Final Report for the Detroit Sustainability Indicators Project

Project Title:

"Measuring the Greenness of Cities: A New Methodology for an Urban Sustainability Index (USI)"

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1. Executive summary

Research strategy and findings: The growing importance of nonmarket assets such as the environment, combined with the unprecedented availability of high-resolution data, has renewed broad interest in quantifying sustainability at different spatial levels. Policy-related decision making requires that potential sustainability measures meet three key requirements: (i) sustainability metrics need to be *comprehensive* so that they reflect the experience of representative households, (ii) sustainability indices need to be *comparable* across different geographic scales, and (iii) measures of sustainability need to be *economically meaningful*, ideally tying into the larger system of national accounts. However, conventional sustainability indices do not tend to meet these criteria, rendering them inappropriate for public-policy efforts. The subjectivity and theoretical inconsistency of common sustainability indices presents the biggest obstacle for their adoption as valid public policy targets.

The central contributions of this project are threefold. First, it introduces a methodology for an urban sustainability index that is based on a theoretically consistent, empirical measure of quality of life. Second, building on the work of Bieri, Kuminoff and Pope (2013), we update their dataset of over 70 county-level amenities for the entire United States to the year 2010. Ranging from geographic and climate amenities, environmental externalities, local public goods and cultural amenities, this collection is the most comprehensive database on county-level amenities to date and forms the basis for a range of quantitative applications for sustainability-related public policy analysis. Third, highlighting one such application, namely the quantification of sustainability for policy, this project shows that greenness of cities has a strong positive correlation with urban quality of life, suggesting that the greener the city, the nicer a place to live it is. This is largely because energy efficiency is capitalized into economic activity and ultimately into urban quality of life. This relationship appears to hold across cities of all sizes, clearly emphasizing the direct link between progressive environmental policy and locational desirability. The takeaway message is straightforward: More "greenness" correlates to higher quality of life in urban areas.

Takeaway for practice: Commonly available sustainability indices are unsuitable for policy; instead, amenity-based hedonic quality-of-life measures provide a practical approximation for quantifying interurban sustainability differentials.

Keywords: Sustainability, quality of life, urban policy, local public goods.

Research output associated with this project: Bieri, D. S. (2013): "Are Green Cities Nice Places to Live? Examining the Link between Urban Sustainability and Quality of Life," *Michigan Journal of Sustainability*, inaugural issue; 51-74.

2. Overview of project

Climate change is expected to have significant economic impacts and is generating the near term-need for sizeable investments in infrastructure, mitigation and preparedness projects. Yet because the transition to sustainable growth and the comprehensive reduction of CO_2 greenhouse gas emissions from growth-related energy consumption carry all the hallmarks of public goods, these goals will not be achieved by private sectors alone. Instead, there is an active role for public policy. From the perspective of policy makers, however, the prioritization of such large investment needs is very complex and fraught with a number of implementation challenges. To make matters worse, the recent financial crisis has left federal, state and particularly municipal governments in a state of fiscal crisis with very little capacity to make the necessary investments to achieve de-carbonization in the housing sector, transportation and public infrastructure.

In the context of sustainability, however, it is less clear what the appropriate indices for policy ought to be. This is largely due to the broad definitional scope of the term sustainability itself; conceptually, at least, sustainability indices rely on a broad range of indicators that can usually be grouped into three categories: *economic* indicators such as employment, energy consumption or local food sufficiency; *environmental* indicators such as standards for clear air, for clean water or for waste; and *social* indicators such as crime, educational attainment or health outcomes.[1] At the same time, policy-related decision making requires that individual indicators be aggregated into a single, composite index in order to obtain a clear signal that public policy can act upon. Despite increasing attempts to quantify the greenness of cities, these efforts remain largely without a firm theoretical anchor, which renders them unsuitable for policy purposes. For example, recent research initiatives such as the Economist Intelligence Unit's (2009) *European Green City Index* or the *Urban Sustainability Index* produced by the Urban China Initiative (2010) both apply weighting schemes that merely reflect the index providers' own subjective preferences instead of objective economic conditions. Similar efforts also exist for localities in the United States, ranging from the *SustainLane US Cities Sustainability Rankings*, to the *Siemens US & Canada Green Cities Index* (Economist Intelligence Unit 2011), the U.S. Environmental Protection Agency's *Energy Star Buildings Rankings* and the proposed *STAR Community Index*.[2]

Despite their intuitive appeal, each of these sustainability indices uses a different methodology, which tends to produce dissimilar, often counterintuitive rankings. Matters are complicated further because these indices also tend to have sparse coverage, often ranking only a limited sample of the largest metro areas. Thus, the subjectivity and theoretical inconsistency of existing sustainability indices presents the biggest obstacle for their adoption as valid public policy targets.

This project addresses these shortcomings of existing indicators and provides an overview of recent theoretical developments that outline a practical solution to the problem of constructing an

[1] At the level of national policies, the *UN Indicators of Sustainable Development* (United Nations 2007) represent the most comprehensive benchmark for the formulation of national sustainable development policies. The World Bank's *Eco2Cities* program (Suzuki et al. 2010) attempts to develop a set of pragmatic benchmarks for national policies of sustainable urban development.

[2] For example, recent research initiatives such as the Economist Intelligence Unit's (2009) European Green City Index or the Urban Sustainability Index produced by the Urban China Initiative (2010) both apply weighting schemes that merely reflect the index providers' own subjective preferences instead of objective economic conditions. Similar efforts also exist for localities in the United States, ranging from the SustainLane US Cities Sustainability Rankings, to the Siemens US & Canada Green Cities Index (Economist Intelligence Unit 2011), the U.S. Environmental Protection Agency's Energy Star Buildings Rankings and the proposed STAR Community Index.

objective measure of sustainability that can be used for public policy. Specifically, I discuss the relationship between an ideal urban sustainability index (USI) and market-based measures of urban quality of life as an alternative to popular sustainability rankings. Specifically, the project scope is summarized as follows:

1. To provide a comprehensive review of existing sustainability index methodologies; to focus on the theoretical shortcomings of current approaches and on specific problems of using indices based on existing methodologies as policy targets.
2. To propose a new methodology to create urban sustainability indices (USI) for U.S. cities that are both theoretically consistent and suitable for policy and decision making.
3. To outline how the USI could be scaled up nationally, providing the first comprehensive system of urban sustainability indices for the United States; to provide an environmental accounting framework for incorporating the sustainability index within the broader structure.

3. Description of methods, analysis and findings

The central issues of this research project – that is, why conventional urban sustainability indices are not suitable for policy and how an objective measure of sustainability is related to urban quality of life – are best introduced by comparing conventional sustainability rankings to our objective sustainability measure, the imputed market-based proxy for sustainability. Columns (1), (4), and (5) of Table 1 record the top- and bottom-ranked cities according to three conventional sustainability indices listed above. For the first set of these green city rankings, column (2) lists a first version of the ideal Urban Sustainability Index (USI), derived from a market-based measure of quality of life that is expressed as the annual implicit average household expenditures for local amenities. For comparative purposes, Table 1 also lists a survey-based measure of subjective well-being in column (3).

Table 1: Sustainability rankings and quality of life

Siemens-EIU Green Cities Rankings	*USI**	*GHI***	*SustainLane Rankings*	*EPA EnergyStar Rankings*
(1)	(2)	(3)	(4)	(5)
Top-ranked cities				
San Francisco	$ 7,176	1.26	Portland	Los Angeles
New York	$ 4,941	-0.32	San Francisco	Washington
Seattle	$ 5,973	0.65	Seattle	Atlanta
Denver	$ 3,590	0.70	Chicago	Chicago
Boston	$ 3,807	0.79	New York	San Francisco
Bottom-ranked cities				
Pittsburgh	$ 3,995	-0.18	Memphis	Miami
Phoenix	$ 3,143	0.38	Las Vegas	San Diego
Cleveland	$ 5,831	-0.09	Tulsa	Detroit
Saint Louis	$ 2,324	-0.41	Oklahoma City	San Jose
Detroit	$ 1,187	-0.74	Mesa	Portland
N. Obs: 22	363	187	50	21
Correlation with Siemens-EIU Rankings			0.7676	0.4472

Notes: To ensure comparability, all index rankings in columns (1), (4) and (5) are for the year 2011. *"Quality-of-life urban sustainability index (USI)" for each metropolitan statistical area is expressed as the annual implicit average household expenditures for local amenities (see Bieri (2013), and Bieri, Kuminoff and Pope (2013) for more details). **Standardized values of the 2011 Gallup-Healthways Well-Being Index (GHI), a large-scale daily assessment of U.S. residents' health and well-being.

Three key themes emerge from this table. First, there is the issue of *comparability*. Despite some correlation, the conventional sustainability rankings in columns (1), (4), and (5) are not directly comparable, mainly because they use different indicators and methods to rank a small sampling of cities. Second, these conventional rankings are *not representative*. This means that it is not clear to what extent, if at all, the rankings reflect the experience of average households for a given geographic area. Lastly, there is the issue of the *economic relevance* of the rankings. Because these popular rankings are ordinal, it is not possible to compare differences in rankings, say, the difference between the levels of sustainability of the highest- and lowest-ranked city, in any way that is meaningful for policy. Specifically, this means that is not possible to compare how sustainable San Francisco is according to the EnergyStar index versus the Siemens-EIU index, nor is it possible to say anything meaningful about how much more sustainable a city ranked 2 is over a city ranked 3 for a given index. For the same reasons, changes in the rankings over time are equally difficult to interpret. By contrast, the quality-of-life-based measure of sustainability listed in column (2) of Table 1 avoids these drawbacks altogether; it covers the entire universe of U.S. metropolitan statistical areas; it is derived using data from official sources; it characterizes the average experience of representative households while accounting for local difference in the cost of living; and it is expressed in terms of implicit expenditures on local amenities, permitting economically meaningful comparisons with other categories of household expenditure as well as comparisons across time and space.

3.1. Nature's numbers: Accounting for amenities and the nonmarket economy

From a theoretical perspective, a policy-relevant measure of sustainability should be directly grounded in the national income and product accounts (NIPA), since they are also the source of other objective measures that guide much of public policy. The NIPA arguably represent one of the "greatest innovations in economics" (Jorgenson 2009); they are the national equivalent to a corporation's balance sheet and provide a snapshot summary of different aspects of the national economy. Operationally, the NIPA form the backbone for the tabulation of such metrics as GDP, personal consumption expenditure and net exports of goods and services. Economists have long recognized the potential value of expanding national accounts to provide a richer description of nonmarket activity (Kuznets 1934; 1946). Perhaps most importantly, in the context of sustainability, GDP does not account for the negative externalities associated with environmental degradation and the depletion of natural resources that went hand in hand with much of the process of economic development since the Industrial Revolution.

Motivated by the need to include sustainability metrics in the public policy discourse, Nordhaus and Tobin (1972) provided an early attempt to adjust NIPA for the value of leisure time and nonmarket, environmental activity. The growing importance of environmental issues has renewed broad interest in "green accounting." These efforts have culminated in the ground-breaking work on the Integrated Environmental and Economic Satellite Accounts (IEESA) at the U.S. Bureau of Economic Analysis (BEA) and a series of subsequent recommendations to develop nonmarket accounts for the U.S. by both the National Research Council's Committee on National Statistics (National Research Council 1999; 2005) and the NBER (Jorgenson, Landefeld, and Nordhaus 2006; Jorgenson and Landefeld 2009).[3] Similar endeavors in China have led to the much-debated pilot project of the 2004 China Green National Economic Accounting Study Report. Despite these conceptual advances, however, applied

[3] So-called satellite accounts are intended to supplement existing national accounts, maintaining both flexibility of definitions and methods (Carson 1994). See also Nordhaus (2000) and Abraham and Mackie (2006).

progress with regard to a "greening" of the NIPA has remained rather limited. The main impediment to progress in this matter can be attributed to two central challenges: first, there is the need for reliable data on nonmarket *quantities*, and second, there is the inherent difficulty of imputing *prices* for these nonmarket goods and services.

3.2. Green cities, urban sustainability and the quality of life

The relationship between urban sustainability and the quality of life is linked to the relative importance of different factors to household well-being, usually expressed as utility. The key insight here rests on the observation that location-specific differences in wages and (land) rents should compensate for the differences in non-market characteristics, such as natural or cultural amenities that increase the attractiveness of a given locality. Thus, although geographic disparities in the quality of life themselves – much like sustainability – are unobservable, quality-of-life differentials can be measured by prevailing wage differentials with the local cost-of-living netted out. Since the work of Rosen (1979), Haurin (1980) and Roback (1982; 1988), a growing body of literature has tried to produce theoretically consistent quality-of-life rankings for urban areas by deriving wage and rent differentials via hedonic methods, calculating the implicit prices of location-specific amenities which are then used as utility valuation weights.[4]

3.3. From theory to practice: Linking urban sustainability and the cost of living

At first sight, disentangling mutual causation between sustainability and quality of life is complicated by the fact that neither sustainability nor quality of life is directly observable, which renders them both elusive targets for policy. Yet despite these challenges, progress in quantifying urban sustainability for public policy is not necessarily beyond practical reach. The pivotal element in such an undertaking is a closer examination of the empirical link between urban environmental quality, sustainability and quality of life. Indeed, important theoretical and empirical progress has been made in the hedonic valuation literature with regard to improving estimates of urban quality of life.[5] Because the methodology in this literature has direct parallels to the methodology for producing an optimal urban sustainability index (USI), empirical quality-of-life measures could serve as second-best proxies for urban sustainability. Conceptually, therefore, the regional measures of aggregate urban sustainability must tie in directly with the logic of "green" asset and production accounting of IEESA in the same way that measures for inflation, such as the GDP deflator or the chain price index for personal

[4] See, for example, Gyourko, Kahn, and Tracy (1999), Blomquist (2006) and Lambiri, Biagi, and Royuela (2007) for comprehensive surveys of the literature.

[5] See Bieri (2010) for an overview. The key insight of this literature rests on the observation that location-specific differences in wages and (land) rents should compensate for the differences in nonmarket characteristics, such as natural or cultural amenities that increase the attractiveness of a given locality. Thus, although geographic disparities in the quality of life themselves are unobservable, they can be measured by prevailing wage differentials with the local cost of living netted out.

consumption expenditures (PCE), are direct by-products of NIPA.[6] *To the extent that targeting urban quality of life is consistent with urban sustainability, green cities are therefore also nice places to live*.

From a technical perspective, any measurement of urban sustainability should therefore fall into the more general class of cost-of-living indices that measure changes in the amount that consumers need to spend to reach a certain utility level or standard of living that is consistent with sustainability. Technically, the urban sustainability index should thus be conceptualized as a traditional price-quantity index, much like other economic indices such as the BLS's CPI-U or the BEA's GDP and PCE deflator.[7] As indicated above, this implies two specific practical challenges for the implementation of the USI. First, we need to identify and quantify appropriate measures for the *quantities* (i.e., the relevant nonmarket or near-market goods), and second, we need to derive a set of theoretically consistent imputed equilibrium *prices* which will serve as valuation weights. Simultaneously, geographical granularity and scope must allow for both interurban and intraurban comparisons. In sum, widely observed practices among both statistical agencies and commercial index providers thus suggest the following generally accepted principles by which a sustainability index should abide:

- *Scope and coverage*: The index should reflect the experience of representative households for a given geographic area; the index should also be geographically representative and should be as broad and inclusive in its scope as possible.
- *Transparency and reproducibility*: The index performance should be reproducible; as far as possible, objective rather than subjective criteria should be used in selecting the data. At a minimum, the source of the underlying data should be published; the index should be valid over a reasonably long time horizon.

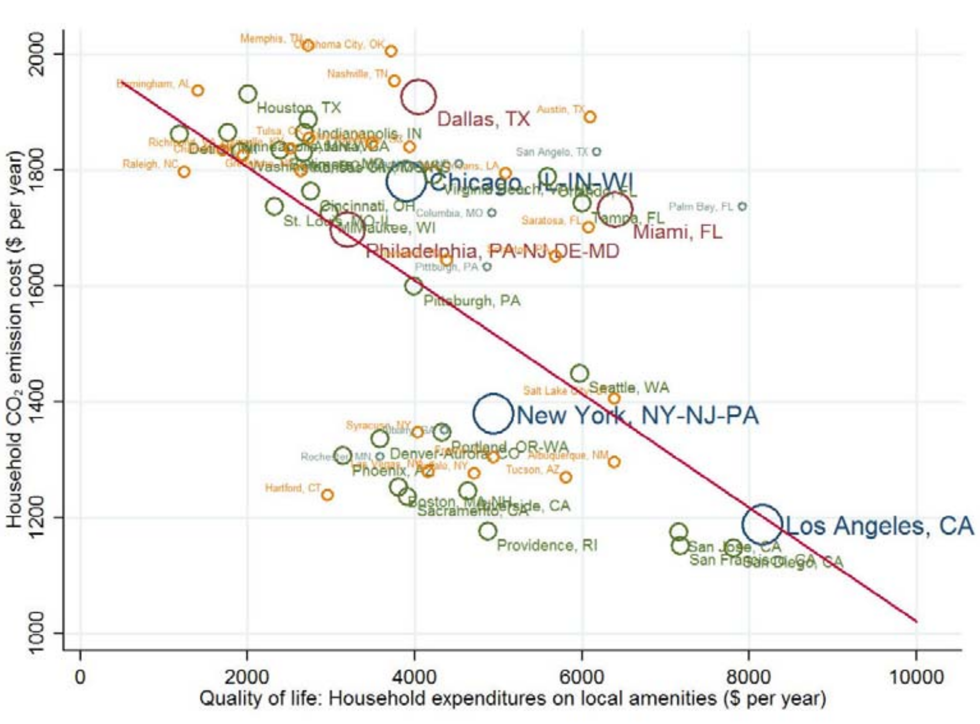
[6] There are two broad indices of consumer prices: the consumer price index (CPI) and the PCE. See Clark (1999) and Garner et al. (2006) for a good overview of the theoretical relationship between the CPI and the PCE deflator.

[7] Irving Fisher's (1922) index number theory provides the intellectual framework for this family of indices. See Diewert (1976; 1978) for a comprehensive discussion of the theoretical properties of such indices. See glossary for more details on different price indices.

4. Recommendations for data use

To illustrate a direct application of the amenity data to the construction of a pilot version of the USI, I construct a set of estimates for implicit prices of non-market goods in U.S. metropolitan areas, relying on an econometric methodology that is developed in Bieri, Kuminoff, and Pope (2013). Using these empirical quality-of-life estimates reveals the tension between sustainability and quality of life, which is illustrated in Figure 1. The annual cost of carbon dioxide emissions per household from driving, public transit, home heating, and electricity usage is plotted on the vertical axis and metropolitan quality of life is shown on the horizontal axis.

Figure 1: The greenness of cities and their quality of life



Notes: Quality of life (QOL) for each MSA is measured by deriving wage and rent differentials via hedonic methods, calculating the implicit prices of location-specific amenities which are then used as utility-valuation weights. The $ amounts represent the annual implicit average household expenditures for local amenities (see text for more details). The fitted line is obtained from a weighted regression using population weights for each MSA and is given by $CO_2 = 2{,}001.72 - 0.0979 * QOL$ with a t-statistic $= -7.15$ for the slope coefficient and an adjusted $R^2 = 0.4521$, where CO_2 is the annual cost of carbon dioxide emissions and QOL is household expenditures on local amenities. *Sources*: Author's calculations using data from Bieri, Kuminoff and Pope (2013) and Glaeser and Kahn (2010).

While the lowest emissions areas are generally in California and the highest emissions areas are in Texas and Oklahoma, this graph highlights that the presence of emissions has a strong negative correlation with urban quality of life, i.e., the greener the city, the nicer a place to live it is. This is because energy efficiency is widely capitalized into economic activity and ultimately into urban quality of life. At the same time, however, this relationship appears to hold across cities of all sizes, clearly emphasizing the direct link between progressive environmental policy and locational desirability. All else equal, Figure 1 thus supports the hypothesis that greener cities enjoy a greater quality of life. The statistical reliability of the relationship between sustainability and quality-of-life-related expenditures in its most simple specification is illustrated by the regression line in Figure 1. More robust specifications of the sustainability-QOL relationship increase the overall explanatory capacity of amenity-related expenditures to over 90% of the variation of the annual cost of CO_2 emissions across U.S. cities.[8] In other words, *inferring an amenity-based measure of expenditures that are associated with local quality of life provides a highly accurate, comprehensive predictor for urban sustainability, proxied here by the household-level cost of CO_2 emissions*. Perhaps most importantly in the context of obtaining a policy benchmark, sustainability thus quantified meets all the *scope, coverage, transparency* and *reproducibility* criteria introduced in the previous section.

4.1. The USI expenditure data for Detroit

Using the average annual amenity expenditures per household as an aggregate proxy for sustainability on the horizontal axis, Figure 1 highlights the uneven distribution of sustainability outcomes across major U.S. metropolitan areas. According to the estimates in Bieri, Kuminoff and Pope (2013), in the year 2000 the average household –expenditure for local amenities in the Detroit MSA is just over \$1,190.– per year, the lowest amount for any MSA with a population of more than 0.5 million inhabitants. Among the largest 50 MSA, households in Los Angeles and in San Francisco have the largest implicit expenditures on non-market goods that matter for sustainability, households in Detroit spend the least (see also table 1 in section 3). By comparison, the average amenity expenditure level across all MSA is \$4,550.– per household, peaking in Naples, FL with \$10,350.– per household.

Given the large national variation in urban household incomes, expressing sustainability-relevant household expenditures in as a share of household income provides additional context that underscores the large spatial variation of implicit household expenditures for amenities. In terms of "sustainability expenditure share", Detroiters spend a mere 3.1% of annual household incomes on non-market goods that matter for sustainability, compared to the national average share of 10.2% and the maximum share of over 24.7% in San Luis Obispo, CA. Table 2 below lists the cities with the five highest household amenity expenditures and those with the five lowest expenditures for the 50 largest U.S. metro areas. The highest amenity expenditure shares occur in Western cities, whereas cities in the South and Detroit display the lowest expenditure shares. In contrast to cities with the highest amenity expenditure shares, these cities also tend to have less tightly regulated residential land-use arrangements as measured by the Wharton Residential Land-Use Regulation Index (WRLURI; see Bieri (2013) for a more detailed discussion of the link between land-use regulation and sustainability.)

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[8] Alternative specifications for the sustainability-QOL relationship take the form $CO_2 = \alpha + \beta QOL + \gamma X + \varepsilon$, where X is a set of controls that include, depending on the specification, metro-level population, the Gallup-Healthways well-being index and Census Division indicators. In the preferred specification, all regressors enter significantly with an adjusted $R^2 = 0.9190$.

Table 2: Amenity expenditure shares across MSAs

	Population (million)	*Amenity expenditure share*	*USI**	*WRLURI***
	(1)	(2)	(3)	(4)
Top-ranked cities				
Los Angeles-Long Beach-Santa Ana, CA	12.37	23.4%	$8,160	0.49
San Diego-Carlsbad-San Marcos, CA	2.81	19.9%	$7,810	0.51
San Francisco-Oakland-Fremont, CA	4.12	18.6%	$7,180	0.75
Portland-Vancouver-Beaverton, OR-WA	1.93	16.1%	$4,330	0.33
Sacramento-Arden-Arcade-Roseville, CA	1.80	16.0%	$3,920	0.59
Bottom-ranked cities				
Dallas-Fort Worth-Arlington, TX	5.16	4.4%	$4,050	-0.36
Memphis, TN-MS-AR	1.21	4.0%	$2,730	1.07
Detroit-Warren-Livonia, MI	**4.45**	**3.1%**	**$1,190**	**0.12**
Birmingham-Hoover, AL	1.05	3.1%	$1,410	-0.06
Houston-Sugar Land-Baytown, TX	4.72	0.8%	$2,000	-0.39

Notes: *"Quality-of-life urban sustainability index (USI)" for each metropolitan statistical area is expressed as the annual implicit average household expenditures for local amenities. **The Wharton Residential Land Use Regulation Index (WRLURI) provides an aggregate measure of regulatory constraint on development that allows us to rank areas by the degree of control over the residential land- use environment. WRLURI values for each MSA were constructed from town-specific indices (see Bieri (2013), and Bieri, Kuminoff and Pope (2013) for more details).

4.2. Detroit's sustainability indicators in national and state-level context

This section provides a brief illustrative overview of the underlying database for the over 70 county-level amenities that forms the basis for the imputed household expenditures on local amenities upon which the quality-of-life based urban sustainability indicator (USI) is based (Appendix A lists the complete set of amenities). Specifically, the individual amenities are classified into five categories (geography and climate, environmental externalities, local public goods, infrastructure and cultural amenities) and the following table list the lowest and highest amenity values in each of the categories for the city of Detroit (Wayne county, MI), and then compares this "amenity performance" relative to the six county Detroit MSA, relative to the state of Michigan and relative the universe of all counties in the contiguous United States.

Table 3 highlights that in terms of geographical and climate amenities, annual humidity is the amenity where Detroit ranks highest in the national comparison, and relative sunshine is the amenity where Detroit "performs" worst relative to the nation. For these highest and lowest performing amenities among geographical and climate amenities, Detroit ranks in the 95% percentile for annual relative humidity and in the bottom 10% of all counties in terms of average amount of sunshine per year. Climate in Alpena County in Michigan is even more humid and less sunny, placing it in the top 99% and bottom 1% counties nationally, respectively. For environmental externalities, Detroit has the fourth highest number of treatment, storage and disposal facilities (TSD), but among the lowest annual average concentrations of ozone. In terms of local public goods, Wayne County has the ninth highest rate of child mortality in the nation and among the lowest teacher-pupil ratios, a common proxy for school quality. In combination, Detroit thus lies at the distributional extremes for both environmental quality and for the quality of local services, both important components of overall sustainability that feed into quality of life.

By contrast, Detroit fares relatively well in the category of infrastructure amenities. Wayne County is in the top ten counties in the nation with regard to the total amount of mileage for urban arterial roads. At the same time, the lowest ranking infrastructure amenity in Detroit is federal per capita expenditures which still fall in to the top 75% of all county-level federal expenditure. In the category of cultural amenities, Detroit's highest and lowest amenity, i.e. the density of restaurants and bars and the density of theatres, both lie in a narrow range slightly above and below the national median of the distribution. Taken together, the individual amenity indicators suggest that Detroit is relatively well-endowed with infrastructure, whereas it is at a comparative disadvantage to the rest of the nation in terms of its environmental externalities, its local public goods, and – to a lesser degree – its climate.

Table 3: Comparative amenity concentrations in Detroit, 2010

		Detroit (Wayne, MI)			Detroit-Livonia-Warren MSA		State of Michigan		Contiguous USA (all counties)	
	Amenity	*Amount*	*Rank*	*%ile*	*Amount*	*County (Rank)*	*Amount*	*County (Rank)*	*Amount*	*County (Rank)*
Geography and climate										
High	Annual relative humidity	**72.15**	#187	95%	72.95	St. Clair, MI (#82)	73.79	Alpena, MI (#30)	79.84	Pacific, WA (#1)
Low	Sunshine (% possible)	**50.01**	#2,900	10%	48.71	St. Clair, MI (#2,991)	47.51	Alpena, MI (#3,077)	46.2	Coos, NH (#3,109)
Environmental externalities										
High	Treatment, storage, disposal facilities	**12**	#4	99%	4	Wayne, MI (#4)	12	Wayne, MI (#4)	28	Cook, IL (#1)
Low	Ozone (mean annual concentr., ppm)	**34.81**	#3,030	5%	34.81	Wayne, MI (#3,030)	34.81	Wayne, MI (#3,030)	27.63	King, WA (#3,109)
Local public goods										
High	Child mortality (per 1000 births)	**10.74**	#9	99%	10.74	Wayne, MI (#9)	10.74	Wayne, MI (#9)	13.15	Shelby, TN (#1)
Low	Teacher-pupil ratio	**0.067**	#2,936	5%	0.058	Livingston, MI (#3,045)	0.03	Keweenaw, MI (#3,101)	0.01	Buffalo, SD (#3,109)
Infrastructure										
High	Urban arterials (mileage)	**507.2**	#7	99%	507.2	Wayne, MI (#7)	507.2	Wayne, MI (#7)	1,790.24	Los Angeles, CA (#1)
Low	Federal expenditures ($ per capita)	**110.1**	#412	75%	10.49	Livingston, MI (#2,208)	2.199	Cass, MI (#2,554)	0	Archer, TX (#3,109)
Cultural amenities										
High	Theatres (per 1,000 people)	**0.013**	#903	55%	0.024	Oakland, MI (#605)	0.126	Arenac, MI (#56)	1.4	Mineral, CO (#1)
Low	Restaurants and Bars (per 1,000 people)	**0.72**	#1,859	35%	0.577	Lapeer, MI (#2,309)	0.515	Ottawa, MI (#2,480)	0	Issaquena, MS (#3,109)

5. Potential policy options for decision makers utilizing the data

Beyond the direct quantification of urban sustainability via the USI, the data and methods developed in this project can also provide useful input for urban growth policy and local economic development practice. One such area of application would be an examination of relationship between quality of life and sustainability in the context of "optimally sized" urban areas, i.e., cities where size-related amenities and disamenities are balanced. This raises similar questions, such as whether there is a trade-off between growth and sustainability, and if so, what are the short-run versus long-run dynamics? What portion of earnings of urban residents may simply be compensation for the negative externalities of urbanization? As green cities might experience higher pressures on house prices, what are the linkages between sustainability and affordable housing?

The USI introduced in this project should provide a practical tool that is able to inform the public policy discourse on sustainability in a tractable way; overcoming common limitations of existing efforts that quantify urban sustainability, the quality-of-life-based implementation of the USI simultaneously conforms to best practices of index construction and is capable of reflecting the idiosyncrasies of individual cities. Given the complexity of the revitalization challenges of Rustbelt cities or the trials of growth management for Sunbelt cities, an amenity expenditure measure such as the one presented here offers a sufficiently flexible and transparent benchmark for policy makers to rank sustainability-related public investments. Lastly, the approach put forward in this article also underscores the practical feasibility of environmental accounting in an integrative way.

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A. County-level inventory on amenities

Table A1 summarizes the county-level data that forms the basis for the imputed household expenditures on local amenities that form the basis for the quality-of-life based urban sustainability indicator (USI) using the econometric methodology developed in Bieri, Kuminoff and Pope (2013).

Table A1: List of Amenities

	*Sources**		*Sources*
GEOGRAPHY AND CLIMATE		**LOCAL PUBLIC GOODS**	
Mean precipitation (inches p.a., 1971-2010)	NOAA-NCDC	Local direct general expenditures ($ per capita)	COG07
Mean relative annual humidity (%, 1971-2010)	NOAA-NCDC	Local exp. for hospitals and health ($ per capita)	COG07
Mean annual heating degree days	NOAA-NCDC	Local exp. on parks, rec. and nat. resources ($ pc)	COG07
Mean annual cooling degree days	NOAA-NCDC	Museums and historical sites (per 1,000 people)	CBP
Mean wind speed (m.p.h., 1971-2010)	NOAA-NCDC	Municipal parks (percentage of total land area)	ESRI
Sunshine (% of possible)	NOAA-NCDC	Campgrounds and camps	CBP
Heavy fog (no. of days with visibility ≤ 0.25 mi.)	NOAA-NCDC	Zoos, botanical gardens and nature parks	CBP
Percent water area	ICPSR	Crime rate (per 100,000 persons)	ICPSR
Coast (=1 if on coast)	NOAA-SEAD	Teacher-pupil ratio	COG07
Non-adjacent coastal watershed (=1 if in watershed)	NOAA-SEAD	Local expenditure per student ($, 2006-07 fiscal year)	COG07
Mountain peaks above 1,500 meters	ESRI	Private school to public school enrollment (%)	2000 Census
Rivers (miles per sq. mile)	USDI-NPS	Child mortality (per 1000 births, 2000-2010)	CDC-NCHS
Federal land (percentage of total land area)	USGS-NA		
Wilderness areas (percentage of total land area)	USGS-NA	**INFRASTRUCTURE**	
National Parks (percentage of total land area)	USGS-NA	Federal expenditure ($ pc, non-wage, non-defense)	COG07
Distance (km) to nearest National Park	USDI-NPS	Number of airports	USGS-NA
Distance (km) to nearest State Park	USDI-NPS	Number of ports	USGS-NA
Scenic drives (total mileage)	USGS-NA	Interstate highways (total mileage per sq. mile)	USGS-NA
Average number of tornados per annum (1950-2010)	USGS-NA	Urban arterial (total mileage per sq. mile)	USGS-NA
Property damage from hazard events ($1000s, per sq. mile)	USGS-NA	Number of Amtrak stations	USGS-NA
Seismic hazard (index)	USGS-NA	Number of urban rail stops	USGS-NA
Number of earthquakes (1950-2010)	USGS-NA	Railways (total mileage per sq. mile)	USGS-NA
Land cover diversity (index, range 0-255)	USGS-NA		
		CULTURAL AND URBAN AMENITIES	
ENVIRONMENTAL EXTERNALITIES		Number of restaurants and bars (per 1,000 people)	CBP
NPDES effluent dischargers (PCS permits, 1999-2009)	EPA-TRI	Theatres and musicals (per 1,000 people)	CBP
Landfill waste (metric tons, 2010)	EPA-TRI	Artists (per 1,000 people)	CBP
Superfund sites	EPA-TRI	Movie theaters (per 1,000 people)	CBP
Treatment, storage and disposal facilities	EPA-TRI	Bowling alleys (per 1,000 people)	CBP
Large-quantity generators of hazardous waste	EPA-TRI	Amusement, recreation establishments (per 1,000 people)	CBP
Nuclear power plants	USDOE-INSC	Research I universities (Carnegie classification)	CCIHE
PM2.5 (μg per m^3)	EPA-AQS	Golf courses and country clubs	CBP
PM10 (μg per m^3)	EPA-AQS	Military areas (percentage of total land area)	USGS-NA
Ozone (μg per m^3)	EPA-AQS	Housing stress (=1 if > 30% of households distressed)	USDA-ERS
Sulfur dioxide (μg per m^3)	EPA-AQS	Persistent poverty (=1 if > 20% of pop. in poverty)	USDA-ERS
Carbon monoxide (μg per m^3)	EPA-AQS	Retirement destination (=1 if growth retirees > 15%)	USDA-ERS
Nitrogen dioxide (μg per m^3)	EPA-AQS	Distance (km) to the nearest urban center	PRAO-JIE09
National Fire Plan treatment (percentage of total area)	USGS-NA	Incr. distance to a metropolitan area of any size	PRAO-JIE09
Cancer risk (out of 1 million equally exposed people)	EPA-NATA	Incr. distance to a metro area > 250,000	PRAO-JIE09
Neurological risk	EPA-NATA	Incr. distance to a metro area > 500,000	PRAO-JIE09
Respiratory risk	EPA-NATA	Incr. distance to a metro area > 1.5 million	PRAO-JIE09

Notes: The amenity data were constructed from the following sources: CCIHE: Carnegie Classification of Institutions of Higher Education; CBP: 2010 County Business Patterns published by the Census Bureau; CDC-NCHS: Centers for Disease Control and Prevention, National Center for Health Statistics; COG07: 2007 Census of Governments; EPA-AQS: 2000 data for criteria air pollutants from the Air Quality System produced by the Environmental Protection Agency (EPA); EPA-NATA: 1999 National-Scale Air Toxics Assessment conducted by the EPA; EPA-TRI: 2010 Toxic Release Inventory published by the EPA; ESRI: Environmental Systems Research Institute ArcGIS maps; ICPSR: U.S. County characteristics compiled by the Inter-university Consortium for Political and Social Research ICPSR2008; NOAA-SEAD: Strategic Environmental Assessments Division of the National Oceanic and Atmospheric Administration; NOAA-NCDC: National Climatic Data Center of the National Oceanic and Atmospheric Administration; PRAO-JIE09: Partridge et al. (*Journal of International Economics* 78 (2), 2009); USDA-ERS: Economic Research Service of the US Department of Agriculture; USDI-NPS: National Park Service of the US Department of the Interior; USDOE-EERE: Energy Efficiency and Renewable Energy, US Department of Energy; USDOE-INSC: International Nuclear Safety Center at the US Department of Energy; USGS-NA: National Atlas of the US Geological Survey.

B. Data collection manual and methodology for individual amenity variables

1. FIPS code change

The major change between 2000 and 2010 is that Clifton Forge (independent) city, Virginia (51-560) was changed to town status and added to Alleghany County (51-005) effective July 1, 2001. However, some datasets still work with old FIPS codes so it is important to use the following links to update these FIPS codes:

http://www.itl.nist.gov/fipspubs/fip6-4.htm
http://wonder.cdc.gov/wonder/help/Census1970-2000.html
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=nrcs143_013710

2. Mean annual precipitation

Variable name	Variable label	Units
precip	Mean total annual precipitation	inches

Mean annual precipitation usually is expressed as the mean annual precipitation over the last thirty years. Hence, using the climate normals seems convenient.

1981-2010 climate normals
NOAA's National Climate Data Center (NCDC) provides the 1981-2010 Climate Normals in the following website:
http://www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

It is vital to read the readme.txt file. For instance, in this file, it is mentioned that the units in which precipitation is stored are hundredth of inches and whole degrees Fahrenheit for heating and cooling degree days (expect high precision files, these are stored in hundredths of degrees Fahrenheit).

Mean precipitation	hundredths of inches
Mean annual heating degree days (HDD)	ºF
Mean annual cooling degree days (CDD)	ºF

Station locations can be downloaded from: http://www1.ncdc.noaa.gov/pub/data/normals/1981-2010/station-inventories/.

After importing these two files into Stata and merging them together, the newly created dta file can be exported as a xls or csv file and then imported into ArcGIS. Once the precipitation data is plotted spatially, we can estimate the precipitation at the county population-weighted centroid using ordinary kriging or universal kriging. However, given that the climate conditions will vary throughout space, I decided to use universal kriging with longitude and latitude as explanatory variables within the linear model.

3. Mean winter temperature

Variable name	Variable label	Units
wintertemp	Mean winter temperature	Degrees F

The Global Summary of the Day dataset can be used for obtaining the mean winter temperature (Section 3), mean summer temperature (Section 4), mean annual relative humidity (Section 5), mean July relative humidity (Section 6), mean wind speed (Section 9) and heavy fog (Visibility – Section 11).

Daily meteorological data was downloaded from the Global Surface Summary of the Day Dataset, from NOAA.
ftp://ftp.ncdc.noaa.gov/pub/data/gsod/

The data has the following units (reference: ftp://ftp.ncdc.noaa.gov/pub/data/gsod/readme.txt): Mean temperature (degrees Fahrenheit); mean dew point (degrees Fahrenheit), mean sea level pressure (mb); mean station pressure (mb); mean visibility (miles); mean wind speed (knots); maximum sustained wind speed (knots); maximum wind gust (knots); maximum temperature (degrees Fahrenheit); mMinimum temperature (degrees Fahrenheit); precipitation amount (inches); snow depth (inches); indicator for occurrence of: Fog, Rain/Drizzle, Snow/Ice Pellets, Hail, Thunder, Tornado/Funnel Cloud.
The data is downloaded in zipped format per year. After unzipping it once, we'll obtain zipped files per station so we'll need to unzip these files again. We'll finally obtain files in .op format (tab delimited files). We can merge these op files into a single txt file by using the 'Command

Prompt' application. This file then can be imported into Stata. Then calculating the mean temperature is just a matter of arithmetic. After plotting the temperature in space, we can use ordinary kriging to obtain the mean winter temperature at the county population-weighted centroid.

4. Mean summer temperature

Variable name	Variable label	Units
summertemp	Mean summer temperature	Degrees F

We can use the data from the GSOD data (See Mean Winter Temperature, Section 3). The procedure for obtaining the mean summer temperature is extremely similar, with the caveat that in this case we will only keep data within the summer season.

5. Mean annual relative humidity

Variable name	Variable label	Units
annualRH	Mean annual relative humidity	%

We can use the data from the GSOD data (See Mean Winter Temperature, Section 3). However, this dataset does not contain instantaneous relative humidity information, so we can approximate the mean instantaneous relative humidity by calculating the relative humidity on a daily basis and the average it on a broader period of time. The relative humidity can be calculated by using the Dew point and the ambient temperature (both in Kelvin).

6. Mean July relative humidity

Variable name	Variable label	Units
JulyRH	Mean July relative humidity	%

Using information from the GSOD data (See Mean annual relative humidity, Section 5), and the same procedure as the followed for mean annual relative humidity, one can calculate the mean July relative humidity.

7. Mean annual heating degree days (HDD)

Variable name	Variable label	Units
hdd	Mean annual heating degree days	Degree F-day

1981-2010 climate normals
The 1981-2010 climate normals data can be downloaded from the following website:
http://www1.ncdc.noaa.gov/pub/data/normals/1981-2010/

The procedure is almost the same as the one followed for obtaining the mean annual precipitation (Section 2). Once we have obtained the mean annual heating degree days at the monitoring locations, we can obtain them at the county population-weighted centroids by using ordinary kriging.

8. Mean annual cooling degree days (CDD)

Variable name	Variable label	Units
cdd	Mean annual cooling degree days	Degree F-day

1981-2010 climate normals
The 1981-2010 climate normals data can be downloaded from the following website:
http://www1.ncdc.noaa.gov/pub/data/normals/1981-2010/

The procedure is almost the same as the one followed for obtaining the mean annual precipitation (Section 2) and mean annual heating degree days (Section 7). Once we have obtained the mean annual cooling degree days at the monitoring locations, we can obtain them at the county population-weighted centroids by using ordinary kriging.

9. Mean annual wind speed

Variable name	Variable label	Units
wind	Mean annual wind speed	Mile/hour

Using information from the GSOD data (ftp://ftp.ncdc.noaa.gov/pub/data/gsod/ - See Mean Winter Temperature, Section 3), we can calculate the mean annual wind speed. Finally, see final section of Mean annual Precipitation (Section 2) to import the formatted xls file into ArcGIS, plot it spatially and obtain the mean annual wind speed at the county population-weighted centroids.

10. Mean annual sunshine

Variable name	Variable label	Units
sunshine	Annual mean percent of possible sunshine	%

Sunshine data was obtained from the following ftp site:
ftp://ftp3.ncdc.noaa.gov/pub/data/3210

This ftp site has daily meteorological information from various stations. The readme.txt file can be found at ftp://ftp3.ncdc.noaa.gov/pub/data/3210/README.TXT and the data set documentation can be found at http://www1.ncdc.noaa.gov/pub/data/documentlibrary/tddoc/td3210.doc.

11. Heavy fog

Variable name	Variable label	Units
visibility	Mean number of days per annum with visibility <= 0.25 miles	Days

We can use the data from the GSOD data (See Mean Winter Temperature, Section 3). Heavy fog is defined as the 'number of days with visibility equal to or less than 0.25 miles'. Therefore, instead of simply averaging the visibility on a yearly basis, it is needed to create a Boolean variable is True if the visibility complies with the previous condition and False if it does not.

12. Percent Water Area

Variable name	Variable label	Units
PctWater	Water area per land area, in percent	%

County boundary shapefiles can be downloaded from the following census website: ftp://ftp2.census.gov/geo/tiger/TIGER2010/COUNTY/2010/. Water area features can be downloaded from this census website: ftp://ftp2.census.gov/geo/tiger/TIGER2010/AREAWATER/.

13. Coastal

Variable name	Variable label	Units
coast	1 if coastal watershed, 0 if not	--
n_adj_coa	1 if non-adjacent coastal watershed, 0 if not	--

This information was obtained by contacting the National Ocean Economic Program staff. A list of coastal counties by state was obtained. Two types of coastal information need to be collected.

Coast	=1 if on coast
Non-adjacent coastal watershed	=2 if in watershed

14. Mountain peaks

Variable name	Variable label	Units
Peak1500	Number of peaks above 1500 m above sea level	#

Data of Mountain peaks above 1500 meters can be found in Esri http://www.arcgis.com/home/item.html?id=6706f7e6712b4b479dcb4fce4b7b3172. The single layer can be added into ArcGIS. The attribute table includes information of FIPS code.

15. Rivers

Variable name	Variable label	Units
river_length	River length in miles	Miles
river_length_perland	River length per land in mile/mile^2	Miles/Mile^2

The National Atlas provides a rivers shapefile, which can be found in the following website:

http://nationalatlas.gov/atlasftp-na.html?openChapters=chpwater#chpwater http://nationalatlas.gov/mld/hydro0m.html

16. Federal land

Variable name	Variable label	Units
fedland_mi2	Federal land in square miles	Mile^2
fedland_pct	Federal land in percentage (over land area)	%

The National Atlas provides a shapefile of federal land, which can be found here:
http://www.nationalatlas.gov/atlasftp.html?openChapters=chpagri%2Cchpgeol%2Cchpbound#chpbound

17. Wilderness areas

Variable name	Variable label	Units
wildland_mi2	Wilderness land in square miles	Mile^2
wildland_pct	Wilderness land in percentage (over land area)	%

The National Atlas provides a shapefile of wilderness areas:
http://www.nationalatlas.gov/mld/wildrnp.html.

18. National parks

Variable name	Variable label	Units
NatParkland_mi2	National Park land in square miles	Mile^2
NatParkland_pct	National Park land in percentage (over land area)	%

ESRI provides a shapefile of national parks on the ArcGIS online service. This map is called ‘NPS National Park Service Boundary’.

19. Distance to nearest National Park

Variable name	Variable label	Units
NatPark_dist	Distance to nearest national park in miles	Mile

ESRI provides a shapefile of national parks on the ArcGIS online service. This map is called ‘NPS National Park Service Boundary’.

20. Distance to nearest State Park

Variable name	Variable label	Units
statepark_dist	Distance to nearest state park in miles	Mile

ESRI provides a shapefile of state parks on the ArcGIS online service. This map is called ‘USA Parks’.

21. Parkways (Scenic drives) and Scenic Rivers

Variable name	Variable label	Units
NatParkwayLength	National Parkway length in miles	Mile
ScenicRiverLength	Scenic rivers length in miles	Mile
NatParkwaybyArea	Parkway length per county land area, in mile/mile^2	Mile/Mile^2
ScenicRiverbyArea	Scenic river length per county land area, in mile/mile^2	Mile/Mile^2

ESRI provides a shapefile of scenic drives and scenic rivers on the ArcGIS online service. This map is called ‘USA Federal Lands (lines)’.

22. Tornado

Variable name	Variable label	Units
tornado	Average number of tornados per annum, 1950-2009	#

The Storm Prediction Center from NOAA provides a tornado database from 1950 in .csv format in the following website:
http://www.spc.noaa.gov/wcm/

23. Property damage from hazard events

Variable name	Variable label	Units
property_damage_adjusted_2009	Property damage from hazard events (2000-2009) in $000s, adjusted 2009	$1000
property_damage_per_area	Property damage from hazard events (2000-2009) in $000s/mile^2 of land, adjusted 2009	$1000/mile^2

Data can be downloaded from the "Spatial Hazard Events and Losses Database for the United States", from the University of South Carolina: http://webra.cas.sc.edu/hvri/products/sheldus.aspx

24. Seismic hazard

Variable name	Variable label	Units
seismic_hazard	Seismic hazard index	--

The National Atlas provides seismic hazard information:
http://www.nationalatlas.gov/maplayers.html?openChapters=chpgeol#chpgeol
http://www.nationalatlas.gov/mld/seihazp.html
http://www.nationalatlas.gov/atlasftp.html#seihazp

Using this shapefile we can obtain the seismic hazard at the blockgroup population-weighted centroid and then average the seismic hazard over the whole county accounting for population.

25. Number of Earthquakes

Variable name	Variable label	Units
quake_00_09	Earthquakes 2000 to 2009	#

The USGS provides earthquake information in the following website: http://earthquake.usgs.gov/earthquakes/map/.

The database provides the location of the earthquakes so it may be needed to plot them spatially and the overlay the county boundary shapefile in order to obtain the number of earthquakes that occurred in each county in the last decade or other period of analysis.

26. Land Cover Diversity

The latest data is collected in December 2002. Data can be accessed from the National Atlas website at: http://nationalatlas.gov/atlasftp.html?openChapters=chpgeol%2Cchpbio#chpbio.

27. NPDES effluent dischargers

Variable name	Variable label	Units
NumberPermits	Number of active permits from 2001 to 2010	#

Effluent discharger data can be collected from EPA-TRI http://www.epa.gov/enviro/facts/pcs-icis/index.html. You can customize your selection in http://www.epa.gov/enviro/facts/pcs-icis/customized.html.

28. Landfill Waste

Variable name	Variable label	Units
totalwaste	Total Waste Managed (8.1-8.8)	Metric tons

The EPA Toxics Release Inventory (TRI) Program has developed an application that allows the user to select, sort, and filter TRI data. The software can be downloaded from the following website:
http://www.epa.gov/tri/tridotnet/index.html

29. Superfund

Variable name	Variable label	Units
Superfund	Number of Superfund sites	#

Superfund data can be accessed from http://cumulis.epa.gov/supercpad/cursites/srchsites.cfm.

30. Treatment, storage and disposal facilities

Variable name	Variable label	Units
TSD	Number of Treatment, storage, and disposal facilities	#

The LQG and TSD data is presented every two years in the biennial reports. The 2009 Biennial Report can be downloaded from the following website: ftp://ftp.epa.gov/rcrainfodata/br_2009/See Large Quantity Generators of hazardous waste. In order to import the data appropriately, it is important to use the 'File specification guide'. The links for the 1999 and 2009 guides are the following:
http://www.epa.gov/epawaste/inforesources/data/brs99/brshelp.pdf
http://www.epa.gov/epawaste/inforesources/data/br09/br09-specification.pdf

31. Large quantity generators of hazardous waste

Variable name	Variable label	Units
LQG	Number of Large Quantity Generators	#

See Treatment, storage and disposal facilities (Section 30).

32. Nuclear power plants

Variable name	Variable label	Units
nuclearplant	Number of nuclear plants	#

The U.S. Nuclear Regulatory Commission (NRC) provides nuclear power plants information at: http://www.nrc.gov/info-finder/reactor/index.html#listAlpha. Data from decommissioned nuclear power plants was collected from the following NRC website: http://www.nrc.gov/info-finder/decommissioning/.

33. Coal-fired power plants

Variable name	Variable label	Units
plant	Number of coal-fired plants	#

Coal-fired power plants info is collected from the Annual Electric Generator data website: http://www.eia.gov/electricity/data/eia860.
We can download data per year on this website.

34. PM2.5

Variable name	Variable label	Units
PM25	Mean annual PM2.5 concentration	µg/m^3

EPA has a dataset of air quality concentrations estimation at the census track level using downscaling for PM2.5 and O3, for years 2001 to 2008. The webpage is the following: http://www.epa.gov/nerlesd1/land-sci/lcb/lcb_faqsd.html. However, 2001 data is not available for the whole Contiguous U.S., this data is only available for the eastern part of the U.S. Since the data is available at the census track level it is important to use population information to average the concentration at the county level, therefore obtaining the population-weighted average annual mean concentration. Data can also be downloaded from the EPA Air Quality System database at: http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm. However, this data is at the monitoring location site, so in order to obtain the concentration at the county population-weighted centroid some geostatistical interpolation is needed, such as kriging.

35. PM10

Variable name	Variable label	Units
PM10	Mean annual PM10 concentration	µg/m^3

There is air quality data (PM10, PM2.5, lead, Ozone, Sulphur dioxide, Carbon monoxide, and Nitrogen dioxide) from 1993 to 2012, available for download from: http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm. The site monitoring location data can be downloaded from the following website: http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm

36. Ozone

Variable name	Variable label	Units
O3	Mean annual O3 concentration	ppb

See PM2.5 (Section 34).

37. Sulphur dioxide

Variable name	Variable label	Units
SO2	Mean annual SO2 concentration	ppb

See PM10 (Section 35).

38. Carbon Monoxide

Variable name	Variable label	Units
CO	Mean annual CO concentration	ppm

See PM10 (Section 35).

39. Nitrogen dioxide

Variable name	Variable label	Units
NO2	Mean annual NO2 concentration	ppb

See PM10 (Section 35).

40. Non-attainment areas

Variable name	Variable label	Units
naaPM25	Share of the population in the county in a PM2.5 non-attainment area	0-1
naaPM10	Share of the population in the county in a PM10 non-attainment area	
naaLead	Share of the population in the county in a Lead non-attainment area	
naaO3	Share of the population in the county in a O3 non-attainment area	
naaSO2	Share of the population in the county in a SO2 non-attainment area	
naaCO	Share of the population in the county in a CO non-attainment area	
naaNO2	Share of the population in the county in a NO2 non-attainment area	

The National Transportation Atlas Database (NTAD) 2010 from the Research and Innovative Technology Administration – Bureau of Transportation Statistics contains information regarding the level of attainment of air quality standards throughout the whole U.S. See Section 58 – Number of airports for obtaining these data. You should have 7 shapefiles of non-attainment areas, one for each criteria pollutant, i.e. O_3, CO, NO_2, SO_2, PM_{10}, $PM_{2.5}$ and Lead. These shapefiles are polygons so averaging this information over the counties is needed. A way to accomplish this is by obtaining the share of the population that is within non-attainment area per county.

41. Cancer Risk

Variable name	Variable label	Units
CancerRisk	People at possible risk out of 1 million	#

Data is available for years 1996, 1999, 2002 and 2005. EPA provides figures for cancer risk, neurological risk, and respiratory risk in the National Air Toxics Assessments at: http://www.epa.gov/ttn/atw/natamain/index.html. However, it is important to keep in mind that “due to the extent of improvements in methodology, it is not meaningful to compare the assessments. This is because any change in emissions, ambient concentrations, or risks may be due to either improvement in methodology or to real changes in emissions or source characterization.”

42. Neurological risk

Variable name	Variable label	Units
NeuroRisk	Neurological risk index	--

See Cancer risk (Section 42).

43. Respiratory risk

Variable name	Variable label	Units
RespRisk	Respiratory risk index	--

See Cancer risk (Section 42).

44. Local direct general expenditures

Variable name	Variable label	Units
dirgen_localexp	Local direct general expenditure ($000 per capita)	$1000 per capita

U.S. Census provides different revenue and expenditure information for the government in the U.S. Census of Governments website. The latest available data is from 2007, and one can access it at the following ftp site: http://www2.census.gov/pub/outgoing/govs/special60/

45. Local exp. for hospitals and health

Variable name	Variable label	Units
hosphealth_localexp	Local expenditure for hospitals and health ($000 per capita)	$1000 per capita

See Local direct general expenditures (Section 45).

46. Local exp. on parks, rec. and nat. resources

Variable name	Variable label	Units
parknat_localexp	Local expenditure for parks, rec. and nat. resources ($000 per capita)	$1000 per capita

See Local direct general expenditures (Section 45).

47. Museums and historical sites

Variable name	Variable label	Units
museums	Number of museums and historical sites	#
museums_per1000	Number of museums and historical sites per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Museums and Historical sites NAICS codes are equal to 71211 and 71212, respectively. Using these NAICS codes one can retrieve the number of these facilities or sites per county, and then normalize it by population.

48. Municipal parks (percentage of total land area)

Variable name	Variable label	Units
localpark_mi2	Local park land in square miles	Mile^2
localpark_pct	Local park land in percentage (over land area)	%

ESRI provides a shapefile of parks on the ArcGIS online service. This map is called 'USA Parks'.

49. Campgrounds and camps

Variable name	Variable label	Units
camps	Number of campgrounds and camps	#
camps_per1000	Number of campgrounds and camps per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Campgrounds and camps NAICS codes are equal to 72121 (Recreational vehicle parks and campgrounds) and 72124 (Recreational and vacation camps), respectively. Using these NAICS codes one can retrieve the number of these facilities or sites per county, and then normalize it by population.

50. Zoos, botanical gardens and nature parks

Variable name	Variable label	Units

zoos	Number of zoos, botanical gardens and nature parks	#
zoos_per1000	Number of zoos, botanical gardens and nature parks per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Zoos and botanical gardens, and nature parks NAICS codes are equal to 71213 (Zoos and botanical gardens) and 71219 (Nature parks and other similar institutions), respectively. Using these NAICS codes one can retrieve the number of these facilities or sites per county, and then normalize it by population.

51. Crime rate (per 100,000 persons)

Crime here refers to Personal crime, not property crime.
See introduction in http://www.icpsr.umich.edu/icpsrweb/content/NACJD/guides/ucr.html
Data is accessible from ICPSR at
http://www.icpsr.umich.edu/icpsrweb/NACJD/studies/30763?q=Uniform+Crime+Reporting+Program+Data+%5BUnited+States%5D%3A+County-Level&archive=NACJD&y=13&x=29&sortBy=5&paging.rows=25.

52. Teacher-pupil ratio

Variable name	Variable label	Units
teacher_pupil_ratio	Teacher-pupil ratio	ratio

U.S. Census provides different employment information for the government in the U.S. Census of Governments website. The latest available data is from 2007, and one can access it at the following ftp site: http://www2.census.gov/pub/outgoing/govs/special60/

53. Local expenditure per student

Variable name	Variable label	Units
edu_localexp	Local education expenditure ($000s per student)	$1000/student

See Local direct general expenditures (Section 45) for gathering data on local expenditure on education. Then see Teacher-pupil ratio (Section 53) to gather data on the number of students per county.

54. Private school to public school enrollment (%)

Variable name	Variable label	Units
priv_to_pub	Private school to public school enrollment	%

Data on school enrollment can be gathered from the Census-ACS datasets, which one can build from the American FactFinder website: http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t

55. Child mortality (per 1000 births, 1990–2000)

Variable name	Variable label	Units
childmort	Child mortality rate (deaths per 1000 births), 2000 - 2009	Death/1000birth

The Center for Disease Control and Prevention provides this information at: http://wonder.cdc.gov/lbd.html.

56. Federal expenditure ($ pc, non-wage, non-defense)

Variable name	Variable label	Units
fedexp	Federal expenditure ($000s per capita, non-wage, non-defense)	$1000 per capita

See Local direct general expenditures (Section 45).

57. Number of Airports

Variable name	Variable label	Units
airports	Number of airports, NTAD 2010	#

The National Transportation Atlas Database (NTAD) 2010 from the Research and Innovative Technology Administration – Bureau of Transportation Statistics can be ordered from the following website:
https://1bts.rita.dot.gov/pdc/user/products/src/products.xml?p=3194&c=-1

However, this data is only available in DVD, so you will have to order it. From 2011 onwards, the Research and Innovative Technology Administration provides this data for download at:
http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_atlas_database/index.html

58. Number of Ports

Variable name	Variable label	Units
ports	Number of ports, NTAD 2010	#

See Number of Airports (Section 58).

59. Interstate highways (total mileage per mi^2)

Variable name	Variable label	Units
InterstateHwys	Mileage of Interstate Highways per county, NTAD 2010	Mile
InterstateHwys_perland	Mileage of Interstate Highways per county (mi/mi2 of land), NTAD 2010	Mile/Mile^2

See Number of Airports (Section 58).

60. Urban arterial (total milage per mi^2)

Variable name	Variable label	Units
UrbanArterials	Mileage of urban arterials per county, NTAD 2010	Mile
UrbanArterials_perland	Mileage of urban arterials per county (mi/mi2 of land), NTAD 2010	Mile/Mile^2

See Number of Airports (Section 58).

61. Number of Amtrak stations

Variable name	Variable label	Units
amtrak	Number of Amtrak stations, NTAD 2011, data 2010	#

See Number of Airports (Section 58).

62. Number of urban rail stops

The data is accessible from http://nationalatlas.gov/atlasftp.html?openChapters=chptrans#chptrans. The latest is in 2005.

63. Railways (total mileage per mi^2)

Variable name	Variable label	Units
Railways	Mileage of railways per county, NTAD 2010	Mile
Railways_perland	Mileage of railways per county (mi/mi2 of land), NTAD 2010	Mile/Mile^2

See Number of Airports (Section 58)

64. Number of restaurants and bars (per 1,000 people)

Variable name	Variable label	Units
restau_bar	Number of restaurants and bars	#
restau_bar_per1000	Number of restaurants and bars per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website:
http://www.census.gov/econ/cbp/download/10_data/.

Restaurants and bars NAICS codes are equal to 722110 (Full-services restaurants) and 7224140 (Drinking places (alcoholic beverages)), respectively. Using these NAICS codes one can retrieve the number of these facilities or sites per county, and then normalize it by population.

65. Theatres and musicals (per 1,000 people)

Variable name	Variable label	Units
theatre	Number of theatres and musicals	#
theatre_per1000	Number of theatres and musicals per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Theatres and musicals NAICS codes are equal to 711110 (Theatre companies and Dance theatres), 711120 (Dance companies), 711130 (Musical group and artists, and 711190 (Other performing arts companies). Using these NAICS codes one can retrieve the number of these facilities or sites per county, and then normalize it by population.

66. Artists (per 1,000 people)

Variable name	Variable label	Units
artists	Number of artists	#
artists_per1000	Number of artists per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Artists NAICS codes are equal to 711410 (Agents and managers for artists, athletes, entertainers and other public figures), and 711510 (Independent artists, writers, and performers). Using these NAICS codes one can retrieve a proxy for the number of artists per county, and then normalize it by population.

67. Movie theatres (per 1,000 people)

Variable name	Variable label	Units
movie	Number of movie theatres	#
movie_per1000	Number of movie theatres per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Movie theatres NAICS codes are equal to 512131 (Motion pictures theatres (except Drive-Ins)), and 512132 (Drive-In motion pictures theatres). Using these NAICS codes one can retrieve the number of these facilities or sites per county, and then normalize it by population.

68. Bowling alleys (per 1,000 people)

Variable name	Variable label	Units
bowling	Number of bowling centers	#
bowling_per1000	Number of bowling centers per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Bowling alleys NAICS code is equal to 713950 (Bowling centers). Using this NAICS code one can retrieve the number of these facilities or sites per county, and then normalize it by population.

69. Amusement, recreation establishments (per 1,000 people)

Variable name	Variable label	Units
amusement	Number of amusement and recreation establishments	#
amusement_per1000	Number of amusement and recreation establishments per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website: http://www.census.gov/econ/cbp/download/10_data/.

Amusements and recreation establishments NAICS code is equal to 713990 (All other amusement and recreation industries). Using this NAICS code one can retrieve the number of these facilities or sites per county, and then normalize it by population.

70. Research I universities (Carnegie classification)

Variable name	Variable label	Units
ResearchI	Research-I universities	#

Research I universities are currently classified as 'Research universities (very high research activity) – RU/VH'. The classifications are described in the following website: http://classifications.carnegiefoundation.org/descriptions/basic.php.

The Classifications Data File can be downloaded from this website:
http://classifications.carnegiefoundation.org/resources/.

71. Golf courses and country clubs

Variable name	Variable label	Units
golf	Number of golf courses and country clubs	#
golf_per1000	Number of golf courses and country clubs per 1000 people	# per 1000 people

The U.S. Census provides County Business Patterns datasets for download in the following website:
http://www.census.gov/econ/cbp/download/10_data/.

Golf courses and country clubs NAICS code is equal to 713910 (Golf courses and country clubs). Using this NAICS code one can retrieve the number of these facilities or sites per county.

72. Military areas (percentage of total land area)

Variable name	Variable label	Units
milarea_mi2	Military area in square miles	Mile^2
milarea_pct	Military area in percentage (over land area)	%

See Number of Airports (Section 58).

73. Distance (km) to the nearest urban center, MSA of multiple sizes

Data source and method follows PRAO-JIE09: PARTRIDGE, M. D., D. S. RICKMAN, K. ALI, AND M. R. OLFERT (2009): "Agglomeration Spillovers and Wage and Housing Cost Gradients Across the Urban Hierarchy," Journal of International Economics, 78(2), 126–140.