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Demand for Urban Forests and Economic Welfare: Evidence from the Southeastern U.S. Cities

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This study examines the relationship between urban forests and household income and population density in the 149 cities with populations over 40,000 in nine southeastern states. Our empirical results show that urban forest percentage across the cities has characteristics of the environmental Kuznets curve. We find that household income around $39,000 is a threshold that changes the relationship between income and urban forest coverage from negative to positive, whereas the impact of population density on urban forests is just the opposite, from positive to negative when population density is around 180 persons per square kilometer.

Key Words: environmental Kuznets curve, environmental quality, income, land use, population density, tree canopy

JEL Classifications: C31, Q23, Q56, Q57, R14

Economics is the study of how individuals, as well as societies, allocate scarce resources to satisfy their various needs. Economic decisions are reflected not only in individual choices, but also in public decisions such as public budgets, policies, and regulation. An important aspect of economic choices is associated with enjoyment of environmental amenities versus traditional economic goods. The term environmental Kuznets curve (EKC) was coined to describe the relationship between environmental quality, such as air quality, and income by analogy to the relationship between income inequality and national income first observed by Simon Kuznets. EKC has been tested in many studies (e.g., De Groot, Withagen, and Minliang; Lindmark; Rupasingha et al.; Stern, Common, and Barbier).

Studies of forests in this empirical framework have focused on the relationship between forest coverage and income at the national level and regional level. The results were mixed. Shafik and Bandyopadhyay found that net change in forest cover did not significantly relate to income in 149 countries between 1961 and 1986. Panayotou used strictly cross-sectional international data and found a turning point in deforestation at $1,275 (in 1985 prices) of household income. Cropper and Griffiths created pooled time series cross-section data for three separate regions of the

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world and found that per capita national income was a significant factor in both Africa and Latin America but not in Asia.

So far we have not found any similar studies on urban forests. In fact, one of the best indicators of the urban environment and amenities is the status of trees present in a city. Trees have been recognized as an important component of urban landscapes throughout the history of urbanization. Sociologists and economists found that urban trees, in addition to providing environmental and aesthetic benefits, also brought a broad range of economic, social, and even psychological benefits. Trees in urban landscapes moderate temperature and microclimates, thereby reducing the needs for air conditioning and thus saving energy (Heisler; McPherson; Meier; Oke).

Urban trees help improve air quality and sequester carbon (Nowak; Nowak and McPherson; Rowntree and Nowak; Smith), help stabilize soils, reduce erosion, improve groundwater recharge, control rainfall runoff and flooding (Sanders), reduce urban noise levels (Cook), and provide habitat that increases biodiversity (Johnson). Urban trees also make neighborhoods aesthetically more appealing and add to the value of property (Schroeder). Evidence has also been shown that urban forests may reduce human stress levels (Ulrich), promote social integration of older adults with their neighbors (Kweon, Sullivan, and Wiley), and provide local residents with opportunities for emotional and spiritual fulfillment that help them cultivate a greater attachment to their residential areas (Chenoweth and Gobster).

Trees in cities are beneficial but are not free. They require space that is usually very costly in a city, as well as planting and maintenance. Any community has to face the difficulties in allocation of its limited budget for planting trees and other purposes and in allocation of the urban land for planting trees and other alternative uses. Individuals have to make the decision of what size lot to purchase for their homes and in which kinds of urban settings. So lot size and tree presence reflect, to some extent, the market forces determined by the welfare of the city citizens and their preferences. This study tests the relationship between the economic welfare and the tree presence in urban areas.

At the city level, which factors contribute to the variation in status of urban forests is interesting and may have some policy implications. Although researchers have noticed that urban forest canopy cover correlates with ecological and geographic factors as well as with urban form, they have not shown how canopy cover varies with socioeconomic conditions across all regions. Is there an EKC for urban forests? In the following sections, we first introduce econometric models and data, and then the results are presented and conclusions are made.

Econometric Model

Urban forests are either public goods, private goods, or a combination of both. They are determined by demand and supply. Unfortunately, it is impossible to get the prices and costs. Neither shadow prices nor instrumental prices or indicators, such as the residential land values, are available for each city. Only two variables, population density and income, which should be strongly related to the presence of urban forests, are obtainable for all cities. Since other variables (such as residential land value) might be fundamentally determined by these two variables, we simply use the reduced form of urban forests (*FOR*) as a function of population density and income:

$$(1) \qquad FOR = F(POD, INC) + e$$

$$\ln FOR = a_0 + a_1 \ln INC + a_2 \ln POD + a_{11}(\ln INC)^2 + a_{22}(\ln POD)^2 + a_{12}(\ln INC^{*}\ln POD) + e_i,$$

where *FOR* represents the percentage of urban forest canopy coverage; *INC* is the median household income in 2000; *POD* represents the population density in the city; a_1, a_2, a_{11}, a_{22}, and a_{12} are the coefficients of the variables, respectively; e_i is the error term. It should be noted that a_{11} and a_{22} measure the second-order effect of income and population density on the urban forest canopy cover percentage, respectively, and a_{12} measures the cross effect.

There are no studies on urban forests, but some studies on other issues may be relevant. For example, most studies have concluded that public parks or recreation services, a substitute for urban forests, are a normal good with a positive income elasticity, either less than one or greater than one (Bergstrom and Goodman; Borcherding and Deacon; Perkins; Santerre). Basically, all these conclusions agree that higher income will result in more demand for environmental amenity. The difference among them is only whether environmental amenity represents a luxury good with an income elasticity greater than one.

EKC suggests that urban forest would decrease first with economic development since people choose to sacrifice environment in order to get other uses, but later it would increase with economic development because wealthy people prefer to have more environmental amenities. In fact, this subsequent positive effect of income on the demand for environmental amenity might be specified from two aspects. First, with higher income, the city gets richer and has more money in the budget for urban environmental programs. Second, rich people will also have more money in their budgets for landscaping in the construction of their houses, thereby causing more trees to be planted or maintained.

Our economic model can test whether there is a threshold that can change the impacts of income on urban forests. To get the turning point, we simply derive the function by income:

$$(2) \quad \frac{\partial \ln FOR}{\partial \ln INC} = a_1 + 2a_{11}\ln INC + a_{12}\ln POD = 0$$

$$INC^* = \exp\left(\frac{-a_1 - a_{12}\ln POD}{2a_{11}}\right).$$

We suppose that a similar relationship may exist between urban forests and population density. The biggest difference between urban areas and rural areas is that there exist various urban management programs in cities. With people first clustered in cities, urban services and programs, including urban forest programs, start to provide citizens abundant urban civilizations. At the beginning of urbanization, the clustering of people doesn't actually reduce the urban forest volume. Inversely, various urban forest programs that are not often available for small communities will have an overwhelming influence on the volume and health of our urban forests. But when population density further increases, the opportunity land value for alternative uses will convert some urban trees and green space to other uses, particularly industrial, residential, and commercial uses.

To get the turning point, we derive the function by population density:

$$(3) \quad \frac{\partial \ln FOR}{\partial \ln POD} = a_2 + 2a_{22}\ln POD + a_{12}\ln INC = 0$$

$$POD^* = \exp\left(\frac{-a_2 - a_{12}\ln INC}{2a_{22}}\right).$$

Data

Considering that the natural environment will have a great impact on the urban tree situation, we sought a region with a relatively more homogenous climate and environment. Thus we decided to select nine southeastern U.S. states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia). Cities with populations below 40,000 are considered rural communities, and their surrounding areas become strong substitutes to urban forests; therefore, these cities are excluded from our analysis. We selected a total of 149 cities for this study. Demographic and economic data, such as population, land area, and median household income, are obtained from the U.S. Census Bureau.

The U.S. Department of Agriculture (USDA) Forest Service collected and published forest canopy cover data (Dwyer et al.) in accordance with the Forest and Rangeland Renewable Resources Planning Act, which re-

Table 1. Data Description of Variables

	Mean	S.D.	Min.	Max.	Sample Number
Urban forest canopy cover percentage (%)[a]	27.4	19.7	0.2	74.4	149
Urban forest area per capita (m^2/person)	422.56	776.002	0.85	8,559.47	149
Population 2000[b]	112,118	112,989	40,214	735,617	149
Land area (km^2)[b]	146.24	235.655	12.9	1,965	149
Population density in 2000 (persons/km^2)	1,208.56	796.47	61.45	4,831.48	149
Median household income ($)[b]	39,786.5	12,924.4	17,206	93,561	149

[a] Dwyer et al. (2000).
[b] U.S. Census Bureau (2000).

quires the Forest Service to assess "the current and expected future conditions of all renewable resources in the Nation" (Forest and Rangeland Renewable Resources Planning Act). The Forest Service has summarized results at state, county, metropolitan statistical area (MSA), urban area, and Census Designated Place (CDP) levels for the entire contiguous United States. These estimates of canopy cover are based on the USDA's national resources inventory and advanced very high-resolution radiometer (AVHRR) data. Urban forest canopy cover, on a 0–100 percentage scale, was calculated for every 1 km^2 in the United States using statistical models for particular physiographic regions.

These statistical models predict forest canopy per square kilometer based on the proportion of individual AVHRR pixels or cells within particular land cover. After the complete coverage for the United States was generated, selected jurisdictional boundaries (e.g., state, county, urban area) were added to the data set to extract the urban forest canopy cover percentage within these boundaries. Table 1 presents the data description of all the variables in our empirical analysis.

Results

Standard ordinary least square estimates are used for the regressions. The results are presented in Table 2. Moreover, we compare two models in our estimation to infer the significance of the cross effect of income and population density on the demand for urban forest,

Table 2. Regression Results

	Coefficient (t value)			
	Model A (with cross effect) (Sample = 149)		Model B (without cross effect) (Sample = 149)	
Independent Variables				
Constant	322.093	(3.53)	328.696	(3.64)
Log of income	−66.1883	(3.85)	−64.5134	(3.82)
Log of population density	8.86332	(1.12)	4.3839	(2.69)
Square of log of income	3.26349	(3.74)	3.05329	(3.85)
Square of log of population density	−0.444164	(3.53)	−0.422496	(3.53)
log(income) × log(population density)	−0.398351	(0.58)		
Adjusted R^2	0.405		0.408	

The dependent variable is the log of urban forest canopy cover percentage.
Cross effect is represented by the last term in Model A: $a_{12}(\ln INC \times \ln PD)$.

one with the interaction part (model A), another one without the interaction part (model B).

We find that including the cross effect term in the empirical model decreases the adjusted R^2 value (from 0.408 to 0.405), indicating that the cross effect term doesn't contribute to the explanation power of the model. Moreover, the t ratio of the cross effect term is as low as 0.58, suggesting that its value is not statistically significant at all. Therefore, we will use model B to interpret our results.

The regression results in model B show that all of the estimated coefficients are statistically significant at the 1% level. As expected, the positive coefficient on the second-order effect of income suggests a first negative and then positive impact of income on the demand for urban forests. Inversely, the negative coefficient on the second-order effect of population density suggests a first positive and then negative influence of population density on the demand for urban forest. Based on model B, the equations used to calculate the threshold income value and population density influence in Equations (2) and (3) will be transformed as below:

$$(4) \qquad INC^* = e^{-a_1/(2a_{11})}$$

$$(5) \qquad POD^* = e^{-a_2/(2a_{22})}.$$

Substituting the coefficients estimated for model B into the above equations, we get that the income threshold value is \$38,739 per household and the population density threshold value is 179 persons per square kilometer.

The existence of income threshold value provides more powerful evidence in support of the EKC. When the household income is less than \$38,739, the percentage of urban forest cover decreases as income increases, indicating a negative income elasticity. As the income approaches the critical point, the income elasticity also approaches 0. After the income surpasses the threshold value, the income elasticity becomes positive and the demand for urban forest increases with the increasing income.

Similarly, there also exists a population density threshold value: 179 persons per square kilometers. When population density is less than 179 persons per square kilometer, the percentage of urban forest increases as population density increases. This is because the urbanized areas use land more efficiently than rural areas and save more land for urban forest development. After the population density surpasses the critical value, the demand for urban forest decreases with the increasing population density because of the increasing stress on providing sufficient accommodation.

The income elasticities of the demand for urban forests for all the sample cities are calculated using the following equation:

$$(6) \qquad \varepsilon_{\text{Income}} = \frac{\partial \ln FOR}{\partial \ln INC} = a_1 + 2a_{11} \ln INC.$$

Results are presented in Figure 1. The income elasticities vary from −2.86 to +4.92. The critical value of the income influence is located on the point where income elasticity equals 0. As the income gets farther away from this critical value on both sides, the absolute value of income elasticity also increases. The highest (+4.92) and lowest (−2.86) income elasticities are reached where the highest (\$93,561) and lowest (\$23,483) income stand. The income elasticity for the mean household income (\$39,787) in our sample cities is 0.11, indicating urban forest coverage is inelastic to income. However, we must point out that this mean income elasticity doesn't have much applicable significance compared to the income threshold value found in our analysis.

Conclusions

This paper analyzes the relationships between urban forest presence and income and population density. Our results indicate a similar trend of EKC in urban forests. With continuous economic development and urbanization, its impacts on urban forests are mixed. In general, population growth will cause urban forests to be replaced by other land uses. As a result, although urban forest programs still endeavor to protect urban forests, many urban forests and green spaces are inevitably converted for construction purposes to accom-

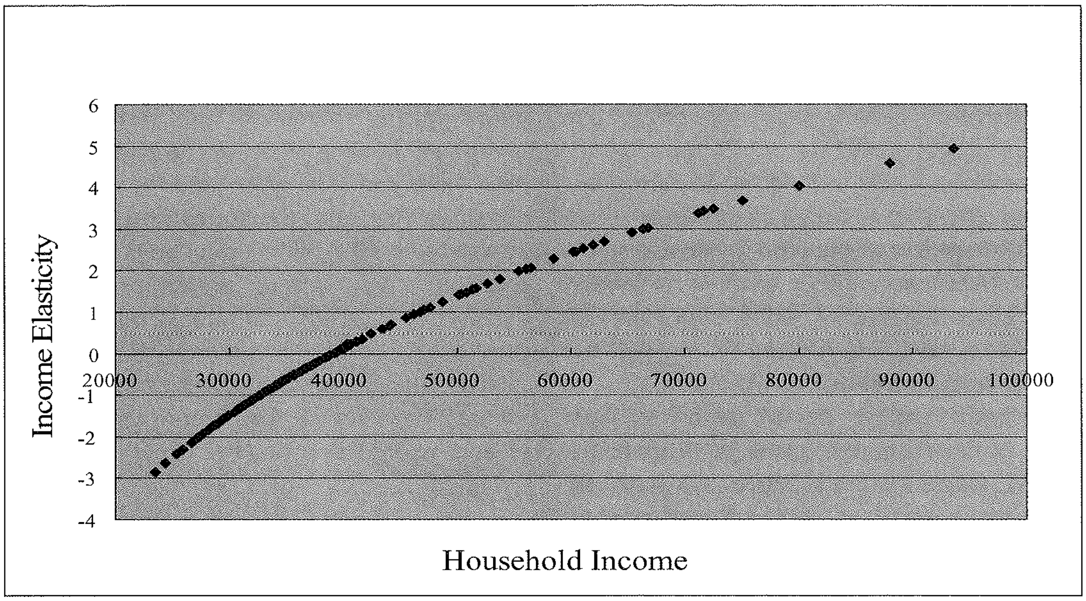

Figure 1. Income Elasticity in Sample Cities

modate the increasing population. In this period, the demand for urban forests will continuously decrease due to the increasing population density, which places more and more pressure on the urban land use.

Economic welfare will finally play a positive role in urban forest after reaching a certain level. Better economic welfare will help people afford to have more urban forests and other green spaces. Higher income will lead to higher environmental quality at the expense of alternative land use and the planting and maintaining of urban trees. Therefore, although economic development may convert more land, including open and green spaces, for construction purposes, societal wealth is significant in affording a higher quality environment.

We must point out some weaknesses of this study. Even though we limit our sample cities to the southeastern United States, the climate and natural conditions, such as landscape and soil, still vary significantly from city to city. However, from the relatively good R^2, we can say that income and population density are good indicators of the variation in urban forests.

References

Bergstrom, T.C., and R.P. Goodman. "Private Demands for Public Goods." *American Economic Review* 63(1973):280–96.

Borcherding, T.E., and R.T. Deacon. "The Demands for the Services of Nonfederal Governments." *American Economic Review* 62(1972): 891–901.

Chenoweth, R.E., and P.H. Gobster. "The Nature and Ecology of Aesthetic Experiences in the Landscape." *Journal of Landscape* 9(1990):1–18.

Cook, D.I. "Trees, Solid Barriers, and Combinations: Alternatives for Noise Control." *Proceedings of the National Urban Forestry Conference.* G. Hopkins, ed., pp. 330–39. New York: USDA Forest Service, 1978.

Cropper, M., and C. Griffiths. "The Interaction of Population Growth and Environmental Quality." *The American Economic Review* 84(1994): 1358–93.

De Groot, H.L.F., C.A. Withagen, and Z. Minliang. "Dynamics of China's Regional Development and Pollution: An Investigation into the Environmental Kuznets Curve." *Environment and Development Economics* 9(September 2004): 507–37.

Dwyer, J.F., D.J. Nowak, M.H. Noble, and S.M. Sisinni. *Connecting People with Ecosystems in* *the 21st Century: An Assessment of Our Nation's Urban Forests.* Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-490, 2000.

Forest and Rangeland Renewable Resources Planning Act of August 17, 1974 (Public Law 93-378, 88 Stat. 476, as amended); 16 U.S. Code 1600–1614.

Heisler, G.M. "Effects of Individual Trees on the Solar Radiation Climate of Small Buildings." *Urban Ecology* 9(1996):337–59.

Johnson, C.W. "Planning for Avian Wildlife in Urbanizing Areas in America Desert/Mountain Valley Environments." *Landscape and Urban Planning* 16(1988):245–52.

Kuznets, S. "Economic Growth and Income Inequality." *The American Economic Review* 45(1955):1–28.

Kweon, B.S., W.C. Sullivan, and A.R. Wiley. "Green Common Spaces and the Social Integration of Inner-City Older Adults." *Environment and Behavior* 30(6)(1998):832–58.

Lindmark, M. "Patterns of Historical CO_2 Intensity Transitions among High and Low-Income Countries." *Explorations in Economic History* 41(4)(2004):426–47.

McPherson, E.G. "Modeling Residential Landscape Water and Energy Use to Evaluate Water Conservation Policies." *Journal of Landscape* 9(1990):122–34.

Meier, A.K. "Measured Cooling Savings from Vegetative Landscapes." *Energy Efficiency and the Environment: Forging the Link.* E. Vine, D. Crawley, and P. Centolella, eds. Washington, DC: American Council for an Energy-Efficient Economy, 1991.

Nowak, D.J. "Atmospheric Carbon-Reduction by Urban Trees." *Journal of Environmental Management* 37(3)(1993):207–17.

Nowak, D.J., and E.G. McPherson. "Quantifying the Impact of Trees: The Chicago Urban Forest Climate Project." *Unasylva* 173(44)(1993):39–44.

Oke, T.R. "The Micrometeorology of the Urban Forest." *Philosophical Transactions of the Royal Society of London* 324(Series B)(1989):335–49.

Panayotou, T. *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development.* Geneva: International Labor Office, Technology and Employment Programme Working Paper WP238, 1993.

Perkins, G.M. "The Demand for Local Public Goods: Elasticities of Demand for Own Price, Cross Prices, and Income." *National Tax Journal* 30(1977):411–422.

Rowntree, R.A., and D.J. Nowak. "Quantifying the Role of Urban Forests in Removing Atmospheric Carbon Dioxide." *Journal of Arboriculture* 17(10)(1991):269–75.

Rupasingha, A., S.J. Goetz, D.L. Debertin, and A. Pagoulatos. "The Environmental Kuznets Curve for US Counties: A Spatial Econometric Analysis with Extensions." *Papers in Regional Science* 83(2)(2004):407–24.

Sanders, R.A. "Urban Vegetation Impacts on the Hydrology of Dayton, Ohio." *Urban Ecology* 9(1986):361–76.

Santerre, R.E. "Spatial Differences in the Demands for Local Public Goods." *Land Economics* 61(1985):119–28.

Schroeder, H.W. "Environment, Behavior and Design Research on Urban Forests." *Advances in Environment, Behavior and Design,* E.H. Zube and G.T. Moore, eds. New York: Plenum, 1989.

Shafik, N., and S. Bandyopadhyay. "Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence." *Background Paper for the World Development Report.* Washington D.C.: The World Bank, 1992.

Smith, W.H. *Air Pollution and Forests.* New York: Springer, 1981.

Stern, D.I., M.S. Common, and E.B. Barbier. 1996. "Economic Growth and Environmental Degradation: The Environmental Kuznets Curve and Sustainable Development." *World Development* 24(7):1151–60.

Ulrich, R.S. "View through a Window May Influence Recovery from Surgery." *Science* 224(1984):420–21.