenities, which refer to natural geographic and climatic features that humans find appealing. McGranahan (1999) finds that rural population growth is strongly predicted by these amenities. Below, we estimate the tremendous value households put in them. Moreover, our amenity analysis helps to determine what kinds of counties benefit the most from infrastructure improvements. One possibility is that infrastructure can *complement* amenities, i.e. investments in amenable areas are more valuable (see Albouy, Christensen, and Sarmiento (2018)). Another possibility is that infrastructure is *compensatory* and can easily make up for the lack of amenities in certain areas. If amenities and infrastructure are substitutes in this way, and subject to diminishing returns, infrastructure benefits would be lower in high-amenity places.

We find that infrastructure investments are most beneficial in high-amenity areas. Low- amenity areas still benefit from infrastructure, but these benefits may not be high enough to justify the costs. Thus, it appears that natural and artificial amenities are indeed complements in consumption and often in production. Infrastructure increases quality-of-life and firm productivity most in areas that are already naturally desirable.

Our analysis of productivity examines four forms of productivity and quality-of-life benefits using four different outcomes. Perhaps the closest early article related to this work is Dalenberg & Partridge (1997), who estimate the effect of infrastructure on rural wages at the state level, arguing that an increase implies a productivity benefit and a decrease, a quality-of-life benefit.[1] Haughwout (2002) combines wage data with housing price data to fully identify quality-of-life effects separately from productivity. Albouy and Farahani (2017) distinguish two forms of productivity, traded versus non-traded (i.e. "home"), and demonstrate how to potentially identify them using population levels. Both of these papers examine the value of infrastructure in central cities. The analysis we provide below builds from these but adapts it to a rural setting by also incorporating agricultural productivity. This is identified independently with the help of data on agricultural land values.[2]

Benefits of Infrastructure in Spatial Equilibrium

The economic model we use to infer productivity and quality-of-life benefits relies on the powerful concept of spatial equilibrium. It assumes that households and firms are mobile, and thus will leave locations that offer them lower well-being or lower profits than other locations. In addition, it assumes that households and potential firms are similar in their tastes and productive capacities. If a household pays $40,000 more for a home in county A than in county B, it is because most households think it is worth the additional $40,000 to live in county A over B. If not, they would move somewhere more satisfying. Similarly, if firms pay workers $5,000 more in county A than in county B, it is because the firm finds it worthwhile because the workers are $5,000 more productive in county A than in B. If the productivity advantage did not exist, the firm would move somewhere more profitable.

Each county is considered to have its own housing and labor market.[3] Land markets for agriculture and housing are treated separately, since many houses are built on land atypical for agriculture. Labor markets are treated as integrated – partly for data purposes – so that workers earn the same wage across sectors, whether it be in agriculture, other traded production, or in non-traded production. The three forms of productivity, quality-of-life benefits, and how they are measured, are described in Table 1.

Traded (Non-Agricultural) Productivity

There are three types of firms, each with its own corresponding form of output. Traded (non-agricultural) output firms use labor and mobile capital to produce a good that can be bought and sold in international markets. We make the simplifying assumption that firms have negligible land costs. As a result, wage and income levels are directly tied to the "trade productivity," associated with this sector.

[1] Without housing prices, it is hard to be sure that there were no decreases in either.

[2] In Albouy, Farahani, & Kim, "The Value of Rural and Urban Public Infrastructure" (2018), we examine the value of public infrastructure in urban counties as well. Much of the material here is related to that paper, which is useful for the technical analysis.

[3] A shortcoming of the model is that it does not handle cross-county commuting particularly well. We have tried to model cross-county spillovers, but often the amenity interactions we estimate are not highly significant or robust.

More productive firms pay workers greater amounts in accordance with their productivity. As an example, a highway that lowers the cost of firms to ship output and inputs could raise trade productivity.[4]

Table 1 Form of Benefit and How It Is Measured

Form of Benefit	Description	How It Is Measured
Trade Productivity	How efficiently local firms can use labor and capital to produce output that can be traded with neighboring counties	Wage levels of local workers, weighted by their share of costs in total production
Agricultural Productivity	How efficiently local producers can use labor, land, and capital to produce agricultural output	Value of agricultural land and wage levels of local workers, weighted by their share of costs in agricultural production
Home Productivity	How efficiently local producers can use labor, land, and capital to produce goods and services not tradable across counties	Population levels relative to housing prices, adjusted for local income levels
Quality-of-Life	How much local households benefit directly from an improvement, holding the consumption of produced goods constant	Willingness to pay of households measured by housing prices relative to income levels **plus** local population levels

Agricultural Productivity

Agricultural firms (or farms) produce output from local labor, agricultural land, and mobile capital. Agricultural goods are traded at prices set by international markets just like traded goods. Thus, through competitive forces, high wage and high agricultural land prices signal greater agricultural productivity. Because labor and capital costs are the same as in other traded sectors, agricultural productivity is identified separately from trade productivity through differences in agricultural land prices. Just as with other traded goods, improved transportation infrastructure – such as better waterways – can raise the agricultural productivity of a county.

Non-Traded or “Home” Productivity

The productivity of firms that produce goods that are consumed locally and not traded across cities, such as housing, also needs to be considered. While in some places, housing prices may be high because of high-paying jobs or amenities that deliver the quality-of-life, housing prices can also be high because productivity in the non-traded sector is low. Our measure of non-traded “home” productivity depends on a standard set of assumptions about how housing markets operate. In short, places with high home productivity are places that have relatively low housing price levels relative to their income and population

[4] Transportation costs are only dealt with indirectly through the productivity parameter. Diminishing returns are not an issue.

levels.[5] Infrastructure such as sewage systems, electrical grids, or paved side roads are improvements that could raise home productivity.

Quality-of-life Benefits

We determine quality-of-life benefits through two main channels. The first is through the willingness-to-pay of a household to live in a location, netting out differences in incomes. Households in counties with high costs-of-living relative to wage levels essentially sacrifice a great deal to live there. As their real incomes are lower, their consumption of market goods is lower. But spatial equilibrium requires that something else is keeping them there, otherwise, they would leave. Thus, their consumption of non-market goods, i.e. quality-of-life benefits, must be higher.

The second channel involves an adjustment for how many households live in an area relative to another. This accounts for possible differences in tastes among households, or potentially moving costs. When only a few people live in a county, we assume that they are among those who value it the most – i.e., they have very idiosyncratic tastes for the area. Thus, their willingness-to-pay measure will be skewed somewhat upwards relative to a county where lots of people live and do not have highly-idiosyncratic tastes. Analogously, when a place shrinks, residents who like the area the most are most likely to stay. Oppositely, when an area expands quickly, pay levels need to be high in order to entice workers to live.

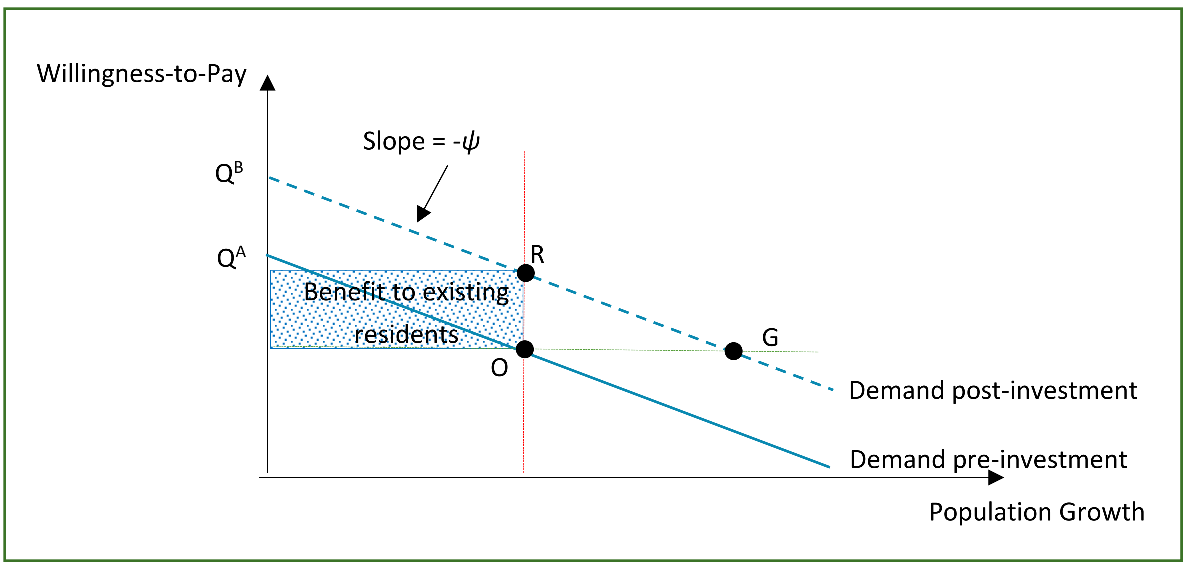


Figure 1 Demand to live in a county before and after an infrastructure investment

[5] A more direct measure of home productivity would measure the price of inputs, like land and labor, relative to output prices. This methodology is used by Albouy & Ehrlich (2018). Since data on residential land is unavailable across counties, we shy away from this more direct measure.

To see this, consider Figure 1, where a county with quality-of-life Q^A has willingness-to-pay and population growth described by point O. The solid blue demand curve shows that the greater the population growth, the lower the willingness-to-pay to live in the county will be. Imagine that a public improvement raises the demand to live in that county by raising its quality-of-life to Q^B, shifting the demand curve upwards to the dashed blue line. Depending on circumstances, such as available housing, different events could happen. First, the county's population growth could rise, so that willingness-to-pay stays the same, but population growth shifts to G. Alternatively, the population might not change, but the willingness-to-pay of locals will rise, as given in point R. How much to weigh population growth relative to willingness-to-pay is given by the slope of the demand curve, RO/OG.

Thus, in summary, we measure quality-of-life benefits from high prices, low wages, and higher population levels or growth. New school or hospital buildings are one example of an amenity that could in principle raise the quality-of-life benefits that households receive.

Who Receives the Benefits of Infrastructure?

Our model implies that four different types of agents could receive the benefits of infrastructure improvements. These are detailed in Table 2. There are two types of property owners, agricultural land-owners such as farmers, as well as residential homeowners. We see residential homeowners as benefiting from increases in the value of their land, not from other factors that could drive housing prices up, such as low housing productivity. Such factors represent an increase in housing costs, not in benefits provided by infrastructure or amenities.

Table 2 Benefits by Beneficiary and How It Is Measured

Beneficiary	Description	How It Is Measured
Agricultural Landowners	The value of agricultural land	Direct measure of agricultural land values
Residential Homeowners	Residential land values improved – considered separately from actual housing price; purged of "cost-disease" effects	Value inferred from housing, income, and population growth interpreted through a model of housing production
Local Residents (as Renters only)	Gain in income or quality-of-life net of increases in housing costs	Population growth interacted with heterogeneity parameter
Federal Tax Revenues	Gain to the federal government in increased revenues; revenues used to offset other taxes	Income interacted with federal tax rate

We also consider benefits to local residents viewed as renters. Thus, a household that occupies the house that it owns may be seen as a residential homeowner as well as a renter.

In the spatial equilibrium model, when preferences for places are completely homogenous and households are mobile, any improvements will result in higher rents, as new or potential residents will bid them up by the value of the benefit. In this case, local renters would not benefit from local improvements.[6] But if preferences are heterogeneous or there are moving costs, rents are not bid up by the amount of the benefits. Renters receive as a benefit the difference between the value of the benefit and the cost of the higher rent. In this case, landlords receive less of the benefit, while their renters earn more. Owner-occupying households receive the same amount in either case.

Finally, the fourth beneficiary of infrastructure is the federal government, and as such the country as a whole. As shown in Albouy & Farahani (2017), the federal government essentially taxes improvements that raise wages. This becomes a tax on tradable productivity benefits, agricultural or not. It may produce a slight implicit subsidy to quality-of-life or home productivity improving investments, as these could potentially lower local wages.

Data

Our county-level dataset spans back to 1970 using a number of datasets. Our panel contains data for 6 periods: 1970, 1980, 1990, 2000, 2006, and 2012.

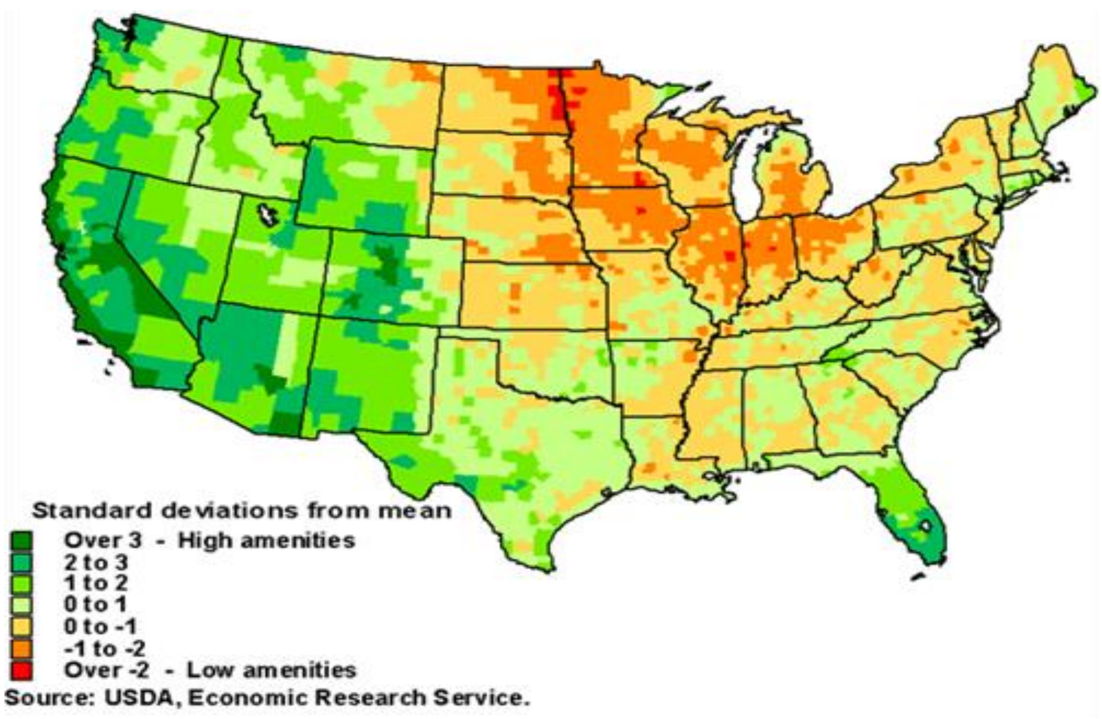


Figure 2 USDA Natural Amenities Scale across Counties

[6] There would still likely to be a small benefit to all renters everywhere, although that is beyond the modeling issues we consider.

The USDA Natural Amenities Scale

The natural amenities scale (hereafter, amenities scale) is from McGranahan (1999). According to USDA, the natural amenities scale is "a measure of the physical characteristics of a county area that enhance the location as a place to live." The scale is calculated based on warm winter, winter sun, temperate summer, low summer humidity, topographic variation, and water area, which are environmental qualities that people generally prefer.

These measures are chosen so as not to be redundant. According to their report, the amenities predict which counties have seen their populations grow over up to 1980.

Census Outcome Variables

Our data come primarily from the Census, including the decennial Census for Population and Housing, for every 10 years between 1970 and 2010. Government spending data are from the Census of Governments. Farm and land value data are provided by the Census of Agriculture. Details about the variables are provided in Table 3.

Table 3 List of Variables

Variable	Source	Description
Public capital stock	Government Finances series (Census)	in 2012 $
Population	Census of Population	Total population count
Average family income	Census of Population	in 2012 $
Number employed	Census of Population	Total number of employed
Share employment in agriculture	Census of Population	Ratio to total number of employed
Share employment in manufacturing	Census of Population	Ratio to total number of employed
Value of farmland and building	Census of Agriculture	in 2012 $ (per acre)
Value of machinery purchased	Census of Agriculture	in 2012 $ (per acre)
Percent farmland	Census of Agriculture	Ratio of farmland to land area
Area	Census of Agriculture	Approximate land area in acres
Average housing value	Census of Housing	in 2012 $
Average gross rent	Census of Housing	in 2012 $

Defining Rural Counties

As our data are at the county level, we cannot perfectly subdivide areas into rural or suburban, as that is defined at the Census tract or block-group level. Most counties contain at least an urban cluster of 2,500, although many are still overwhelmingly rural. Instead, we classify a county as rural if it satisfies either of the following two criteria:

1. Rural Residency: Over 40 percent of its population lives in non-urban Census Block groups areas (blue in Figure 3) in the year 2000.[7]
2. Low Density: The population density over the entire county is under 64 per square mile and the entire population of the county is less than 50,000 (green in Figure 3) in the year 2000.

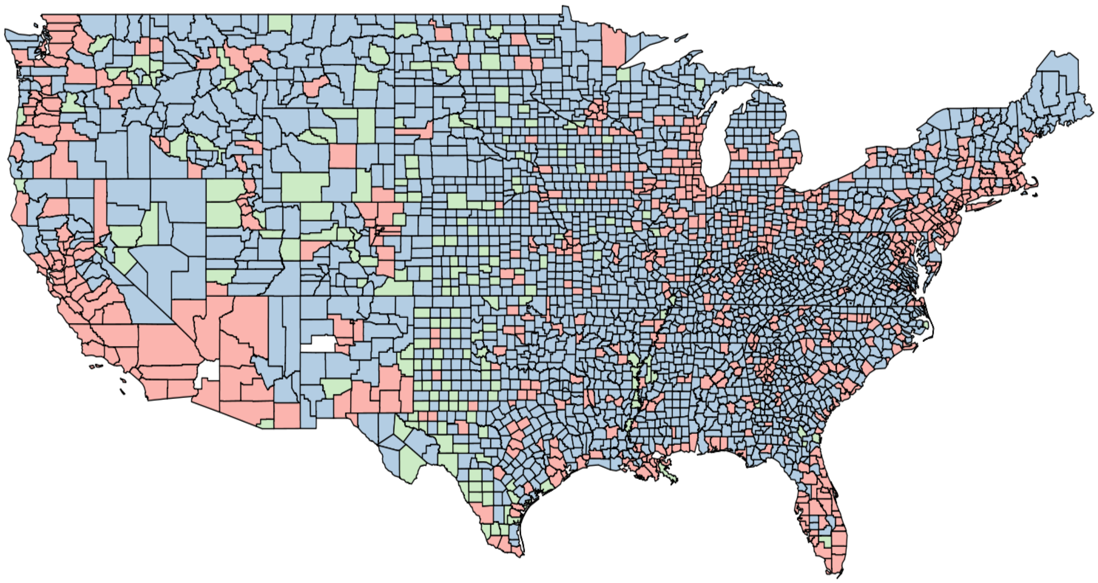
Since counties are too large to be classified singly as all rural or urban, this classification is imperfect. Nevertheless, we find that our results are largely invariant to the precise definition of rural that we use. For instance, our results are very similar if we define rural counties as counties outside of designated Metropolitan (Core-Based) Statistical Areas (See Appendix D).

[7] Our definition of urban-rural builds of the Census report "Defining Rural at the U.S. Census Bureau" (Ratcliffe, Burd, Holder, & Fields, 2016) for classifying counties. Urban and rural areas are defined at the Census block-group and tract level, not the county level. This report classifies counties as "completely rural" (100% rural areas), "mostly rural" (50 to 99%), and "mostly urban" (0 to 49%). It appeared, however, that some of the "mostly urban" counties were still quite rural, with much of the population living in small urban clusters and surrounded by large amounts of sparsely inhabited land. This motivated our definition.

Another approach would involve using all areas outside of non-metro areas. Our general results vary rather little depending on the definition we use. Moreover, we chose not to use that definition based on the following passage from the Office of Management and Budget (2000):

> *The Metropolitan and Micropolitan Statistical Area Standards do not equate to an urban-rural classification; all counties included in Metropolitan and Micropolitan Statistical Areas and many other counties contain both urban and rural territory and populations. Programs that base funding levels or eligibility on whether a county is included in a Metropolitan or Micropolitan Statistical Area may not accurately address issues or problems faced by local populations, organizations, institutions, or governmental units. For instance, programs that seek to strengthen rural economies by focusing solely on counties located outside Metropolitan Statistical Areas could ignore a predominantly rural county that is included in a Metropolitan Statistical Area because a high percentage of the county's residents commute to urban centers for work. Although the inclusion of such a county in a Metropolitan Statistical Area indicates the existence of economic ties, as measured by commuting, with the central counties of that Metropolitan Statistical Area, it may also indicate a need to provide programs that would strengthen the county's rural economy so that workers are not compelled to leave the county in search of jobs.*

This passage indeed appears relevant to the analysis of public infrastructure.



Red → urban: percent rural population < 40%
Blue → Rural: percent rural population > 40%
Green → Rural: percent rural population < 40% but (population density < 64 per square mile and population < 50,000)

Figure 3 Urban/Rural Classification of Counties

Public Infrastructure Stock

County Area Finances dataset of the US Census reports local government finance activities, aggregated for each of the over 3,000 counties in the nation[8]. We use county area capital outlays between 1902[9] and 2012 to measure the replacement value of public capital, that is, the stock of public infrastructure. By applying the perpetual inventory technique to gross-of-depreciation capital investment flows from 1902 to the present. We divide capital investment into two different types: 1) construction, 2) land and existing structures (L&ES) and equipment. County Area Finances data reports the sum of equipment and land & existing structures (L&ES). We use the average of equipment and L&ES depreciation rates weighted by their respective shares in state and city finances to perpetually discount this aggregated category over time.[10]

[8] Local governments comprise counties, municipalities, townships, special districts, and independent school districts. Activities of dependent public school systems are included with the data of their parent local government. Since County Area Finances do not include the expenditures by state governments, we separately control for state infrastructure which is estimated similarly.
[9] Since county area finances are aggregated at state level between 1902 and 1955, we use each county's share of state level aggregates between 1955 and 1975 to allocate county area finances in this period.
[10] We use 1.82% depreciation rate for construction. From other government finance reports we know the average of city and state government mean ratio of equipment to L&ES is 25%. Averaging 1.638% for L&ES and 11% for equipment, we arrive at 3.4% for the depreciation rate of the aggregated category of L&ES and equipment.

Figure 4 shows public infrastructure per square mile. This map shows how infrastructure levels tend to be the highest in or near urban areas. It is worth noting that the Census of Finances may have considerable measurement error in its reporting. In addition, the perpetual inventory method may provide a very imperfect method of capturing differences and changes in the public infrastructure stock. The resulting measurement problems mean that our estimates risk being attenuated, i.e. that the effects we estimate are smaller than the actual ones.

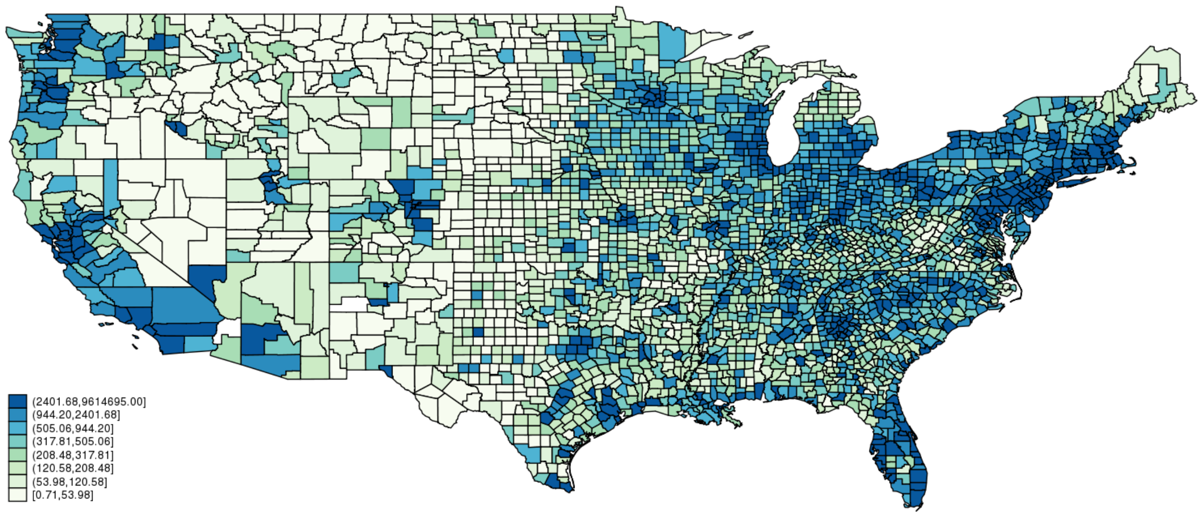


Figure 4 Infrastructure per square mile in 2012

The levels of public infrastructure per capita are mapped in Figure 5. The picture changes considerably if we consider public infrastructure per capita. Here the differences between urban and rural areas are less extreme. Both figures show much greater investment in states like New York, Minnesota, and Wyoming over others. Overall, investment levels are generally higher in the North and West, with the exceptions of Southern Florida, Louisiana, and certain urban agglomerations, like Houston.

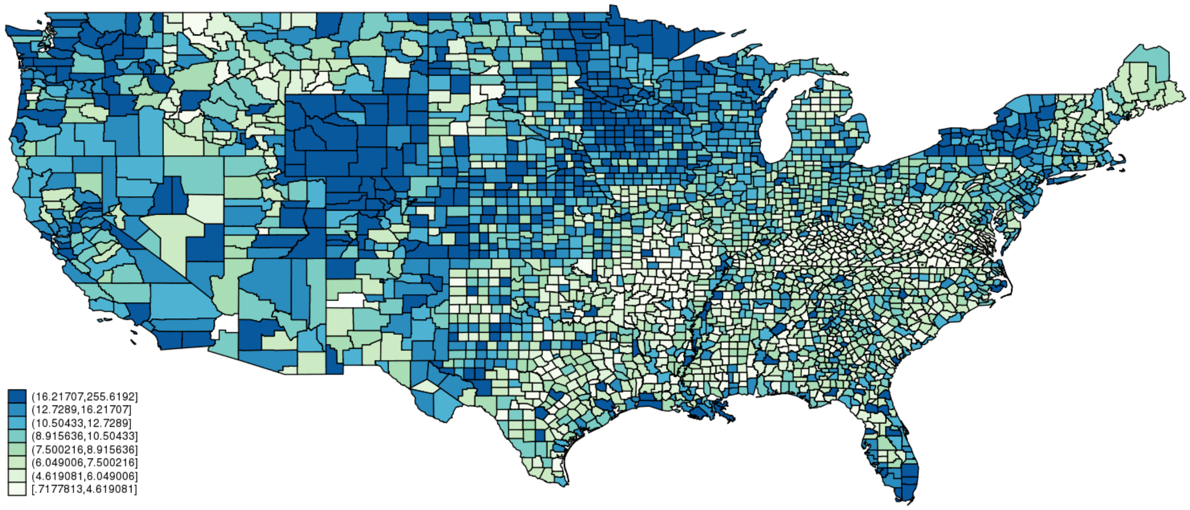


Figure 5 Infrastructure per capita in 2012

Differences and Trends in High and Low Amenity Counties

Characteristics of High and Low Amenity Counties

When urban counties are taken out, the amenity scale is slightly below the average of zero. We define high-amenity counties as having a positive amenities scale; low-amenity, a negative scale. Summary statistics, broken down for high and low amenity counties, are shown in Table 4 Descriptive Statistics for Rural County Panel (1970-2012). The numbers presented show observations for all years. Note that public capital is shown in millions: the average value of public infrastructure in a county is $180 million, however per capita it is closer to $7,500. Meanwhile, housing wealth per capita is over 5 times that at $115,000 per household, or $40,000 per person on average over the period.

Table 4 Descriptive Statistics for Rural County Panel (1970-2012)

	High Amenity	Low Amenity	Rural Total	
	Mean	Mean	Mean	Std Dev.
Amenities scale	1.38	-1.48	-0.34	1.92
Public capital	168	189	180	293
Public capital per capita	6,618	8,044	7,474	8,207
Population	24,247	23,957	24,086	23,902
Average family income	57,438	58,416	58,025	13,344
Average housing value	126,909	111,904	117,898	55,345
Average gross rent	6,901	6,664	6,758	1,903
Value of farm land and building per acre	1,432	1,914	1,630	1,423
Land area in square miles	1,270	705	955	1,202
Percent farm land	0.46	0.66	0.54	0.33

Number employed	9,984	10,143	10,073	10,783
Share employment agricultural	0.05	0.07	0.06	0.06
Share employment mining	0.02	0.01	0.02	0.04
Share employment construction	0.08	0.07	0.07	0.02
Share employment manufacturing	0.19	0.21	0.2	0.11
Sample size (county X years)	6,324	7,980	14,304	
Number of counties	1,054	1,330	2,384	

Note: Public capital is in millions. All values are in 2012 USD.
High amenity is a place where amenities scale is greater than or equal to zero.
Low amenity is a place where amenities scale is less than zero.
County averages are weighted by population or land area to produce national averages.

To probe deeper into the relationship between the outcome measures, public capital, and the amenities scale, we consider their changes over time in the following figures. Thus, we consider the time trends in counties with a positive (high) amenity scale versus those with a negative (low) scale.

Error! Reference source not found. through **Error! Reference source not found.** show the trends in outcomes since 1970 for high amenity counties relative to low amenity counties. Accordingly, **Error! Reference source not found.** shows that in 1970 high amenity counties on average had only 84 percent of the population of low-amenity counties, i.e. they had 16 percent lower populations. However, as previous research has found, population levels grew in high amenity counties. In fact, these now contain 12 percent *greater* population. This reflects an on-going pattern. It should be kept in mind that high-amenity counties have larger areas than low-amenity counties, and therefore they continue to have lower population density when the entire county area is factored in.

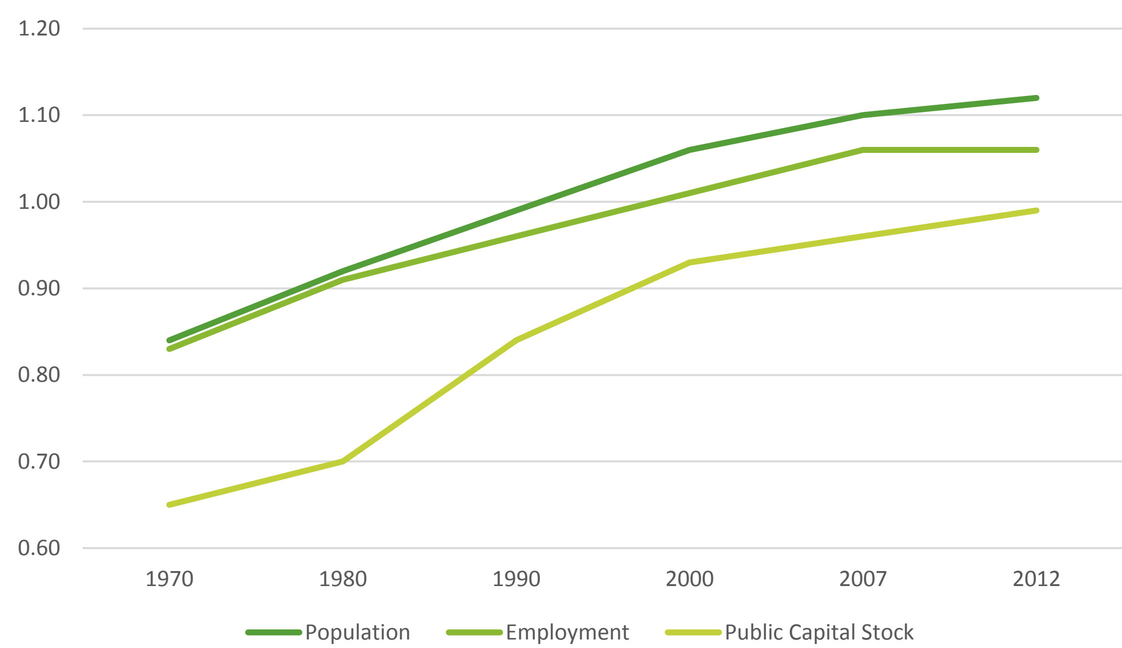


Figure 6 Population, Employment, and Public Capital Stock

The graph shows similar trends in employment, albeit with somewhat less growth. Employment was 17 percent lower in high-amenity counties in 1970, and then 6 percent higher in 2012. This implies a relative decline in the employment-population ratio in high-amenity places. This may have little to do with unemployment, since many of those who are not employed, such as retired persons, are out of the labor force. It seems natural that those outside the labor force would prefer high-amenity areas.

There is less public capital in high-amenity areas. The ratio was only 65 percent in 1970. Comparing this to the population and employment numbers, the amount of capital is actually lower per person and per job. The growth since 1970 has reduced discrepancy but not eliminated it: In 2012 this number was just 1 percent lower. Again, it should be borne in mind that while more newly populated, these high-amenity counties are larger in terms of land area.

In Figure 7, we see that relative family income levels in high and low amenity counties are on average fairly similar. We see only slightly lower income levels at the beginning and end of the sample.

Housing values in high amenity counties show a clear upward trend. In 1970, house values were similar on average. By 2012, they were approximately 20 percent higher in high-amenity areas. Thus, it seems people are paying more for higher amenities than they used to.

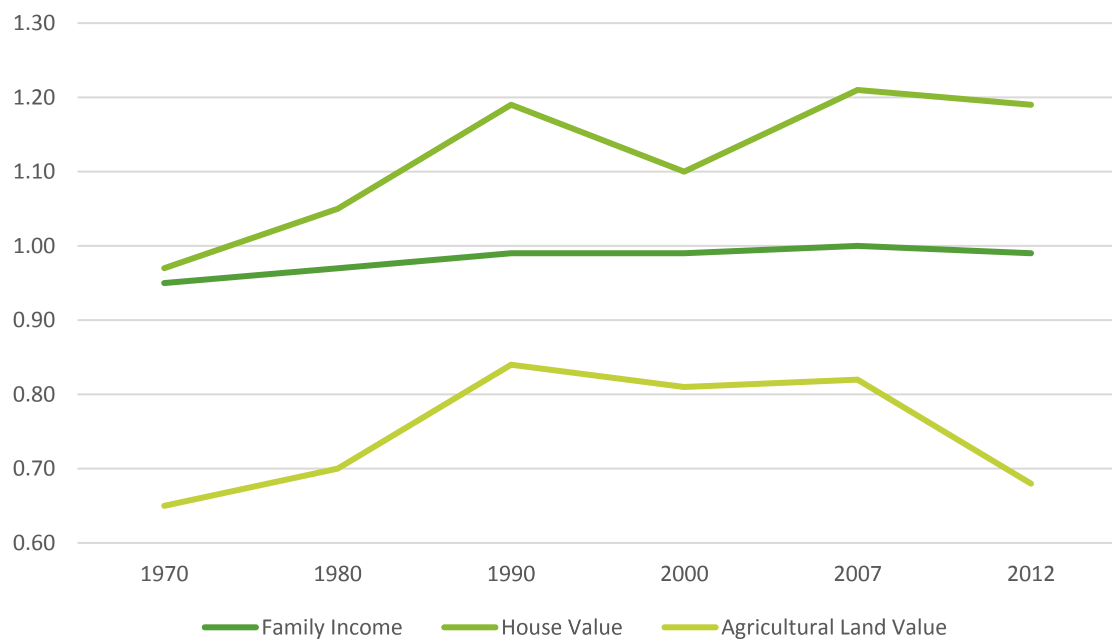


Figure 7 Income, Housing Value, and Agricultural Land Value

At the same time, the trend for agricultural land values mirrors and greatly exaggerates that of incomes. It shows high amenity counties having lower agricultural values for all years. This may have something to do with these counties having lower agricultural productivity. Whatever the case, these differential trends help to justify treated residential and agricultural land markets separately.

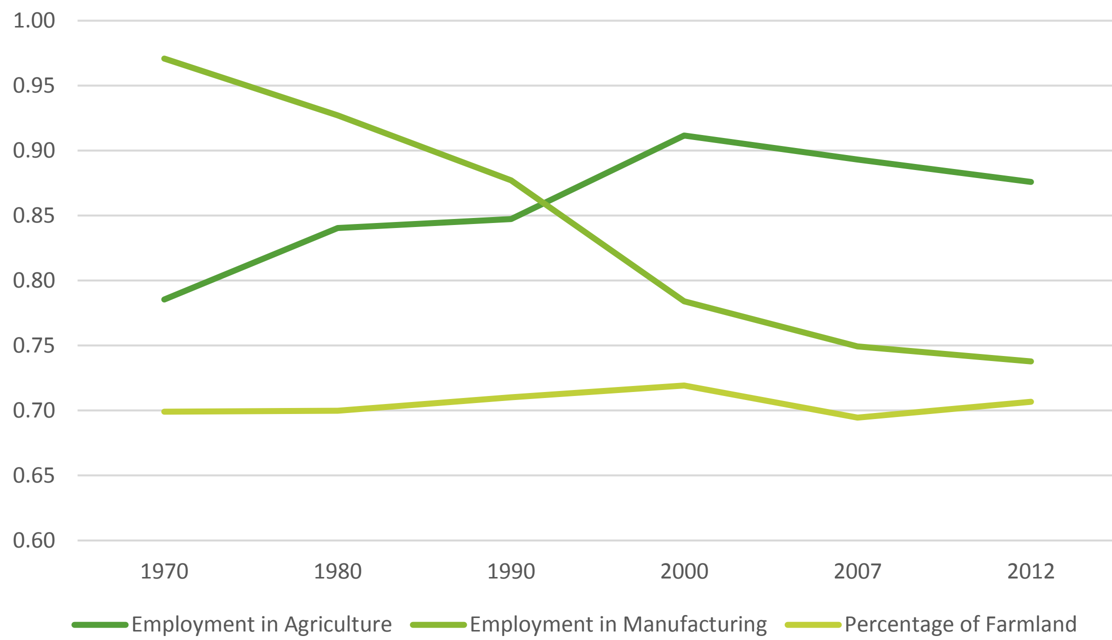


Figure 8 Employment and Farmland High vs. Low Amenity Ratios from 1970 to 2012

Note: Employment in Agriculture variable of 1980 is replaced by 1990 one since the data is not available for 1980.

In **Error! Reference source not found.** we see that farms take up smaller shares of land and agricultural employment in high-amenity counties. High amenity counties have more land devoted to wilderness areas. Also, we see that the share of manufacturing employment in high amenity counties used to be similar to the low amenity counties in the beginning. With the overall decline in manufacturing, high-amenity counties saw a more rapid decline than low-amenity counties. The share of agricultural employment declines both in high and low amenity counties, and the decline is more rapid in low amenity counties.

Spatial Differences in Amenities and Infrastructure

One of the most interesting features of spatial analysis is how different areas show persistent differences in outcomes. Here, we examine long-standing differences, under the understanding that regional convergence has largely slowed down. Rural counties exhibit quite large differences in prices, wages, and population numbers that we use to construct the measures of productivity and quality-of-life alluded to earlier. While our core analysis focuses on changes within counties over time, it is still interesting to see what the differences across counties look like. More caution may be needed in interpreting these numbers as there are potentially more confounding factors across space overall, than within counties over time, once common time trends are taken into account, as our later panel analysis does.

For the simple spatial analysis, we first compute county values of public capital, population, income, housing, and land prices for each of the 6 periods in the sample. We then deflate the values in each period by the national average at the time, to get the value of the county relative to the country in that year. We then averaging the 6 periods together to get the average relative value for all years. This produces county averages that remove year effects. Afterward, we compute county-level measures of revealed quality-of-life and productivity. Note the amenities scale are fixed over time.

First, we consider the relationship between public capital and the amenities scale. **Error! Reference source not found.** shows the time-averaged measure for each of the 2400 counties in our rural sample. The larger markers correspond to counties with higher average populations. The line comes from a simple bivariate regression, weighted by county's average population.

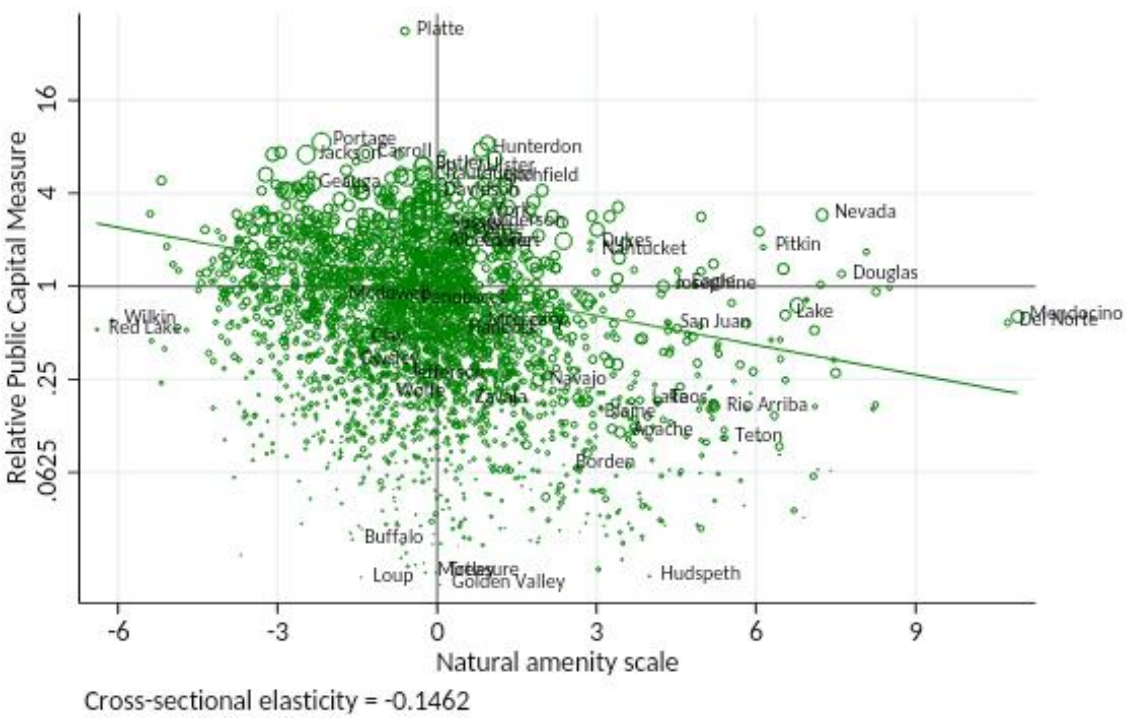


Figure 9 Spatial Public Capital Measure and Amenities Scale

Here, the line shows that on average, high-amenity counties tend to have lower levels of infrastructure. Statistically, the relationship is very significant, with a one-point increase in the amenities scale indicating a 14 percent reduction in public capital. This is presented only as a correlation. As we will see below, historically, lower amenity counties have been more heavily populated, but shrinking relatively – on average over the period. However, the relationship between population and the amenities scale is zero. Thus, this relationship may be due to counties having higher historical population having made greater infrastructure investments in the past. It could also be that households in higher-amenity counties simply have lower preferences for infrastructure investments.

Next, we focus on the relationship between the quality-of-life measure and the amenities scale. As predicted, there is a strong positive relationship between the quality-of-life measure and the amenities scale. The semi-elasticity predicts that for a one-point increase in the amenities scale, households would sacrifice 1.6 percent of their net consumption. Over a wider range of 10 points, from the 1st percentile to the 99th percentile, they would reduce their income by 16 percent. This difference amounts from Piatt County, IL, which is flat and has very seasonal weather, to Nevada County, CA, with mountainous terrain, to Lake Tahoe's mild summers and sunny winters.

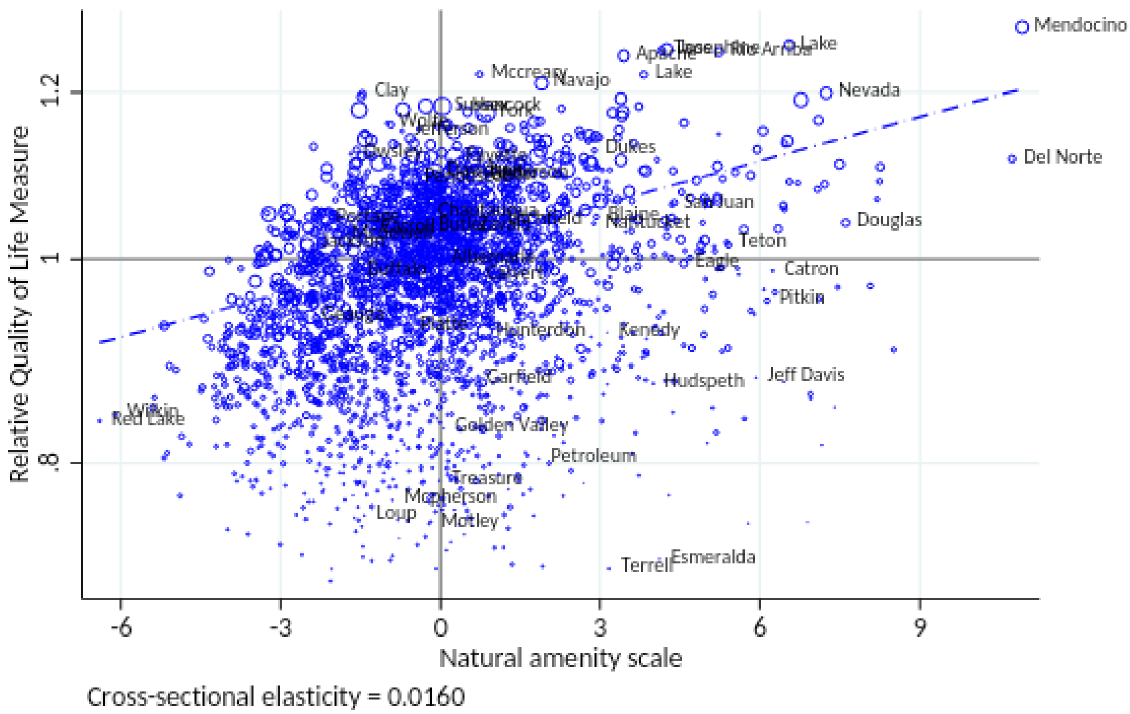


Figure 10 Quality-of-Life Measure and Amenities Scale

Error! Reference source not found. examines the relationship between trade productivity (measured by incomes) and amenities scale. Here we see a slightly negative relationship as the most amenable places are not the most productive on average. This raises serious questions as to whether this correlation is actually causal. It could also be that less productive workers or firms are drawn to higher amenity counties.

Now consider the spatial relationship between quality-of-life and public capital, as seen in **Error! Reference source not found.**. Here there is a strong negative relationship with an elasticity of -0.023. Unlike the amenity measure, this is a full elasticity, comparing one percentage change to another. The willingness-to-pay component of the quality-of-life measure alone, i.e., prices relative to wages, shows a negative relationship with public capital cross-sectionally. Indeed, as we saw earlier, high amenity areas tend to have lower levels of public infrastructure. When we include amenities scale and public capital together, the relationship between quality-of-life and capital becomes negative, while the interacted relationship with amenities scale is positive. This relationship changes in the panel analysis.

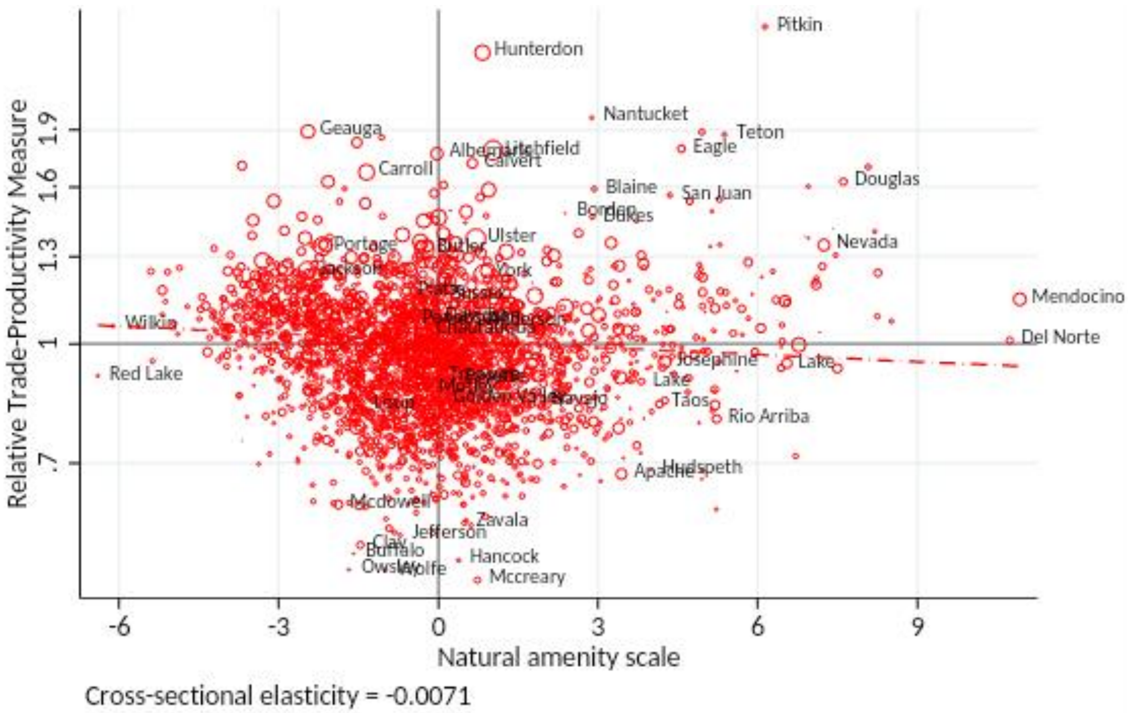


Figure 11 Spatial Trade Productivity Measure and Amenities Scale

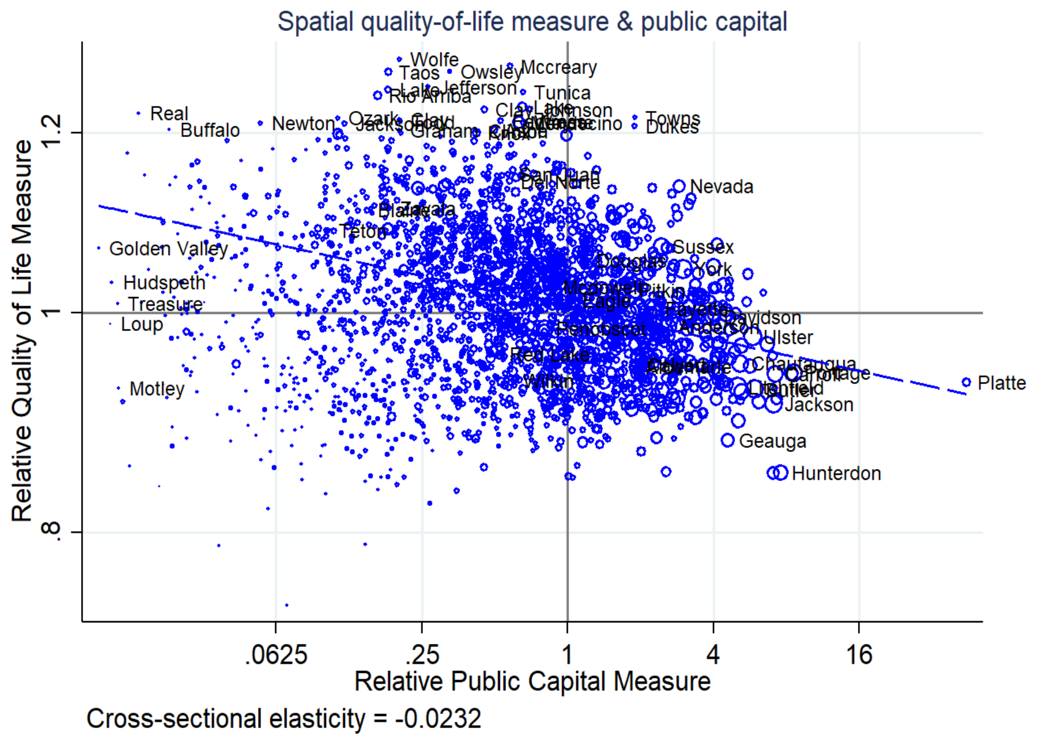


Figure 12 Quality-of-Life Measure and Public Capital

The relationship between trade productivity, as measured by income, shown in Figure 13, reveals a very strong positive relationship between productivity and public capital. Again, a concern here is that productivity may be higher in more populous areas where there is more productivity. Indeed, higher population levels produced agglomeration economies through greater sharing of public goods, such as infrastructure, but also through improved matching of workers to jobs according to their abilities, as well as greater amounts of learning spillovers from non-directed interactions. Interestingly, in the cross-section, the interaction between public capital and amenities scale for determining productivity is negative; this relationship does not hold up in the later analysis.

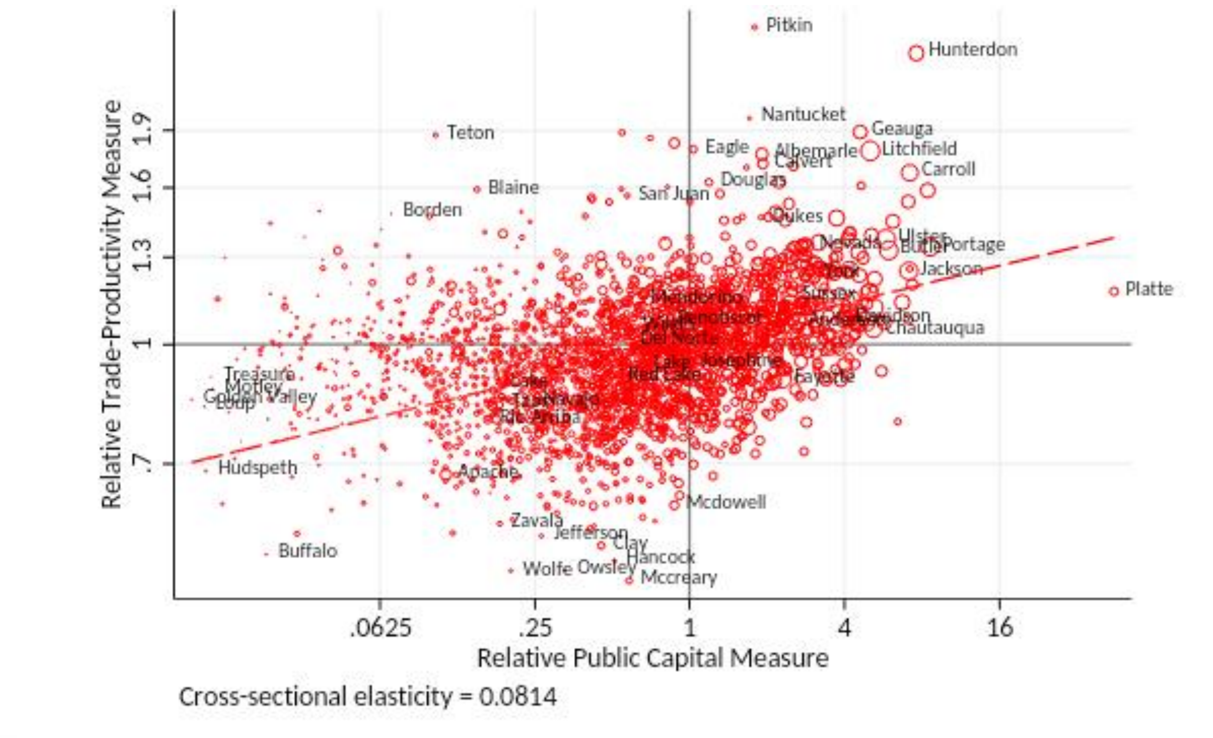


Figure 13 Spatial Trade Productivity Measure and Public Capital

The spatial relationship between home productivity and agricultural productivity and public capital (not shown) is also strongly positive. On the other hand, home productivity is negatively related to the amenities scale, although it shows no relationship with public capital (also not shown). This latter finding suggests to us that areas with greater amenities scale may typically be more difficult to build new housing in. This may have something to do with regulatory restrictions on land use, possibly due to federal or state ownership. It may also have much to do with these areas being more mountainous or surrounded by water, which may hinder new construction. (Saiz, 2010).

Panel Estimates of the Effect of Infrastructure within Counties

With these basic relationships understood, we can now probe the relationship between infrastructure investments over time within counties, and changes in the outcomes of interest. To do this we use a panel estimator, which has "fixed effect" indicator controls for each county to control for the fixed characteristics of each particular county, such as their geography. The econometric specifications also control for a range of potentially important confounding variables that change endogenously over time, such as shares of the population by age, race, and education levels, state tax rates and state infrastructure. By controlling for "year effects," the specifications also control for all national swings in income and capital levels.

Because amenities are fixed, their direct effects from the amenities scale are not seen in the panel estimates. Instead, we examine how the effect of public infrastructure varies in high-amenity vs. low-amenity areas by interacting the amenities scale with the logarithm of public investment. The estimated coefficient on the interaction estimates how much more or less of an impact public infrastructure has in more amenable places.

Rather than report the coefficient for a one-point change in the amenities scale, we multiply the coefficient by the average amenities scale of high and low-amenity counties. Thus, one can see the difference in coefficient between typical low amenity counties from average amenity counties (zero amenities scale) and similarly, the difference in typical high amenity counties from average amenity counties. Later, we present the effects for a typical high versus a typical low amenity county.

Bear in mind that the estimates below are not guaranteed to provide the true causal effects of infrastructure. Infrastructure investments may be targeted towards areas where greater growth in employment and income are projected. In that case, our estimates will be biased upwards towards finding larger effects. In a sense the results could suffer from "reverse causality," as greater (expected) future growth causes infrastructure investments, rather than the other way around. If this is more of an issue in high amenity areas, that could account for interaction effect, although it seems that bias for the interaction is less likely. While we expect reverse causality to estimate biases upwards, measurement error problems discussed before, are expected to bias estimates in the opposite way. Therefore, it is important to interpret all of the magnitude estimates appropriately.

In Figure 14, we see that infrastructure is positively related to population growth, with an elasticity of 0.175. Thus, a 10-percent increase in infrastructure, predicts a 1.75 percentage-point increase in population. Note that a 10% permanent increase in infrastructure, would require about $191 per household per year to finance and maintain.[11] Furthermore, the interaction effect is almost half as high as the main effect, meaning the effect is almost a quarter stronger in high-amenity counties (0.218), and a quarter weaker in low-amenity counties (0.129).

The elasticity effects of infrastructure on income at 0.021, are more modest. A 10-percent increase in infrastructure is associated with about a $125 gain in productivity. The interaction effect is two-thirds as large, implying an elasticity of 0.28 ($168) elasticity in high-amenity counties, and 0.14 ($84) elasticity in low-amenity counties. Note that about 30 percent of that increase will go towards greater federal and state tax payments. Thus, after-tax income rises by merely 1.5 percent.

For house values, there is a rather significant elasticity of 0.053. Based on an average house value of $120,000, this would imply that a 10-percent increase in infrastructure raises home values by $636. This is very similar to the cost of the infrastructure. Since housing and similar non-tradables account for

[11] Throughout the sample, the amount of infrastructure is about $750 per person. With an average household size of close to 2.8, this amounts to about $2,100 per household. The discount rate (7%) plus average depreciation rate (2.1%) annualizes this cost at around $191 per household.

about 30 percent of income, total expenditures probably rise by roughly 0.016. Since this elasticity is about the same as for nominal income after taxes, real incomes do roughly stay constant in response to infrastructure investments, i.e. willingness-to-pay stays constant. In Figure 1, this situation is described by point G, where quality-of-life improvements are largely identified through greater population growth.

The even larger interaction effect suggests this price effect is much greater in high-amenity counties by an amount exceeding the interaction for incomes. Therefore, after-tax real incomes in fact drop slightly, revealing a slightly positive increase in willingness-to-pay. Meanwhile, in low-amenity counties, willingness-to-pay may even drop slightly.

The elasticities for agricultural land values of 0.086 are larger than for house values.[12] Since the mean value per acre is just over $1,600, this amounts to a $13.8 appreciation per acre for a 10-percent increase in infrastructure. The interaction effects toggle this amount from $8.7 in low-amenity counties to $18.8 in high-amenity counties.

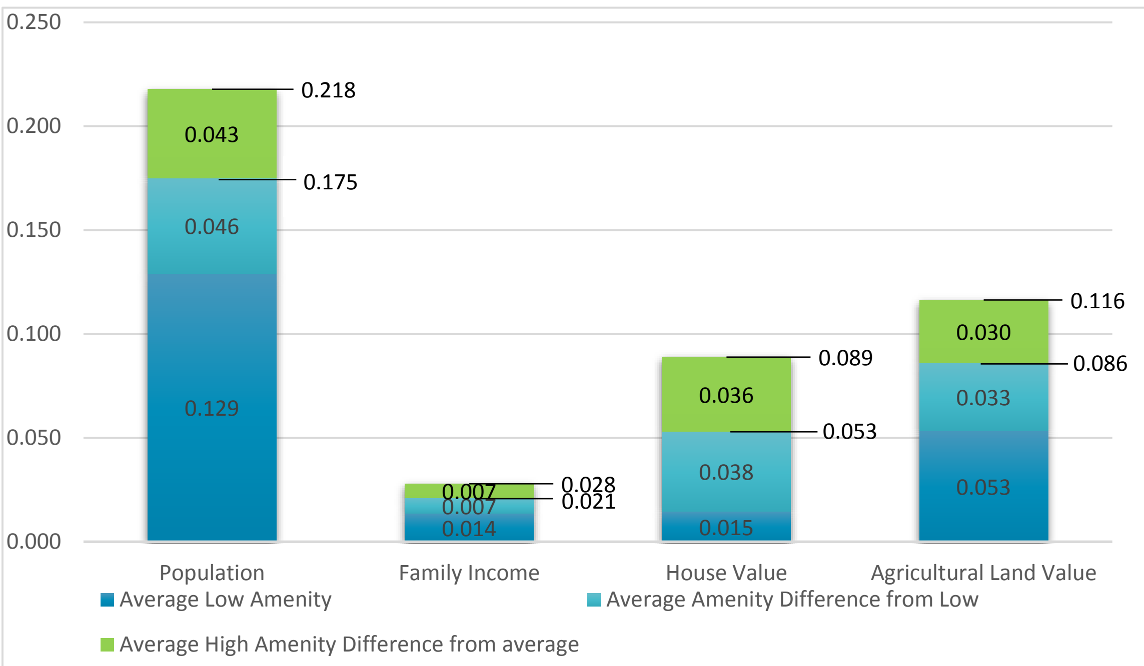


Figure 14 Elasticity of Main Outcomes with Respect to Infrastructure with Amenity Interaction

Note: Low/high amenity coefficient is calculated by multiplying average amenities scale of low/high amenity counties (-1.48 and 1.38 respectively) to the interaction coefficient. Numbers next to the stacked bars are the coefficients of the main effect and the average high amenity counties.

In Figure 15, we consider the elasticities of other outcomes not used in the equilibrium model, but which are still potentially interesting. First, elasticities of employment are similar to those of population.

[12] This is not altogether surprising since housing is only partly land, and land values can vary spatially much more across areas than construction costs due to so-called "land leverage."

Agricultural employment is on the whole less responsive to infrastructure investments, except in very amenable areas. Manufacturing employment is also less responsive.

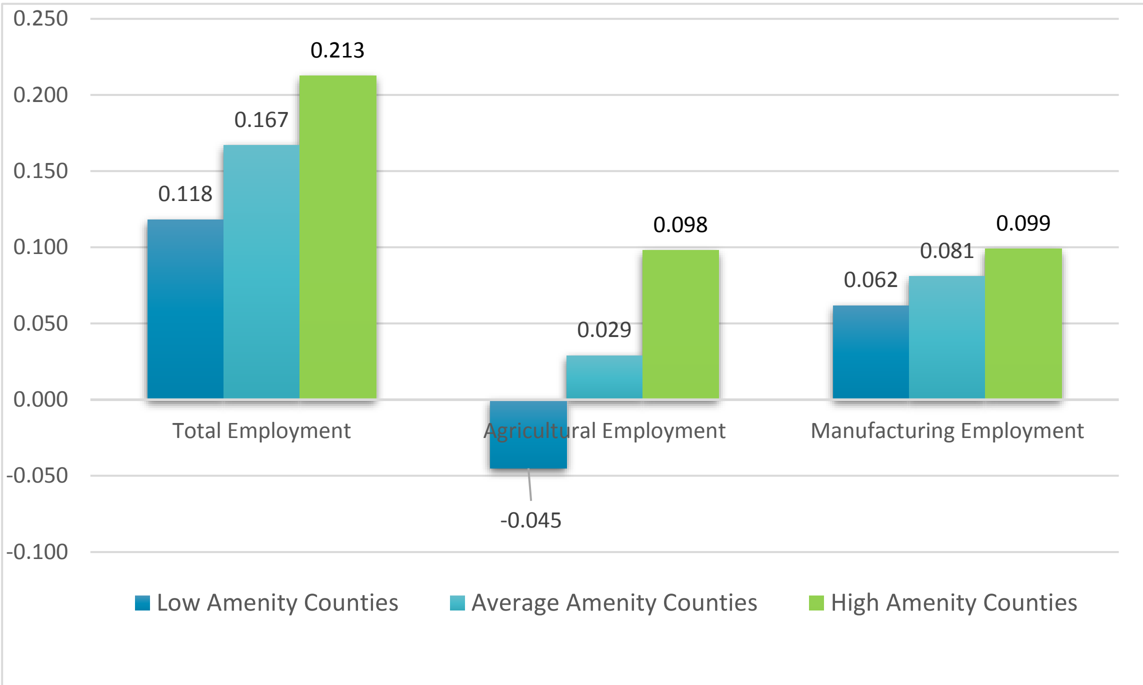


Figure 15 Elasticity of Additional Outcomes with Respect to Infrastructure with Amenity Interaction

Note: Low/high amenity coefficient is calculated by multiplying average amenities scale of low/high amenity counties (-1.48 and 1.38 respectively) to the interaction coefficient. Average amenity refers to average elasticity for all rural counties. Significance levels are in the appendix Table A. 4.

Finally, Figure 16 reveals elasticities for quality-of-life and productivity effects provided by the spatial model. First, there are sizable quality-of-life effects, with the main elasticity of 0.013. This amounts to about $75 per household in value for a 10-percent improvement. As described above, this main effect is identified off of greater population growth. In high-amenity areas, where willingness-to-pay also rises and population growth is greater, the identified elasticity is much greater at 0.023. Meanwhile, in low amenity counties, it is 0.003. Thus, it appears that infrastructure is largely a complement to amenities, as opposed to a substitute for them. Moreover, these are significant benefits that would not show up in traditional income-based approaches.

Trade productivity, which is identified off of income gains alone, has a somewhat higher elasticity than quality-of-life of 0.025. Note this panel estimate is only about a third of the size of that measured off the cross-section above. The interaction effect is comparable to that for income. Overall, these results reinforce the idea that infrastructure grows the economy as traditionally seen, and this is particularly true in high-amenity areas.

Agricultural productivity has a main effect larger in size than trade productivity. With the interaction effect with amenities scale, the effect of infrastructure appears to be stronger.

Lastly, the results for home productivity have a positive main effect as population gains are relatively large relative to housing-price gains (netting out higher construction costs). However, this effect appears to be modest economically. The interaction effect is negative, as population gains are relatively weak relative to price gains in the interaction. This implies home productivity effect in high-amenity areas indistinguishable from zero. This could be related to the spatial finding that home productivity is negatively related to amenities scale, as high-amenity areas may be subject to geographic or regulatory constraints that prevent infrastructure from making places more affordable.

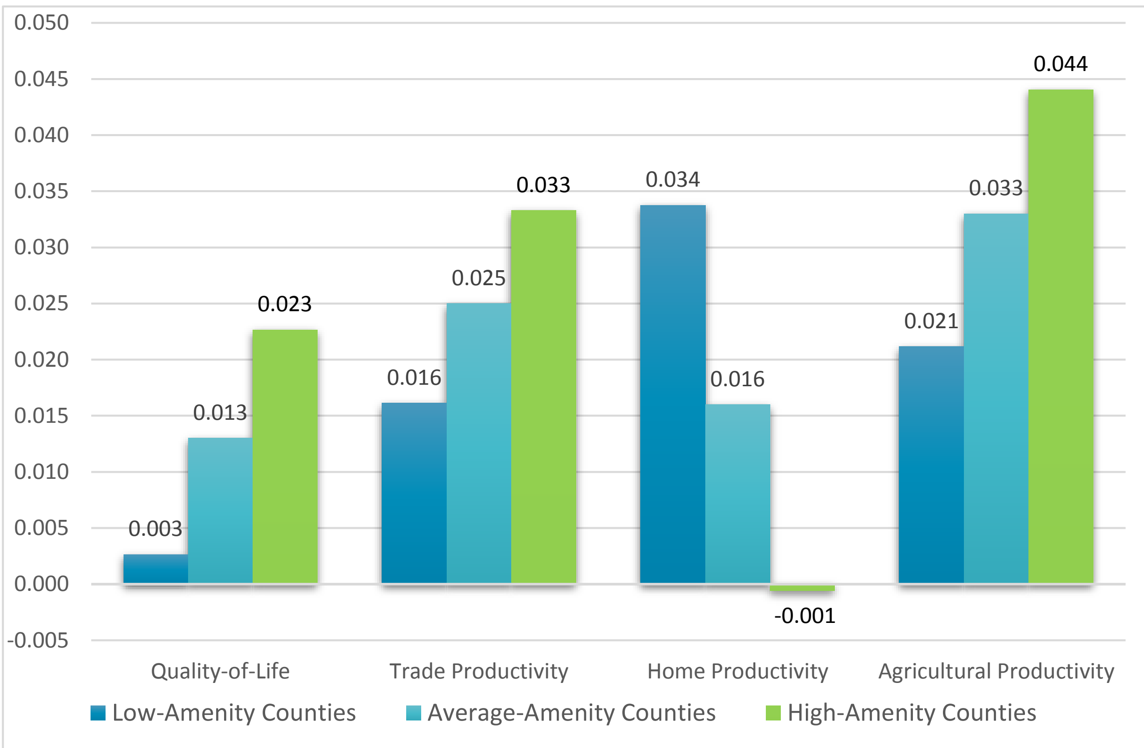


Figure 16 Elasticity of Quality-of-life and Productivities with Respect to Infrastructure and Amenity

Note: Low/high amenity coefficient is calculated by multiplying average amenities scale of low/high amenity counties (-1.48 and 1.38 respectively) to the interaction coefficient. Average amenity refers to average elasticity for all rural counties. Significance levels are in the appendix Table A. 6.

The Form and Distribution of Benefits

Evaluating the benefits of infrastructure relative to the costs requires converting the estimated elasticities into dollar amounts. Doing this requires comparing changes in assets, like housing prices and land values, to changes in incomes, which are flows. Thus, we capitalize the income flows using a somewhat conservative rate of 7 percent, based on a standard user-cost of housing formula. Table 5 shows capitalized flow variables in the year of 2012. Comparing the capitalized income to the capital stock, the user cost of the public capital stock relative to income appears to be about 3.4 to 3.8 percent of total income overall in high and low-amenity counties respectively. In other words, income is 24 to 29 times expenditures on public capital.

Table 5 Aggregate Values of Rural Counties in 2012

	High Amenity		Low Amenity		Rural Total	
	Mean	Sum	Mean	Sum	Mean	Sum
Public Capital	246	259	249	331	248	590
Aggregate Family Income	510	538	460	612	482	1,150
Aggregate Family Income (capitalized)	7,288	7,681	6,573	8,742	6,889	16,423
Aggregate House Value	1,445	1,518	1,084	1,442	1,243	2,960
Aggregate Gross Rent (capitalized)	347	366	283	376	311	742
Aggregate Farmland Value	525	549	811	1,077	685	1,626

Note: Mean values in millions and sums values in billions.

With these numbers, the dollar values for the quality-of-life and productivity benefits of public infrastructure are stacked in **Error! Reference source not found.** below for low and high amenity counties. In low amenity counties, most of the benefits accrue in the form of traded and home productivity, with small benefits in agricultural productivity and quality-of-life. In high-amenity counties, the benefits in terms of traded productivity and quality-of-life are much higher. This suggests that for the most part, amenities scale and public infrastructure are complements, especially when it comes to quality-of-life benefits, but also for traded forms of productivity. High-amenity areas appear to have a hard time getting benefits to home productivity benefits for reasons that deserve further investigation.

Whether or not the infrastructure investments pass the cost-benefit test depends much on how they were financed in the data. Our sources do not contain a good account of whether local, state, or federal money was granted to pay for them. However, as we are controlling for local tax rates, most of the remaining variation in infrastructure likely comes from external sources.

If funds were generated locally, then the benefits we estimate may be seen as net benefits after netting out the cost. Brueckner (1982) shows that when the effects of local taxes are netted out, a positive marginal effect on local benefits implies that more public expenditures out of local funds would be welfare-enhancing. In this case, any positive effect would imply that on average the benefits of infrastructure exceeded the cost.

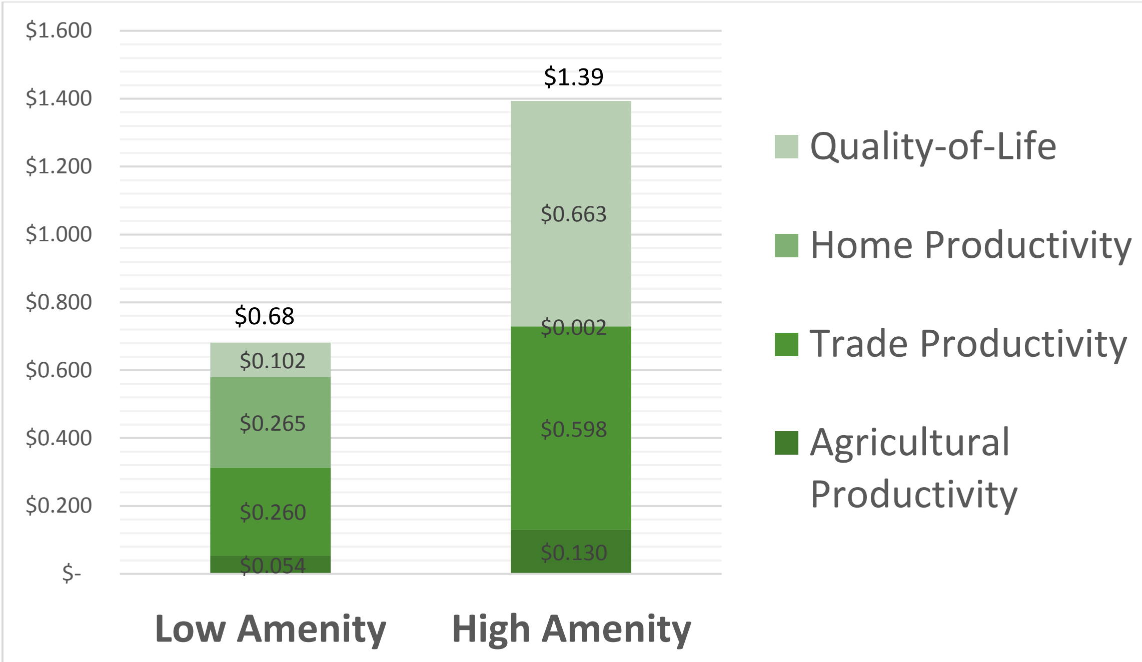


Figure 17 Form of Benefits of Public Capital per Dollar Invested in Rural Counties by Amenities Scale

This would not be the case if funds were provided externally. In that case, the numbers provided represent gross benefits per dollar spent. This second case appears to be more appropriate given the nature of our empirical estimates. [13] In this case, the minimum threshold that needs to be achieved is the one-dollar benchmark. If it costs the economy more than a dollar for the federal government to raise a dollar, then this amount, the marginal cost of public funds (MCPF), should be considered the cost. According to MCPF literature, depending on how the elasticity assumptions and the method how federal government raises funds in the United States, $1 dollar of additional funds costs between $1 and $1.35 (see Kleven and Kreiner (2003) for income taxes and Dahlby (2008, pp. 205-40) for borrowing).

If the federal-fund interpretation does hold, then infrastructure projects in high-amenity counties are counties are likely to pass a standard cost-benefit test. This takes into account that the marginal cost of public funds, while above $1 because of the administrative and economic costs of raising taxes, is probably less than $1.39, which again is a conservative estimate of the benefits given the discount rates we use. The situation is more precarious for low-amenity counties, where the benefits are significantly

[13] Following (Haughwout, 2002), "The regression equations on which the… calculations are based include major local tax rates, outstanding long-term debt per capita, and measures of public safety and education services, which are presumably related to spending. The … results are thus interpretable as the effect of increased infrastructure conditional on these variables remaining unchanged. The new infrastructure might thus be funded by aid from higher levels of government, high levels of past investment, or changes in excluded portions of the local budget. The finding of significantly positive coefficients thus indicates that city residents (and/or businesses) place a positive value on infrastructure that comes without changes in major taxes or the level of key public services. While this is perhaps unsurprising, the key policy question for federal, state and local officials is whether aggregate willingness to pay for such investments is as large as their cost."

below the $1 mark, which is the lowest possible marginal cost of public funds. Using a lower discount rate, would however ease this target.

This latter finding suggests that it may not be cost effective to revive local economies in low-amenity counties, which on average appear to have more infrastructure already. Unless discount rates are low, this does not bode particularly well for infrastructure investments areas such as the Great Plains, where population levels have stagnated or sometimes fallen. The result may be upward biased due to reverse causation as explained in the previous section. However, the result still goes along with Deller et al. (2001), which reports that rural counties with higher amenity has faster growth.

Who Benefits from Rural Infrastructure Improvements?

Finally, the analysis provides a distribution of benefits, which is useful for doing welfare analysis and determining who might pay for additional infrastructure investments. The breakdown below suggests roughly similar breakdowns in both low and high-amenity counties. Roughly half of the benefits go to property owners, most residential home-owners. Another third goes to local residents, seen as renters. The remaining amount, roughly a fifth, goes towards federal tax revenues. This breakdown may justify a typical matching rate of 20 percent on average from the federal government, but with half the revenues being paid for by property taxes.

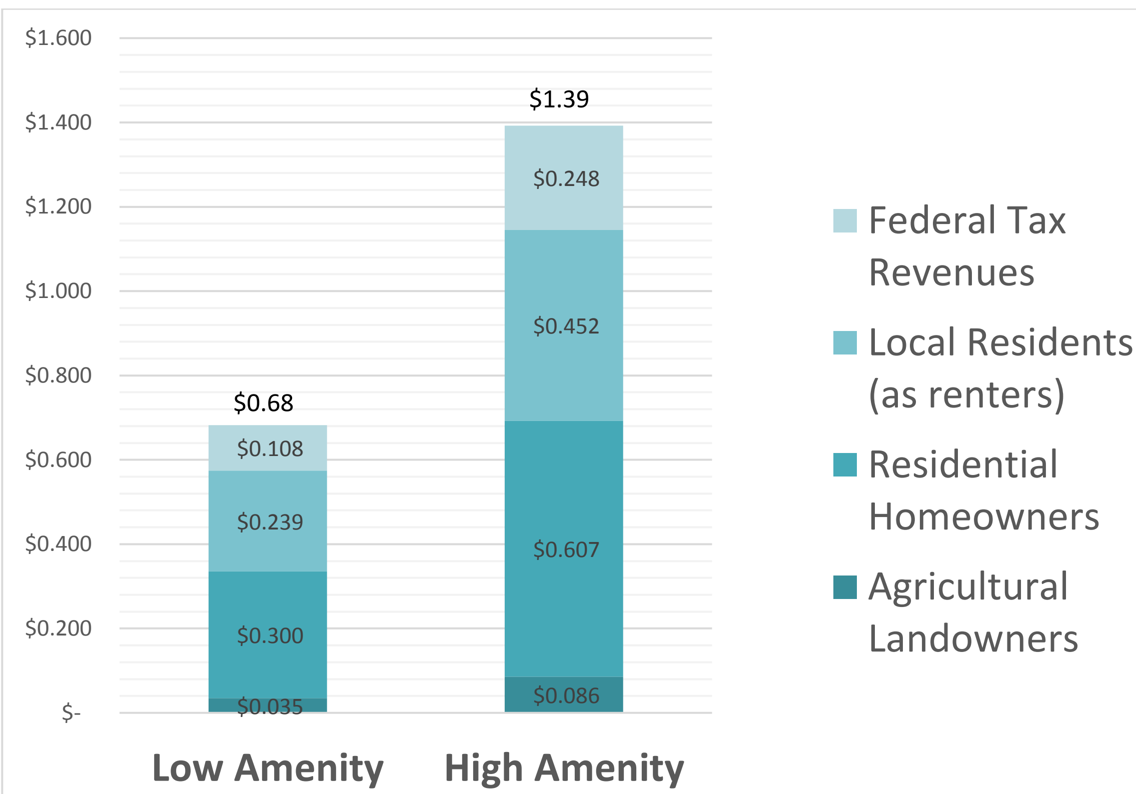


Figure 18 Distribution of Benefits from Public Capital per dollar Invested by Amenities Scale

A caveat to these findings is that there may be benefits to local infrastructure that are not felt locally. There may be substantial spillovers to residents who live outside the county, particularly for transportation infrastructure. Infrastructure may also provide environmental benefits or costs that have spillovers to adjoining areas as well.

Conclusion

On the whole, public infrastructure appears to have had sizable positive effects on incomes, property values, and employment growth in the rural counties that invested in it. The effects were more positive in counties with more natural amenities. Thus, the evidence suggests that funds are most efficiently spent on the higher-amenity counties that have been attracting population growth already for decades. These counties have somewhat lower infrastructure levels historically, and thus there is arguably a need for these counties to catch up to their less amenable, more weakly-growing, peers. Furthermore, in these counties, many of the benefits seem to considerably improve the quality-of-life of residents in ways not seen in traditional income or output economic measures. This may have led to public underinvestment if such benefits were overlooked. Our estimates may be biased downwards by measurement problems, or upwards due to reverse causation, and thus we cannot be sure whether the benefits we measure are too high or too low. The estimates do suggest infrastructure may have a wide variety of benefits to rural residents, however, and come out of a constructive framework that we hope continuing research will improve on.

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Appendix

A. Theoretical Apparatus

This section will introduce details in our model, especially the relationship between each elasticity of outcome variables, which we call "β", with those of productivities and quality-of-life measures.

To begin with, let *b* be the share of income from wages. This means that the relationship between income and wages is given by $\beta_m = b\beta_w$ or $\beta_{\mathrm{w}} = \beta_{\mathrm{m}}/b$, where β_m is an elasticity of family income with respect to infrastructure, and β_{w} is that of wage with respect to infrastructure. Since we do not observe wage level directly, we infer it from family income with this equation. The tax differential coefficient with respect to infrastructure is $\beta_\tau = \tau\beta_w$. The spatial equilibrium for households is given by the general equation

$$\boldsymbol{\beta_Q = s\beta_p - b(1-\tau)\beta_w + \psi\beta_N} \qquad \text{(A. 1)}$$

where β_Q is an elasticity of quality-of-life with respect to infrastructure, β_p and β_N are elasticities of house value and population with respect to infrastructure, respectively. *s* is the expenditure share on housing, and τ is the marginal tax rate. Ψ is the slope of local demand to live in the county, illustrated in Figure 1.

To determine productivity in the non-agricultural traded sector, simply multiply the cost-share of labor, θ times the wage differential. This will generate the elasticity of trade good with respect to infrastructure.

$$\boldsymbol{\beta_{AX} = \theta\beta_w = \frac{\theta}{b}\beta_m} \qquad \text{(A. 2)}$$

For productivity in the agricultural (traded) sector, take a weighted average of land costs, with cost share ω and the cost share of labor out of non-land costs, *c*.

$$\boldsymbol{\beta_{AZ} = \omega\beta_{rZ} + c(1-\omega)\beta_w} \qquad \text{(A. 3)}$$

Deriving non-traded productivity requires a foray into housing demand and supply. Let $\eta \geq 0$ be the own-price elasticity of housing supply, Y. Then the supply of housing depends on the supply of residential land, the price of housing (relative to construction costs), and home productivity in the following way.

$$\boldsymbol{\beta_Y = \beta_{L2} + \eta(\beta_p - a\beta_w) + (1+\eta)\beta_{AY}} \qquad \text{(A. 4)}$$

where *a* is labor's share of construction costs.

To determine the population level, *N*, let *y* be per-capita housing demand. Market clearing requires that supply equals demand: $Y = Ny$, thus in logarithms, housing demand changes are the sum of population changes and per-capita consumption changes, $\boldsymbol{\beta_Y = \beta_N + \beta_y}$. In spatial equilibrium, per-capita consumption of housing falls with the own-price compensated elasticity of demand $-\epsilon \leq 0$ according to the price level. It also falls, with the quality-of-life, *Q*, since real incomes are lower — we assume housing is a neutral good for simplicity so that housing demand falls proportionally with real income. These facts together imply that housing demand in the aggregate is given by:

$$\boldsymbol{\beta_Y = \beta_N - \epsilon\beta_p - \beta_Q} \tag{A. 5}$$

Putting together the supply and demand equations, (A. 4) and (A. 5), substituting in (A. 1), and solving for productivity parameter

$$\boldsymbol{(1+\eta)\beta_{AY} = \beta_N(1-\psi) - \beta_L - (\eta+\epsilon+s)\beta_p + [a\eta + b(1-\tau)]\beta_w} \tag{A. 6}$$

With this solution, we may then infer changes in the price of residential land:

$$\boldsymbol{\beta_{rY} = \frac{\beta_p + \beta_{AY} - a(1-\phi)\beta_w}{\phi}} \tag{A. 7}$$

We then consider how much value is received from different parties. The value received by local residents is $\boldsymbol{\psi\beta_N}$. That received from landowners is proportional to $\boldsymbol{s\beta_{rY} + \alpha\beta_{rZ}}$. The federal government receives: $\boldsymbol{\beta_r = \tau\beta_m}$.

B. Parameterization

The parametrization shown in **Error! Reference source not found.** provides a set of parameters for rural counties. The immobility friction parameter is taken from Notowidigdo (2013).

Table A. 1 Model Parameters and Possible Values

Parameter	Notation	Rural Average
Home-goods share	s	0.30
Marginal tax rate on labor	τ	0.30
Immobility friction	ψ	0.07
Home-good c. demand elasticity (-)	ϵ	0.50
Traded-good cost-share of labor	θ	0.85
Home-good cost-share of land	ϕ	0.21
Home labor's share of structure	a	0.67
Home-good supply elasticity	η	2.40
Agric share of output	α	0.10
Agric cost-share of land	ω	0.25
Agric labor's share of rest	c	0.50
Labor share of income	b	0.71
Land share of income	$s\phi + \alpha\omega$	0.09

C. Data Details

We change regions of interest from metropolitan cities (Albouy & Farahani, 2017) to rural counties. We collected the available data of 2,223 counties from the Census of Population and Housing, Census of Agriculture, and Census of Governments.

Years of interest in this paper are 1970, 1980, 1990, 2000, 2007, and 2012. 2007 and 2012 are chosen to match to the years of Census of Agriculture. Population and housing data of 2007 and 2012 are from 2005-2009 and 2010-2014 American Community Survey (ACS) of Census Bureau, respectively. **Error! Not a valid bookmark self-reference.** and Table A. 3 shows detailed information on the control variables that are not explained in the main discussion.

Table A. 2 List of variables (control variables)

Variable	Source	Description
Gender ratio	Census of Population	Share of male to total population
Share age under 15	Census of Population	Share of population from 0 to 14
Share age between 16 and 64	Census of Population	Share of population from 15 to 64
Share age over 65	Census of Population	Share of population ≥65
Share white	Census of Population	Ratio of white to total population
Share black	Census of Population	Ratio of black to total population
Share ever married	Census of Population	Share of population ever married
Share less than high school	Census of Population	No high school diploma
Share finished high school	Census of Population	With high school diploma
Share more than high school	Census of Population	Above high school education
Stock of state level public infrastructure	Government Finances series (Census)	
Top state income tax rate	The Book of States	
Bottom state income tax rate	The Book of States	
Sales tax rate	The Book of States	
Corporate income tax rate (top bracket)	The Book of States	

Table A. 3 Descriptive Statistics (control variables)

	High Amenity	Low Amenity	Rural Total	
	Mean	Mean	Mean	Std Dev.
Gender ratio (male to total)	0.49	0.49	0.49	0.02
Share age under 15	0.22	0.22	0.22	0.04
Share age between 16 and 64	0.63	0.63	0.63	0.04
Share age over 65	0.14	0.14	0.14	0.04
Share white	0.85	0.89	0.87	0.16
Share black	0.09	0.09	0.09	0.15
Share ever married	0.77	0.76	0.76	0.05
Share less than high school	0.26	0.25	0.25	0.12
Share finished high school	0.4	0.42	0.41	0.09
Share more than high school	0.34	0.33	0.34	0.14
Stock of state level public infrastructure	47,622	38,236	42,386	37,687
Top state income tax rate	4.39	5.56	5.05	3.44
Bottom state income tax rate	1.53	2.12	1.86	1.59
Sales tax rate	4.33	4.58	4.47	1.49
Corporate income tax rate (top bracket)	4.84	6.07	5.52	2.9

N	6,324	7,980	14,304

Note: Stock of state level public capital is in millions (in 2012 USD). All values are weighted averaged by population in 1970 except state level infrastructure and tax rates.

C.1 Census of Population, Housing, and Agriculture

Definition of demographic variables such as races, age, marital status, employment, and educational outcomes are consistent throughout years, whereas the definition of housing and rent values slightly vary over time. Census of Housing in 1970 and ACS of 2005-2009 and 2010-2014 measure aggregate value by owner-occupied units. On the other hand, Census of Housing in 1980 and 1990 measure the variable by specified owner-occupied non-condominium units and owner-occupied condominium units. Census of Housing in 2000 measures by specified owner-occupied units and owner-occupied units. Thus, for 1980 and 1990, aggregate values of owner-occupied units are from the sum of aggregate values of specified owner-occupied non-condominium units and owner-occupied condominium units. For other years, aggregate values of owner-occupied units are used.

House rent value also has the similar issue. 1970, 2007, and 2012 values are from renter-occupied units whereas 1980, 1990, and 2000 values are from specified renter-occupied units. Specified renter-occupied units are units excluding one-family homes on 10 acres or more. Since the number of one-family homes on 10 acres or more is not significant in rural areas, the difference in data universe would not affect our estimation.

The years of Census matches the nearest years of Census of Agriculture. The years of Census of Agriculture in this paper are 1969, 1982, 1992, 2002, 2007, and 2012. These years correspond to 1970, 1980, 1990, 2000, 2007, and 2012, respectively. Agricultural employment data of 1980 are missing for all counties in the sample, and they are replaced by those of 1990 data.

D. Panel Estimation Results

Following Table A. 4 and Table A. 6 shows the panel fixed effect estimation results used in our paper. All dependent variables and public capital are transformed into mean differential and entered with time dummy and county fixed effect to control variations due to specific years and unobserved county-specific effect. For the calculation of dependent variables in Table A. 6, please refer to A. theoretical Apparatus. For a robustness check, we conducted the same regression with different specification in Table A. 5 and Table A. 7. In this specification, rural counties are non-MSA counties. Figure 19 shows a visual comparison between rural definition of this paper and non-MSA definition.

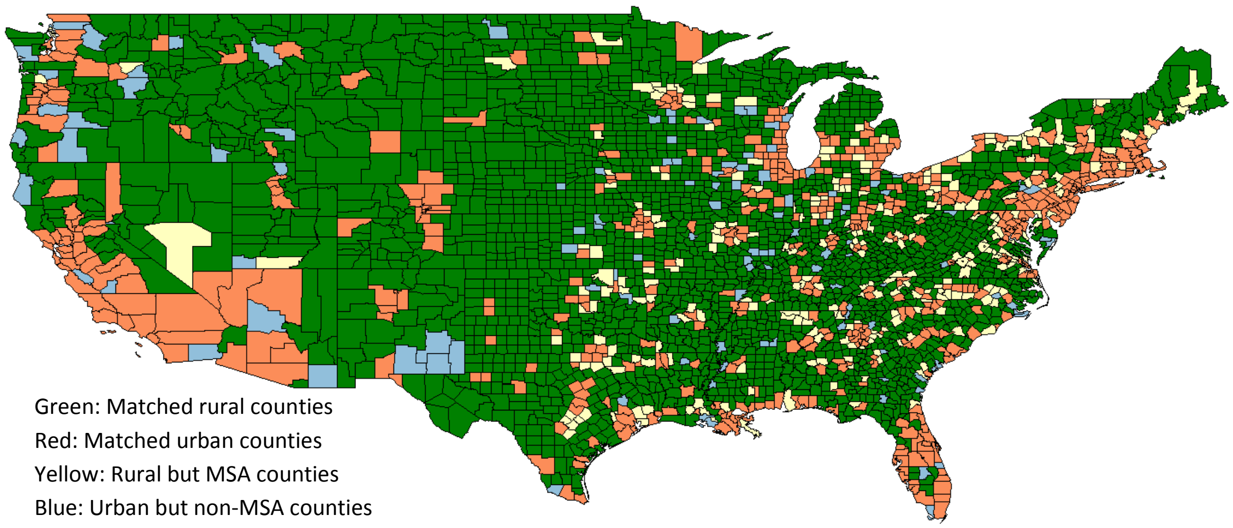

Figure 19 County Compositions by Rural Definitions: this paper and Non-MSA definition

Note: For the criteria of rural counties, see Defining Rural Counties section. Non-MSA definition regards non-MSA counties as rural counties. The MSA definition is based on Office of Management and Budget (2000). The number of counties that rural under our definition but MSA is 277; the number of urban but non-MSA counties is 130. The classification of rest of 2,701 counties were the same under both definitions.

Table A. 4 Panel Fixed Effect Estimates of County Outcomes on Public Capital and Amenity: 1970-2012

	Population	Population	Income	Income	House Value	House Value
Public Capital	0.196*** [0.011]	0.175*** [0.011]	0.024*** [0.004]	0.021*** [0.004]	0.072*** [0.008]	0.053*** [0.008]
Public Capital x Amenity		0.031*** [0.003]		0.005*** [0.001]		0.026*** [0.002]
Constant	-3.395*** [0.618]	-2.914*** [0.597]	-2.539*** [0.272]	-2.466*** [0.268]	-0.693 [0.554]	-0.285 [0.517]
Adjusted R-Sq.	0.552	0.579	0.869	0.870	0.846	0.852

	Agr. Land Value	Agr. Land Value	Employ	Employ
Public Capital	0.101*** [0.012]	0.086*** [0.012]	0.190*** [0.011]	0.167*** [0.011]
Public Capital x Amenity		0.022*** [0.003]		0.033*** [0.003]
Constant	-2.921*** [0.874]	-2.583*** [0.856]	-1.354** [0.621]	-0.842 [0.585]
Adjusted R-Sq.	0.748	0.750	0.728	0.745

`	Agr. Employ	Agr. Employ	Mfg. Employ	Mfg. Employ
Public Capital	0.068*** [0.019]	0.029 [0.019]	0.090*** [0.016]	0.081*** [0.015]
Public Capital x Amenity		0.050*** [0.004]		0.013*** [0.005]
Constant	6.715*** [1.416]	7.187*** [1.361]	-0.408 [1.184]	-0.198 [1.187]
Adjusted R-Sq.	0.393	0.405	0.263	0.264

Note: All dependent variables and public capital are mean differential. Standard errors in bracket. *'s indicate statistical significance levels. All regressions include 14304 county-year observations except for agricultural employment (11,920) due to missing data in 1980. Time dummy, county fixed effects, and demographic controls are added. The list of control variables is in Table A. 3.

Table A. 5 Panel Fixed Effect Estimates of County Outcomes on Public Capital and Amenity: 1970-2012 (with Non-MSA counties as rural)

	Population	Population	Income	Income	House Value	House Value
Public Capital	0.193*** [0.011]	0.155*** [0.010]	0.024*** [0.004]	0.019*** [0.004]	0.081*** [0.008]	0.053*** [0.008]
Public Capital x Amenity		0.038*** [0.003]		0.005*** [0.001]		0.028*** [0.002]
Constant	-3.856*** [0.649]	-3.424*** [0.608]	-2.490*** [0.268]	-2.431*** [0.267]	-0.508 [0.644]	-0.189 [0.554]
Adjusted R-Sq.	0.494	0.549	0.858	0.859	0.846	0.854

	Agr. Land Value	Agr. Land Value	Employ	Employ
Public Capital	0.117*** [0.013]	0.093*** [0.013]	0.190*** [0.012]	0.148*** [0.011]
Public Capital x Amenity		0.023*** [0.004]		0.040*** [0.003]
Constant	-2.044** [1.021]	-1.783* [0.971]	-1.731** [0.676]	-1.269** [0.625]
Adjusted R-Sq.	0.744	0.747	0.685	0.720

`	Agr. Employ	Agr. Employ	Mfg. Employ	Mfg. Employ
Public Capital	0.099*** [0.020]	0.034* [0.021]	0.101*** [0.018]	0.082*** [0.017]
Public Capital x Amenity		0.057*** [0.004]		0.018*** [0.006]
Constant	4.991*** [1.323]	5.255*** [1.185]	-1.558 [1.342]	-1.355 [1.383]
Adjusted R-Sq.	0.393	0.414	0.241	0.244

Note: All dependent variables and public capital are mean differential. Standard errors in bracket. *'s indicate statistical significance levels. All regressions include 13338 county-year observations except for agricultural employment (11,115) due to missing data in 1980. Time dummy, county fixed effects, and demographic controls are added. The list of control variables is in Table A. 3.

Table A. 6 Panel Fixed Effect Estimates of Quality-of-Life and Productivities on Public Capital and Amenity: 1970-2012

	QOL	QOL	Trade Productivity	Trade Productivity
Public Capital	0.018***	0.013***	0.029***	0.025***
	[0.003]	[0.003]	[0.005]	[0.005]
Public Capital x Amenity		0.007***		0.006***
		[0.001]		[0.001]
Constant	1.332***	1.437***	-3.059***	-2.971***
	[0.200]	[0.196]	[0.328]	[0.323]
Adjusted R-Squared	0.541	0.549	0.869	0.870

	Non-Traded Productivity	Non-Traded Productivity	Agricultural Productivity	Agricultural Productivity
Public Capital	0.008	0.016**	0.038***	0.033***
	[0.006]	[0.006]	[0.004]	[0.004]
Public Capital x Amenity		-0.012***		0.008***
		[0.002]		[0.001]
Constant	-2.494***	-2.682***	-2.080***	-1.956***
	[0.459]	[0.454]	[0.274]	[0.264]
Adjusted R-Squared	0.643	0.647	0.863	0.865

Note: Public Capital is mean differential value. Standard errors in bracket. *s indicate statistical significance levels. All regressions include 14,304 county-year observations. Time dummy, county fixed effects, and demographic controls are added. The list of control variables is in Table A. 3.

Table A. 7 Panel Fixed Effect Estimates of Quality-of-Life and Productivities on Public Capital and Amenity: 1970-2012 (with Non-MSA counties as rural)

	QOL	QOL	Trade Productivity	Trade Productivity
Public Capital	0.021***	0.014***	0.029***	0.022***
	[0.003]	[0.003]	[0.005]	[0.005]
Public Capital x Amenity		0.007***		0.006***
		[0.001]		[0.001]
Constant	1.321***	1.405***	-3.000***	-2.929***
	[0.227]	[0.209]	[0.323]	[0.321]
Adjusted R-Squared	0.541	0.552	0.858	0.859

	Non-Traded Productivity	Non-Traded Productivity	Agricultural Productivity	Agricultural Productivity
Public Capital	-0.003	0.009	0.042***	0.033***
	[0.006]	[0.006]	[0.004]	[0.004]
Public Capital x Amenity		-0.011***		0.008***
		[0.002]		[0.001]
Constant	-2.751***	-2.881***	-1.834***	-1.738***
	[0.530]	[0.502]	[0.307]	[0.290]
Adjusted R-Squared	0.674	0.678	0.854	0.857

Note: Public Capital is mean differential value. Standard errors in bracket. *s indicate statistical significance levels. All regressions include 13,338 county-year observations. Time dummy, county fixed effects, and demographic controls are added. The list of control variables is in Table A. 3.