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This paper is preliminary and will be revised. Comments and criticisms are particularly welcome. Please contact me for a copy of the revised version of the paper.

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> "Drive down any highway leading into any town in the country, and what do you see? ... You see communities drowning in a destructive, soulless, ugly mess called sprawl." (Richard Moe, 1996)

Introduction

Concern with "sprawl" is certainly not new. In general, urban economists have studied the spatial distribution of population and economic activity intensively since the pioneering work of Alonso (1964), Muth (1969) and Mills (1972). Of course analysis of population distributions goes back even further, traceable at least back to von Thunen (1826), including studies by other social scientists such as Burgess (1925), Hoyt (1959) and Clark (1951). In addition to population distribution, there are related empirical literatures on the distribution of real estate prices (e.g. Follain and Malpezzi 1981) and the distribution of wages and incomes over space (Eberts 1981, Madden 1985).[1]

The use of the (usually) pejorative term "sprawl" for certain kinds of population distributions has a (not quite as long) history, but less attention paid in the academic literature. Early widely cited papers include Clawson (1962) and Real Estate Research Corporation (1974). Later papers include Mills (1981), Brueckner and Fansler (1983) and Peiser (1989).

It scarcely requires documentation that recently "sprawl" has entered the popular and political discussions of urban development with a vengeance. That mayors, planners, and political activists have focused on sprawl as an important issue (Egan 1996, Norquist 1997, Rusk 1993) is perhaps not as surprising as the fact that commentators as diverse as the Bank of America and Vice President Gore have pointed to sprawl as a central urban issue.

Recent discussions of sprawl suffer from a lack of consensus on the most basic facts about it. To begin with, most discussions fail to define sprawl rigorously, and those few that do present alternative definitions. Given this, it is unsurprising that little systematic attempt has been made to measure sprawl (except as sprawl is proxied by density gradients, see below), or to undertake rigorous cost-benefit analysis of sprawl.[2] Every day throughout the U.S. planning and regulatory decisions, infrastructure investments,

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[1] Much of this literature is ably surveyed by McDonald (1989). Broad reviews of the theoretical models behind this empirical work can be found in, for example, Wheaton (1979) Straszheim (1987) and Anas, Arnott and Small (1998).

[2] Studies such as Real Estate Research Corporation (1974) have examined costs, but their neglect of the demand side of the land market limits the usefulness of their conclusions, as discussed in Windsor (1976).

and the like, are made on the basis of the vaguest and most ill defined notions of the nature, determinants, and costs and benefits of sprawl.

The purpose of this paper is to discuss some alternative definitions of sprawl, and create new measures based on these definitions for U.S. metropolitan areas. The paper will use these new measures to examine the determinants of sprawl, and to examine in turn the effects sprawl has on several key urban indicators on transportation and the like. These results can be used to undertake a rudimentary cost-benefit analysis of sprawl.

This paper is a draft, and comments are particularly welcome. Empirical results may well change as we refine the analysis in future drafts.

Sprawl Defined

Most writers and activists fail to carefully define sprawl. Those papers (such as Downs 1996, Ewing 1997) that do attempt a definition either do not agree, or point out the essential multidimensionality of how sprawl is implicitly defined. Some elements of a definition might include:

Low density

Discontiguous ("leapfrog") development

Lack of public open space

Other outcomes that may be more or less associated with sprawl include:

High auto use, low transit use

Differences in the cost of public services

Excessive loss of farmland

These latter outcomes are sometimes discussed as if they define sprawl, but we would argue that they are better thought of as causes and/or consequences of sprawl.

Since sprawl is notoriously hard to define, it is not surprising few papers have tried to measure it. Many papers rely on average population density in the metro area. We argue (along with others such as Ewing) that this is not a good measure. We offer some alternatives below.

Previous Research

There is a large literature on sprawl, ably surveyed by Burchell *et al.* (1998). However, most of the literature is given over to advocacy pieces, with a number of influential descriptive papers that continue to be widely cited despite severe methodological problems. In the refereed urban and real estate economics literature, surprisingly few theoretical and empirical papers have carefully examined sprawl. In this highly selective review we focus more on the scholarly literature and less on advocacy pieces, although some of the former are omitted and some of the latter are included.

Mills (1981) is an early and influential paper that presents an economic theory of sprawl in a growing monocentric city. Using first a perfect foresight model, Mills outlined conditions under which discontinuities in development are efficient. The intuition behind Mill's result is straighforward. By assumption, developers perfectly foresee future export demands for a city's products and future housing needs. Even though these future needs are discounted, given the putty-clay nature of the development process, and ex post segregation of land uses, developers reserve more close-in land for commercial use than currently utilized, and thus force early residential development farther away from the center.

Mills' results are more complicated in a second model, where the perfect foresight assumption is dropped. In this variant, Mills examines land use in a dynamic model, which may require that internal parcels be with held from development and held for alternative future uses. However the efficiency of leapfrog development followed by infill is possible but no longer assured. Mills also notes that while sprawl may lead to higher infrastructure costs, the larger problem is a failure to charge developers marginal cost for those services. This is not a land market failure *per se*, then, but rather an issue that can be addressed by pricing infrastructure appropriately.

Brueckner and Fan (1983) reviewed the well-known results of the Alonso-Muth-Mills-Wheaton models of the city, that land consumption is a normal good, and also inversely related to transportation costs. Using aggregate 1970 data from 40 urbanized areas, they showed that land consumption was increasing in income and decreasing in agricultural rent (the opportunity cost of urban development). Transport variables had the correct signs but were generally insignificant.

Later papers by Peiser (1989) and Heikkila and Peiser (1992) pick up on this theme. Peiser (1989) analyzes data from California and shows that areas with initial sprawl followed by infill development in the long run developed more densely and maximized land values. Heikkila and Peiser (1992) find similar results using a simulation model.

But perhaps the single most influential study of sprawl to date has been one of the first, Real Estate Research Corporation's "Cost of Sprawl" (1974, hereafter cited as RERC). RERC marshaled data on the public and private capital and recurrent costs of development for five different types of construction, high-rise, walk-up apartments, townhomes, and two kinds of single-family, on third-acre grid lots, and clustered development. They fixed the size of each development at 1,000 housing units. The infrastructure included was primarily schools, roads and utilities. As measured, per housing-unit costs declined as density increased. For example, compared to single family grid development, roads in townhouse developments were one-third cheaper to construct, and half the cost to maintain.

RERC (1974) must be carefully examined by anyone interested in this subject. However the study is not without its critics. Windsor (1979) and Altshuler (1977) point out that RERC focused on per-unit cost, and did not calculate the least costly pattern of housing development for a given population. The analyses of per-unit costs by RERC for different types of projects, whether single-family, multifamily, are greenfield development, with no consideration of later infill, and no adjustment for, e.g., different household sizes in different development types. Differences in density are not disentangled from differences in household composition, demographics and so on.

It should also be pointed out that *The Costs of Sprawl* attempts to study just that. By design RERC neglects the demand side of the market. Thus the benefits, if any, are neglected. In fact, the authors of RERC were careful to point this out in their introduction, but the point seems often lost on later readers. We return to this point in our own simple diagrammatic model below.

Burchell and Listokin and colleagues (e.g. 1978) have developed a series of fiscal impact studies and related methodological treatises that broadly follow RERC lines. Burchell and many other authors have contributed to a recent update of RERC 1974 in The Cost of Sprawl Revisited (Burchell *et al.* 1998).

Many papers analyze population density gradients. McDonald (1989) presents a cogent review and Jordan *et al.* (1998) provides recent evidence on changes in population density gradients. Bertaud and Malpezzi (1999) examine population density gradients in 35 world. Follain and Malpezzi (1981) and Malpezzi and Kung (1997) examine corresponding house price and rent gradients.[3]

One of the potential costs of sprawl is of course higher local government expenditure on local services. Ladd (1992) estimates a regression model that controls for a wide range of determinants of per capita local public spending. With these results she examines the *ceteris paribus* impact of population growth and population density on current account spending, capital outlays, and spending on public safety. A U-shaped relationship between spending and density is found. Higher density typically *increases* public sector spending, except in very sparsely populated areas. Rapid population growth is also shown to impose fiscal burdens on established residents.

A very illuminating pair of articles was published in the *Journal of the American Planning Association* in 1997. Gordon and Richardson (1997) summarized in a very accessible form a wide range of work by themselves and others suggesting compact cities (at least as usually measured) are not necessarily a desirable planning goal. Their paper points out that many studies that concern themselves with the cost of sprawl neglect the demand side of the market. Generally focus groups as well as revealed market behavior provide a prima facie case that many consumers prefer low density development. If one accepts the legitimacy of consumer preferences (as opposed to the preferences of an elite), the rationale for concern about sprawl then has to focus on the existence of some externality.

Gordon and Richardson then go on to argue that most of the externality arguments made are misleading or overstated. For example many activists are concerned with the loss of prime agricultural land. However work by Fischel (1982) and others has shown that the U.S. has little to concern itself with in this area. See Appendix A for evidence that agricultural land is not an issue. Similarly, many arguments revolve around commuting, peak hour congestion, and transit use (or more to the point, lack thereof). In fact a number of studies have shown that under many conditions the automobile is a very efficient form of transport (Dunn 1999). That is not to say that autos are not mis-priced, which is widely accepted. Rather, there is little evidence that the mis-pricing can be corrected by corresponding deep subsidies to lightly used transit systems in most cities.[4]

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[3] Follain and Malpezzi examine house price differentials, which are correlated with gradients; Malpezzi and Kung are currently revising their estimation of a model that jointly examines price gradients and population density gradients.

[4] Most U.S. cities of any size have transit use of less than 10 percent of commuters, and a lower percentage of total trips (commutes are only about a quarter of rush hour trips). This includes cities that have invested as heavily in transit, such as Portland. Of course some older very dense and large cities are outliers. About 40 percent of New York's commuters use public transit, by far the highest

Ewing (1997) provides a counterpoint to Gordon and Richardson, presenting what he characterizes the 'planner's view'. Among other contributions, Ewing points out the confusion that comes from different implicit definitions of sprawl. He categorizes the elements of sprawl as low-density development, strip development, scatter development, and leapfrog development. While these are not necessarily all terribly different - the difference between scattered and leap frog is not immediately clear - most studies implicitly focus on one or two of these four, although some do include all four. Neither Gordon and Richardson, nor Ewing, provide actual measures of sprawl in their articles.

Ewing also notes that there are many implicit subsidies to low density development. Of course Gordon and Richardson do recognize the existence of such subsidies. For example, the latter undertake a back of the envelope calculation that suggests that automobile subsidies add up to approximately 22 cents per passenger mile, which of course falls short of per-passenger-mile transit subsidies. Ewing notes that at typical gas mileage, increasing the cost of transportation by 22 cents per passenger mile would require an additional tax of $6.00 to $7.00 per gallon.[5]

Ewing also criticizes Gordon and Richardson's claim that "the length between high density development and reduced vehicle miles of travel . . . is by no means clear." Citing his own work on Florida and several other studies, Ewing claims that the relationship is on a solid foundation. He claims "as densities rise, trips get short, transit and walk mode shares increase, and vehicle trip rates drop."

Ewing notes that Gordon and Richardson state that the energy impacts of sprawl "are not worth worrying about. They are probably right." But while Ewing believes that they are probably right, he still worries. He suggests that the potential loss if Gordon and Richardson (and Ewing) are wrong is so high that we should act as if energy prices will radically increase.

Gordon and Richardson characterize the general findings of hypothetical studies such as RERC 1974 and Burchell and Listokin (1995) as questionable. These are all based on hypothetical development densities and infrastructure costs, albeit carefully drawn ones. As noted above, Altshuler and Windsor and others have pointed out the

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of any metro area in the country.

[5] Of course most transit economists argue that at least some of these social costs should be recouped by taxing use by time of day in congested areas, using modern electronic technology. Mills (1999) is one prominent dissenter among economists; he argues on political and economic grounds for a gasoline tax. Also, we note in passing that freight trucks and other heavy traffic do almost all physical damage to roads, and are generally undertaxed.

shortcomings of focusing on per unit costs. There would certainly be advantages to relying on *ex post* studies of the relationships between costs and density. However, the only studies to date of actual public spending per capita and density are those by Helen Ladd and her associates, such as Ladd (1992), discussed above.

In Ladd's studies, public spending *rises* with density after an initial fall, in contrast to the claims of hypothetical studies like RERC. Ewing notes that RERC 1974 and similar studies focus on infrastructure costs, but Ladd's studies focus on a broader range of public service costs. Ewing clarifies the fact that, in addition to the per-unit focus discussed above, the RERC-type studies focus on intermediate inputs, e.g. the cost of providing roads to developments of a given density. Ladd's study examines outputs, e.g. total costs of transport. These could easily diverge systematically according to density. For example, given higher road use in denser development, full traffic costs may be driven up by the need to include more traffic lights, police and other inputs to achieve a given level of traffic flow. Ultimately, perhaps the firmest statement that Ewing makes about this is that more study is needed.

Another related literature is that on "wasteful commuting". Hamilton (1982) calculated the difference between actual commuting and theoretical efficient commuting that would occur in a monocentric city. According to his calculations, actual commuting is often five to eight times as large as the theoretically derived efficient level. White (1988) presented alternative results using a polycentric model of the city, and found that most of the "waste" disappeared. (See also Hamilton's (1989) response).

Thurston and Yezer (1994) recomputed the wasteful commuting model in a monocentric city, relaxing the assumption that all households are identical. They point out that labor force participation rates are higher in the suburbs that in the central cities, which suggests that the population gradient is steeper than the resident worker gradient. They argue that the latter is the appropriate measure since only employed individuals commute to work. Thurston and Yezer also computed density functions for different occupational groups using 1980 census data. Following Hamilton, Thurston and Yezer also correct for the fact that in most large cities there is a "crater" in the CBD where no one lives. In large cities, the highest densities are typically ½ mile or so from the actual center of the city.

In addition to these other adjustments, Thurston and Yezer use median rather than mean commuting distance for their calculations. Since travel data are non-normal, means are not a particularly good measure of central tendency. When all adjustments are made, Thurston and Yezer find that median actual commuting exceeded mean efficient commuting distance by 2.2 miles, or wasteful commuting was 50% of optimal commuting. While non-negligible, this is a very large reduction from Hamilton's original result.

Cost and Benefits of Sprawl

The difference between the pure cost view of sprawl and the cost-benefit view can be explained using the following simple diagrammatic approach. Figure 1 shows the "Pure Cost" view, or a view that could be taken by someone reading Real Estate Research Corporation's study without thinking of the caveats they clearly present in chapter 1, i.e. that there is a demand side to the market that they neglect.

Figure 1 shows in a highly stylized way a world in which the costs of development per housing unit fall as density increases. Even if one prefers the simulation results a la RERC, and discounts the empirical evidence of Ladd that costs rise with density, the exact slope of this cost function, and whether it is linear over the entire range, remain to be determined. It is certainly plausible that at least some development costs fall with density.[6] The vertical line in Figure 1 indicates what I will call the maximum feasible density, that is to say the highest density which current rules and practices permit. As drawn, this cost-minimization technique leads to high density and low cost.

But the pure cost view does not take into consideration the benefits and concomitant willingness-to-pay (WTP) for housing at different densities. Many Americans, and in fact people in many cultures, exhibit behavior which suggests space is a normal good, at least over some relevant range. On the other hand, at some extremely low densities, people may be willing to pay for an increase in density to have more of a feeling of community, safety, and so on. Thus we have drawn the willingness to pay or benefit curve as an inverted U, in Figure 2. At very low densities, willingness to pay or perceived benefits increase with density. Past some point, WTP then falls as people find more crowded units less desirable.

The ideal market solution, and every developer's dream, is to maximize the difference between cost and value. That is to say, the market will tend to choose a density that

[6]Certainly those related to streets, sewage, water mains, and other trunk infrastructure can clearly be shown to fall from an engineering standpoint. See, in addition to RERC, the work of Burchell and Listokin and their associates, and the work of Alain Bertaud. Of course, if costs fall with increasing density globally, and if our goal is to minimize the cost of development, we should all live on the head of a pin. Even those who misread Real Estate Corporation's report presumably don't take such an extremist point of view.

maximizes the height between the cost and the WTP curves. As drawn, this is well to the left of the maximum feasible density.[7]

Those who take a market-oriented approach to development do not usually deny the fact that there are external costs in development as well as private costs. It could be that when external costs are considered, the market clearing density is too low. Consider Figure 3. Now we add a second cost function, which includes external costs as well as private costs. That is, assume that Figure 2's costs were private costs, and that there is some additional external costs driving a wedge between private and social costs. As drawn, we assume that these external costs are such that the social cost of low-density development is in fact higher than its private costs would indicate. As drawn, past some point higher density development's social costs are lower than private costs would indicate.

Once again in Figure 3 profit-maximizing developers and consumers would maximize the difference between private benefits and costs, i.e. choose the point where the height between the WTP curve and the flatter private cost curve is greatest. The social optimum is that where the difference between the steeper social cost curve and the WTP curve is maximized. As drawn, this is to the right of the private-cost-maximum. Thus, externalities can clearly lead to a case where unregulated development is less dense that socially optimal.

Notice that as drawn, the maximum feasible density assumed desired by a stylized planner is well to the right of both. Of course that is a cheap shot. There is no reason to believe that this maximum feasible density will always be so far to the right of the maximum social benefit-minus-cost. A good planner would be one who focuses on the difference between social benefits and costs; a bad planner would be one who would simply try to squeeze out every last ounce of feasible density.

We also note that for every regulation or political drive to increase the density of development we can often find a counterpart action that has the effect of decreasing the maximum density of development. Zoning that reduces a developer's ability to provide multifamily housing, stringent floor area ratio regulations, and the like are examples of such perverse regulations. The city of Madison, Wisconsin is a good case in point. Virtually every day carries two or three stories in the local papers about the need to control sprawl or change land use patterns in some way. At the same time the

[7] Note that I have drawn the maximum feasible density as a technical constraint. From an economic point of view, no one would develop to the right of the point where willingness-to-pay and cost intersect, which is in between the profit maximizing point and the maximum *technically* feasible density.

dominant rhetoric is about the importance of tackling sprawl, this city has actually *downzoned* large areas of the central city, reducing the density of prospective development in response to complaints from neighbors about increasing multifamily development in the city. Clearly one cannot have it both ways.

The Measurement of Urban Sprawl

In this section we discuss some measures of sprawl and related measures of urban form. See also Song (1996).

Average Density

The most common measure is average density in the metropolitan area.:

1. Average MSA density

However, the limitations of the measure are obvious. Consider two different single-county MSAs of equal area and equal population. Suppose the first contains all of its population in a city covering, say, a fourth of the area of the county, the rest of which is rural and lightly settled. Suppose the other MSA has a uniform population distribution. Our measure, average density, is the same. But most observers would consider the second MSA as exhibiting more "sprawl" than the first.

Of course there is no reason to limit ourselves to *average* densities. Other moments, and nonparametric measures can also be considered.

Alternative Density Moments

In this paper we construct several new indicators of population density gradients, based on the densities of the Census tracts in each MSA. The starting point for each MSA is to compute these tract densities, and then to sort tracts by descending density. We then construct several indicators of "sprawl", one for each MSA:

2. Maximum tract density, DENMAX
3. Minimum tract density, DENMIN

4. DENMED: the density of the "median tract weighted by population," that is, when tracts are sorted by density, the tract containing the median person in the MSA. For example, suppose the population of the MSA is 100 people, in 7 tracts:

N	Tract Density	Tract Population
1	10	30
2	9	30
3	8	10
4	7	10
5	6	10
6	5	5
7	4	5

The median person is "contained" in tract 2, so DENMED=9.

5, 6: DENPCT10 and DENPCT90, the corresponding 10^{th} and 90^{th} percentiles of tract density, constructed as above.

7: The coefficient of variation of tract densities.

8. Theil's information measure:

DENTHEIL = sum Ai/A x log((Ai/A)/(Pi/P))

Where Ai is the area of the ith tract, A is the MSA area, Pi is the population of the ith tract, and P is the MSA population.

9. Gini coefficient:

Sort tracts within MSA in descending density. Compute cumulative population in percent, CPP and cumulative area in percent, CAP, as you move down tracts. Compute difference between CPP and CAP for each tract. Then sum over all tracts within each MSA.

Population Density Gradients

The measure of city form that has been most often studied by urban economists is the population density gradient from a negative exponential function, often associated with the pioneering work of Alonso, Muth and Mills, but actually first popularized among urban scholars by the geographer Colin Clark.[8] More specifically, the population density of a city is hypothesized to follow:

$$D(u) = D_0 e^{-\gamma u \varepsilon}$$

where D is population density at distance u from the center of a city; D_0 is the density at the center; e is the base of natural logarithms; gamma is "the gradient," or the rate at which density falls from the center. The final error term, ε, is included when the formulation is stochastic.

10, 11: Our 10th measure is the gradient delta, and our 11th is density at the center, D_0.

Among the other attractive properties of this measure, density is characterized by two parameters, with a particular emphasis on γ, which simplifies second stage analysis. The function is easily estimable with OLS regression by taking logs:

$$\ln D(u) = \ln D_0 - \gamma u + \varepsilon$$

which can then be readily estimated with, say, density data from Census tracts, once distance of each tract from the central business district (CBD) is measured.

The exponential density function also has the virtue of being derivable from a simple model of a city, albeit one with several restrictive assumptions, e.g. a monocentric city, constant returns Cobb-Douglas production functions for housing, consumers with identical tastes and incomes, and unit price elasticity of demand for housing.

As is well known, the standard urban model of Alonso, Muth and Mills predicts that population density gradients will fall in absolute value as incomes rise, the city grows, and transport costs fall. Extensions to the model permit gradients to change with location-specific amenities as well (Follain and Malpezzi 1981).

The negative exponential function often fits the data rather well, for such a simple function in a world of complex cities. Sometimes it does not fit well, as we will confirm. Many authors have experimented with more flexible forms, such as power terms in distance on the right hand side.

[8] McDonald, in his excellent (1989) review, points out that Stewart (1947) apparently first fit the negative exponential form described here, but notes that it was Clark (1951) that popularized the form among other urban scholars.

The world is divided up into two kinds of people: those who find the simple form informative and useful, despite its shortcomings (e.g. Muth 1985), and those who believe these shortcomings too serious to set aside (e.g. Richardson 1988).[9] In fact, given the predicted flattening of population density gradients as cities grow and economies develop, it can be argued that the monocentric model on which it rests contains the seeds of its own destruction; and that a gradual deterioration of the fit of the model is itself consistent with the underlying model.

Extensions of the Simple Exponential Gradient

The simplest, and most widely used model is:

$\text{Ln } D = a + b \ln U$

Where D is the tract's density, and U is distance from the center. We are relying on this simple model for our second stage work, but we have also computed three additional models, with right hand side variables:

12. U and U^2
13. U, U^2, and U^3
14. U, U^2, U^3 and U^4

Measuring Discontiguity

A simple and natural measure of discontiguity is:

15. the R2 statistic from the density gradient regressions.

Consider the two panels of Figure 4. Panel A shows a very highly stylized city with a given density gradient, as does Panel B. In Panel A we have drawn a pattern consistent with very contiguous density patterns as one moves from the center of the city outwards. The second Panel shows a city with the same density gradient, but a much more discontiguous pattern. The R-squared from the density gradient regressions is a natural measure of this discontinuity. However it should be noted that a low R-squared is a sufficient but not necessary condition for such discontinuity.

[9] The world is also divided up into people who divide the world into two kinds of people, and people who don't, but that's another paper.

Consider a city where the density gradient is very contiguous from tract to tract, but assume that the gradient varies by direction as well as distance from the CBD. An example would be a metro area in which the gradient declines very rapidly with distance in one direction, but very slowly in another. Suppose this difference is very systematic, and density changes slowly as one rotates from left to right around the central point of the city. Such a city would not be truly discontiguous by most people's thinking, but would have a low R-squared for a simple two-parameter density regression of the usual kind, where it is maintained that density varies with distance but not direction. Of course it would be possible to estimate distance density gradients that vary by direction as well as distance (see Follain and Gross), but undertaking such an exercise would require resources beyond our present ones.

Compactness

In Bertaud and Malpezzi (1999), Alain Bertaud developed a compactness index, rho, which is the ratio between the average distance per person to the CBD, and the average distance to the center of gravity of a cylindrical city whose circular base would be equal to the built-up area, and whose height will be the average population density:

$$\rho = \frac{\sum_i d_i w_i}{C}$$

where rho is the index, d is the distance of the ith tract from the CBD, weighted by the tract's share of the city's population, w; and C is the similar, hypothetical calculation for a cylindrical city of equivalent population and built up area. A city of area X for which the average distance per person to the CBD is equal to the average distance to the central axis of a cylinder which base is equal to X would have a compactness index of 1.

16. Rho, as above.

Of course the denominator, C, is merely a baseline against which to compare the actual compactness of the city. We are not arguing that cylindrical cities are in some sense optimal, merely that some cities will be more compact than this baseline (have a lower value of rho),and some will be less compact (have a higher value of rho).

Other Measures

In addition to the traditional gradient measure, many other measures of urban form have been put forward and studied. The simplest, of course, is the average density of the city or metropolitan area. Others include measures such as the weighted average of straight line or rectangular distances from one set of points in a city to another, or functions based on densities other than the negative exponential, such as the normal density (Ingram 1971; Pirie 1979; Allen *et al.* 1993).

Another set of measures could be developed using techniques developed by urban geographers and others for the analysis of data exhibiting spatial autocorrelation. Anselin and colleagues, and Pace, describe these techniques.

The American Housing Survey has data on land area for single family houses. To my knowledge, no one has used this data in the analysis of sprawl. For example, median lot size of single family homes built in the last five years would be one possible indicator that could be constructed.

Finally, given the multidimensionality of sprawl, sprawl is a natural candidate for data reduction techniques such as principal components.

In this initial working draft we focus on one measure in particular. Our favored measure, for now, is the density of the Census tract containing the 10th percentile of MSA population, when tracts within an MSA are sorted by population density. Other measures will be analyzed more fully in the next draft.

The Determinants of Urban Form

The Standard Urban Economics Model and the Determinants of Urban Form

The well-known "standard urban model" of Alonso (1964), Muth (1969) and Mills (1972)[10] postulates a representative consumer who maximizes utility, a function of housing (H) and a unit priced numeraire nonhousing good, subject to a budget constraint that explicitly includes commuting costs as well as the prices of housing (P) and nonhousing (1). It is easy to show that equilibrium requires that change in commuting costs from a movement towards or away from a CBD or other employment node equals the change in rent from such a movement. For such a representative consumer:

[10] These three references are among the classics in the field. Among many recent treatments and extensions, see Fujita (1989), Turnbull (1995) and Arnott, Anas and Small (1998).

$$\Delta u \cdot t = -\Delta P(u) \cdot H(u)$$

where u is distance from the CBD and t is the cost of transport. This equilibrium condition can be rearranged to show the shape of the housing price function:

$$\frac{\Delta P(u)}{\Delta u} = -\frac{t}{H(u)}$$

Now consider two consumers, one rich and one poor. Assume H is a normal good. If (for the moment), t is the same for both consumers but H is bigger for the rich (at every u), the rich bid rent function will be flatter. The rich will live in the suburbs and the poor in the center. Even if t also increases with income (as is more realistic), as long as increases in H are "large" relative to increases in t, this result holds.[11] Also, as incomes rise generally, the envelope of all such bid rents will flatten. Also, clearly, as tranport costs fall, bid rents will flatten.

The standard urban model has a competitor, which is sometimes called the "Blight Flight" model (Follain and Malpezzi 1981). As presented in the U.S. literature, the Blight Flight Model has a negative tone. People have left the cities not because they preferred suburban living a la the standard model, but because the cities themselves have become less desirable places to live. As U.S. cities became more and more the habitat of low-income households and black households, the argument goes, housing and neighborhood quality declined and white middle-to-upper income households flew to the suburbs.

While "Blight Flight" explanations focus on negative amenities such as crime and fiscal stress, the models are easily generalizable to positive amenities such as high quality schools. Blight Flight can be generalized and formalized by adding a vector of localized amenities (and disamenties) to the standard urban model above. See, for example, Li and Brown (1980), Diamond and Tolley (1982), and many subsequent applications.

Simple Models of Determinants

Green (1999) presents nine causes of sprawl. His paper suggests a model including the following determinants:

[11] But see Wheaton (1977) for a dissenting view.

(1) Rent gradients. Consider an initial solution of an Alonso model with uniform density. Land prices would be higher close to the center, encouraging factor substitution and higher density there; and lower density (a key element of sprawl) farther out.

(2) Demographics. Among other things, larger households increase density, ceteris paribus. Households with many children and/or elderly may have different space requirements than others.

(3) Growing affluence. As incomes rise, the standard urban model predicts increased housing consumption and lower density, under plausible assumptions.

(4) Transportation changes. Again, the standard urban model predicts that cheaper transport implies lower density.

(5) Government service differentials. If central city governments are high tax/low service, households will tend to move to the suburbs, especially high income households.

(6) Racial discrimination and segregation. Blight flight may well have a racial component.

(7) Plattage and plottage. Lot size requirements, subdivision regulations and the like affect sprawl.

(8) Tax policy. In addition to property tax effects (see No. 5), income tax deductibility of mortgage interest is among tax provisions that may encourage the purchase of larger homes on larger lots.

(9) Land use regulation. Clearly this can cut both ways, as discussed briefly above. Some regulations will encourage density, others may discourage it.

Of course other causes can be considered, for example the degree of monocentricity, opportunity cost of land in non-urban uses, and the industrial structure of a city (manufacturing implies different land use patterns than office work, for example). Mills (1999) has a nice discussion of these.

In this draft we will present a model focusing on (2), (3) and (4). Other determinants will be examined more closely in the next draft. Issues that have to be resolved include data collection, and in some cases endogeneity issues (e.g. with (1)).

Empirical Results

Data

Unless otherwise noted, all variables are metropolitan are level variables taken from the 1990 Census. Political variables (% voting Democratic in the 1992 election, % voting Other (Perot) in the 1992 elections) are taken from the Census Bureau's *USA Counties* CD-ROM database. Our transit variable, bus seat-miles per capita, is taken from the 1980 Census because we could not find this variable in the 1990 Census databases. Geographic variables (adjacent to another metro area, or adjacent to a large body of water in the suburbs) are described in Malpezzi (1996). The regulatory variable is derived from Malpezzi Chun and Green's (1998) instrumental variable for development regulation.

The transit seat miles per capita variable is surely endogenous. We therefore constructed instrumental variable using a set of exogenous variables presented in Appendix B. These were chosen from a larger set of variables, including a more detailed set of political and economic structural variables, but many of these proved insignificant.

First Stage Results: Analysis of Alternative Measures of Sprawl

Table 1 presents the measures we have constructed to date, for metropolitan areas (MSAs/PMSAs) using 1990 Census data. Metro areas are sorted by descending population. The measures are, in order presented:

average population density;

measures based on order statistics of the individual tract densities, when sorted by population; namely, the median, the first and third quartiles, and the 10th percentile;

population density gradients, and their fit (R-squared);

compactness as measured by the average and median distances between tracts and the CBD, said averages and medians weighted by tract population;

Gini coefficients and Theil indexes of the dissimilarity of tract densities

We first examined the means and correlations between pairs of some of the alternative measures described above. The tables are omitted from this draft to save space, but are available on request.

We found the following broad patterns. First of all of our measures based on percentiles – whether the median, the first quartile, or the 10th percentile or tracks- are highly correlated. The pair wise correlations among these variables are generally about 0.9. Correlations are less high with the simple person's per square mile density variable used in so many other studies. Notice that the Gini and Theil measures are correlated with each other but not terribly correlated with most other measures.

Generally denser metro areas, by whatever measure using order statistics, are positively correlated with positive population density gradients; but the correlation is modest. Denser metro area by most measures have lower R-squared (worse fits) for the density gradient regressions. Interestingly, it makes more of a difference if one take the logarithm of a given density measure than it does to choose among percentile measure. The correlations among linear percentile based measures are typically about 0.9 as mentioned above; the same high correlation is obtained among the several logarithms of these measure. But across linear and logarithmic measures the correlation is much less, typically from .5 to .6. That is not terribly surprising since there is such a very wide range of densities among metro areas that the log transformation gives a significantly different shape to the data.

Our rental house price gradient is positively associated with the logarithm of percentile density measures; typically the correlation is about 0.2. The larger this coefficient- the flatter the rent gradient- the denser the population of a metro area.

Comparing density measures to just a few key independent variables in pairwise fashion is also instructive. The more central cities in a metro area, the higher the density. The higher the fraction of central city population in the largest central city, the lower the density measure. Unsurprisingly, the higher the population of a city, the higher the density. Higher densities are correlated with longer average daily commutes, higher median household incomes, larger households. None of these patterns is particularly surprising.

Figure 5 plots our density measure against metro population. Figures 6-8 present the same plots for selected measures (Gini coefficient and population density gradient) as well as the fit of the population density gradient, a rough measure of discontinuity.

Second Stage Results: Determinants of Sprawl

Table 2 presents regression results for the determinants of the logarithm of the density of the track containing the 10^{th} percentile of the metro area's population, when said population is ranked by population density. We focused first of the most highly significant variables in the equation. Metro areas with more people per households are denser, as suggested by Green (1999). Also, metro areas with high fractions of children, such as Provo, Laredo, or Salt Lake, are less dense than metro areas with few children, Sarasota, State College, or San Francisco. The strongest relationship, and perhaps the least surprising, is that large metro areas are also denser. It is also not surprising that metro areas which are adjacent to other metro areas (such as many in the northeastern US) have higher density. It is also hardly surprising that metro areas that are highly urbanized are denser than those with significant rural populations. [12]

A number of variables do not seem to have much statistically discernable affect on logarithm of density, at least in this preliminary model. House values, passenger seat miles (as predicted using an instrumental variables approach), the population growth rate in a metro area, and being adjacent to water in the suburban area are all coefficients with very low T-statistics. Performing slightly better, but still well below the usual levels of significance, are income and the number of central cities in a metro area.

Determinants of Average Daily Commute

Table 3 presents our preliminary regression results for the average daily commute from the 1990 census. Again because of potential endogeneity problems we use an instrumental variables for passenger seat miles per capita as well as using the predicted value from Table 2 as our measure of density.

With this instrument, we find a very strong relationship between predicted density and average commute. Denser metro areas have lower commutes. Interestingly, metro areas with higher levels of transit capacity also have longer commutes. This is consistent with the notion that public transit use is often a very lengthy method of commuting once waiting times and movement times from door to transit are included. We also find that metro areas with higher house values have shorter

[12] To simplify somewhat, metro areas are one or more central cities of 50,000 or more and surrounding counties with economic links. Since these counties may contain some rural population, the fraction of metro population that is urban varies from 100% in areas like Jersey City to as low as 40% in Ocala, FL.

commutes. Metro areas with higher incomes have higher commutes, which is consistent with the standard urban model if the income elasticity of demand for housing is higher than the corresponding income commuting elasticity.

Households with more people in them have higher commutes, perhaps because these tend to be multi worker households with a corresponding greater difficulty optimizing housing location-commuting behavior with two or more workers in a household. Commutes are lower in metro areas with more children, perhaps because children don't commute (or when they do they do by bus or with parents as opposed to driving themselves one by one as is customary with most American adults). Another unsurprising result is that larger cities have longer commutes, as do metro areas adjacent to other metro areas.

Metro areas that are more highly urbanized also have longer commutes. Faster growing metro areas have shorter commutes, perhaps because recent movers are more likely to be close to an optimal location than someone who has lived in a metro area for many years. Finally, the higher the fraction of a metro areas urban population in the largest central city, the longer the commute. This is consistent with the hypothesis of Gordon and Richardson that metro areas of larger size are actually less efficient if they are more monocentric.

Conclusions

In this draft we have examined in a very stylized way some possible definitions of sprawl and related literature. We have found that one measure of sprawl, density of census tracks containing the 10^{th} percentile of urban population by density, can be well explained by a number of variables stemming from standard urban economic theory. We have also found that transit infrastructure, at least our measure, has little effect on density *per se*. On the other hand, more mass transit seems if anything associated with longer average daily commutes. Density itself is a commuting saver.

Much work remains to be done. To begin with, several other potential measures of sprawl as described above should be investigated. We have not yet for example examined the relationship between our simple density measure and other decile measures, population density gradients, or measures of discontinuity in development.

Certainly the right hand side of the each of these models needs to be extended. Measures of government performance, tax policy, and regulation need further work. While we have tackled endogeneity in several variables (transit capacity and density) in a simple way, certainly other issues of endogeneity should carefully examined. Comments are welcome as we proceed along these lines.

Clearly we can also consider the effect density (sprawl) has on other outcomes besides commutes. Literature and anecdotal comments suggest investigating such outcomes as racial and economic segregation, the cost of providing urban public services, and environmental quality, among others. These remain fruitful lines for ongoing work.

In the longer run, it would be extremely desirable to work in changes as well as levels. That would more than double the data collection effort, among other issues. But in many respects it's the dynamics of sprawl, real or perceived, that concern policymakers and the public.

Appendix A: Will Urban Development Adversely Affect Agriculture?

As noted above, a number of writers on potential costs of urban sprawl have focused on the "loss of prime agricultural farm land" as a potential serious cost of continued development. See, for example, American Farmland Trust (1994), Dane County Executive (1998). This Appendix focuses on this very narrow but potentially quite important issue.

Figure A.1 shows that urban land is about 3 percent of U.S. land by area. Another significant portion of developed land is rural built up land. This includes, among other things, the built up area of farms, as well as scattered housing, industrial and commercial development. However the bulk of rural built up area is actually take up by roads.

While urban land is a small fraction of the area of the U.S., it is probably the majority of the land by value. To my knowledge, no reliable estimate of the value of U.S. land by use exists, so let us attempt a straightforward order-of-magnitude calculation. Assume that urban land is worth on average $40,000 per acre. Clearly this is a very modest assumption, since even in smaller cities residential land often trades for an order of magnitude more than this.[13] Assume that rural built up land, cropland and pastureland is valued at $2,000 per acre. While this is a generous assessment, of course some agricultural land is worth substantially more, if it's near cities; but most of this extra value is due to its urban development potential. Finally, assume that other land, such as range, federal, forest and other rural is worth, on average, say $400 per acre. This seems a generous assumption, and is of course the hardest number to guess-timate, since much such land in the U.S. has very little economic value, whereas some such land (say, that containing Yosemite National Park or the Grand Canyon) would be extremely valuable if put on the market. But since the bulk of this other land is remote and inaccessible at today's population density, transport infrastructure, and technology, we think an average valuation would be fairly low.

Using these ball park benchmarks we find that the average value of urban land is approximately $2.8 trillion, while agricultural land is worth about $1.3 trillion, and

[13] For comparison, the Urban Land Institute reports data for developable residential land for 30 U.S. metro areas. The average of these MSA averages for 1990 was $42,000. Note that these are fringe values; centrally located land is often more valuable. On the other hand, large MSAs are over-represented in the ULI sample, and land values increase with MSA size. On still another hand, land prices have generally risen since 1990, and developer rules of thumb suggest $1/square foot (near $40,000 per acre) is the minimum price one expects to pay for developable land, outside certain very low cost areas like the Great Plains. Well-located land in large cities like Chicago can sell for $500 per square foot.

other rural land is worth $0.6 trillion.[14] Our point is not to present these figures as anything other than an order of magnitude estimate of valuation, and to illustrate the obvious fact that urban land's share of the nation's capital stock is much higher than its share of land area. If these average value assumptions were accurate, urban land would be about 60 percent of U.S. land by value, compared to 3.1 percent by area. Our back-of-the-envelope assumptions almost surely *understate* urban land's share of value.

Figure A.2 shows that while the amount of land and urban uses has roughly doubled over the past 40 years, the amount of cropland has hardly budged.[15] This is not surprising. Just as on the margin of cities agricultural and other rural land can be converted to urban uses, when relative prices warrant it, land can be readily converted from other uses to agriculture.

Now, the fact that the U.S. share of land under crops has been fairly constant over the last 40 years is interesting, but in fact this is not particularly important for understanding the potential adverse effects of sprawl on agriculture. Consider, for example, the fact that during the same period the share of the U.S. labor force employed in agricultural fell from about 13 percent in 1947 to about 2.8 percent today. This decline in the agricultural work force has not had any noticeable negative consequences for agricultural output or prices, because of the increasing productivity (and wages) of agricultural labor during that period (Ball *et al.* 1997).

We can examine indirectly the productivity of U.S. agricultural land over time by examining the price of U.S. agricultural real estate. Figure A.3 presents this data, from USDA. (This includes the value of farm buildings as well as land, which may skew results somewhat; no separate data for land net of farm buildings is available, to my knowledge.) The top line in Figure A.3 shows what has happened to the real price of agri real estate. There has been a steady secular upward trend since the 1940's, with the well know boom and bust in farmland prices occurred along with the oil shocks, particularly the second oil shock in 1982. Ultimately, there is no necessary one for one link between the amount of land and agricultural and agricultural output, just as there is no necessary one for one link between the amount of agricultural labor and agricultural output.

[14] While crude, these estimates are broadly consistent with estimates of the size of the real estate capital stock. See Arthur Anderson (1991), Miles (1991), and Malpezzi, Shilling and Yang (1998).

[15] An influential study by an interagency team, the National Agricultural Lands Study (1981), presented results that suggested urbanization was responsible for rapid loss of farmland. Fischel (1982) has carefully documented the flaws in that study. When consistently collected and correctly analyzed, USDA data in fact show no appreciable net loss over time.

Examining agricultural labor and land together, in recent years as we all know the share of labor force in agriculture has been falling, while the share of land devoted to crops has been roughly constant. On the other hand almost any measure of agricultural output has shown steady increase over the period (Ball *et al.* 1997, for example). Agriculture's total factor productivity has been rising, and that is certainly an unsurprising fact. This leads us to the most important chart for understanding potential problems in agriculture, that is, what has been happening to the relative price of agricultural *output.*

Figure A.4 presents the last 50 years of data for the food component of the CPI relative to non-food components. It is readily apparent that, despite the significant price shocks associated with the oil shocks, the secular trend in real food prices has been downwards. (It is unsurprising that food prices would be shock upward with the oil price shocks since land prices, fertilizer prices, and tractor fuel, among other key inputs all shot up during that period. But of course they returned to normal levels after markets had time to adjust.)

Thus we see that despite the rising use of urban land, the relative price of food has been falling. This is not new, in fact increasing productivity of agriculture is partly cause and partly effect, of urbanization. It is well know that on the one hand, increases in agricultural productivity were the first and foremost necessary condition for the rise of cities 10,000 years ago (Bairoch 1990). It is also well know in international economic development circles that increases in agricultural productivity are in turn driven partially by urbanization, as markets for commercial farming, suppliers of key inputs, and incubators of changes in technology that can be applied to agriculture (such as the internal combustion engine). See, for example, Evans (1990), Haggblade and Brown (1989), Rondinelli (1987) and Hazell *et al.* (1991).

This points out the fact that the market for agricultural output is of course a world market. A fair question is whether past declines in real food prices, even over a very long period, suggests future declines or at least no long run real increases. For example, in a series of papers by the Worldwatch Institute, Lester Brown and colleagues have argued that prices may start to rise due to increasing demand for food from abroad, especially as China develops and Chinese households demand not only more calories but meat and other items from higher up the food chain.

Of course no one can predict the next 50 years of changes with certainty. However first consider that in fact much of China's recent impressive economic growth has actually been tied to increases in agricultural productivity (Lardy 1983; Weersink and Rozelle 1997; Li, Rozelle and Brandt 1998). There is in fact, enormous worldwide scope for increases in productivity as large food producing countries such as China, Russia and the Ukraine, and others both adopt new technologies and, even more importantly, reorganize their agricultural system from central planning to market lines (Swinnen and van der Zee 1993; Csaki and Lerman 1997).

It is also worth noting that there are certainly further potential gains from changes in agricultural technology. Those from further genetic modification of seeds are only the best known and most obvious.[16] See White (1996), Senauer and Stevens (1996), Gotsch, Bernegger and Rieder (1993), and OECD (1998), among others.

However, if demand warranted it, there is enormous scope for increasing U.S. agricultural land productivity *even without further improvements in technology.* International comparisons of agricultural productivity are an interesting way to examine how much potential remains for increases in American agricultural output using today's technology. We have a lot of agricultural land, and it's cheap, so we don't use it terribly intensively, by world standards. Figure A.5, from Craig, Pardey and Roseboom (1997) is an excellent summary of these patterns. Using panel data from FAO, Craig Pardey and Roseboom plot real output per hectare on the vertical axis, and real output per worker on the horizontal axis (log scales). The dotted diagonal lines indicate constant land-labor ratios, so if a country/region's time path is flatter than these diagonals the amount of land per worker is increasing (notice the amount of land per worker is decreasing for Sub-Saharan Africa).[17]

This marvelous graphic repays careful study, but for our present purpose we simply note that North America's land productivity is safely in the middle of the pack (although our labor productivity is, with the Antipodes, top of the pops). Japan's land productivity is a full order of magnitude higher.[18] Thus if demand and hence relative

[16] Recent controversy has been stirred as some seed companies produce genetically modified sterile varieties, which means every year farmers need to purchase new seed instead of saving seed from their current crop. As long as competition remains in seed production, and as long as competing varieties of improved seeds can be produced by different companies, there will remain an incentive for one company to gain a higher price for its seed (conditional on its other characteristics) by selling an improved but non-sterile variety. Anecdotal press reports also suggest a consolidation in the seed industry. Perhaps the industrial organization of the seed industry bears more careful watching than the kinds of seeds produced *per se.*

[17] Craig *et al.* credit Hayami and Ruttan (1985) with the original design of this marvelously informative graphic.

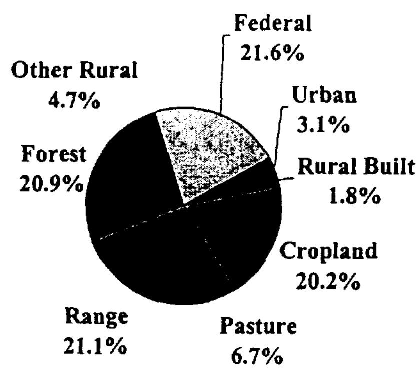
[18] I'm not suggesting we *should* be at Japan's land productivity, but that as a technical matter we *could* if prices warranted. In fact, Japan's high measured land productivity is surely due partly to land policies that inhibit mechanization and economies of scale, and other policies that distort output prices. The point is, higher land productivity *per se* is not sufficient evidence of overall higher agricultural productivity. Note that Japan's labor productivity is lower than South Africa's or Eastern Europe's!

prices warranted, there is tremendous scope for increasing U.S. food production even with today's technology and today's aggregate cropland.

Of course it can be argued that the existence of agricultural land near cities can provide external amenities (although many anecdotes about new suburban dwellers trying to regulate tractor and manure use tell us negative externalities also exist). Some studies of these amenity values exist, thought they are rarely cited by economists (e.g. Chenoweth 1991, Garrod and Willis 1992, Klein and Weilcahns 1996). While there are no doubt individual cases where amenity value is significant, it's hard to imagine net benefits could be large enough to justify the current concern with sprawl in the aggregate.

It is also worth pointing out that the most careful study to date of the ownership of land at the urban fringe, by Brown, Phillips and Roberts (1981), points out that most undeveloped land near the urban fringe is already out of farming. Thus it is unlikely that preferential tax treatment for farming, *per se*, would have much effect on the pace of urban development.

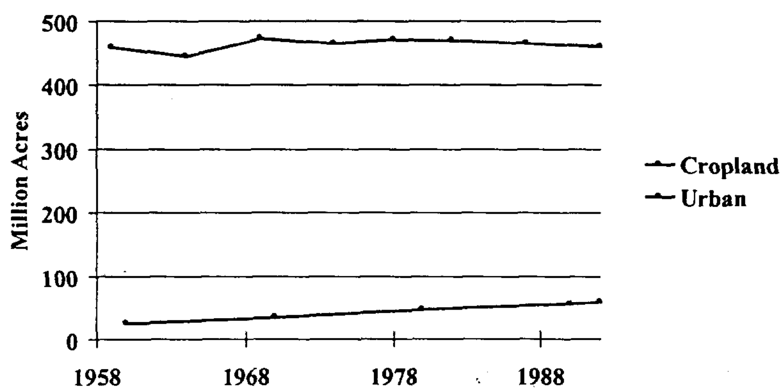
U.S. Land Use, Excluding Alaska and Washington, D.C.



Source: USDA

A-1

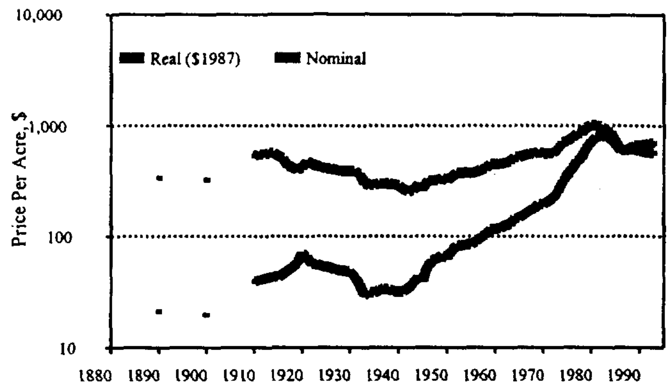
U.S. Cropland and Urban Land Area



USDA, Census

A-2

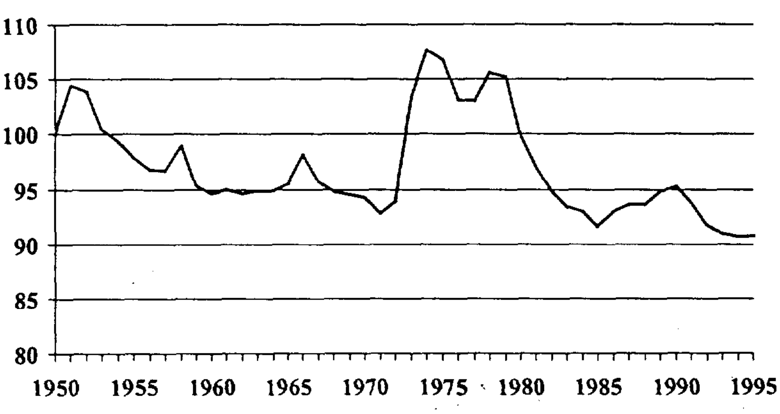
Price of U.S. Agricultural Real Estate



Source: USDA

A-3

CPI, Food to Nonfood



BLS, Reported in Economic Report of the President

A-4

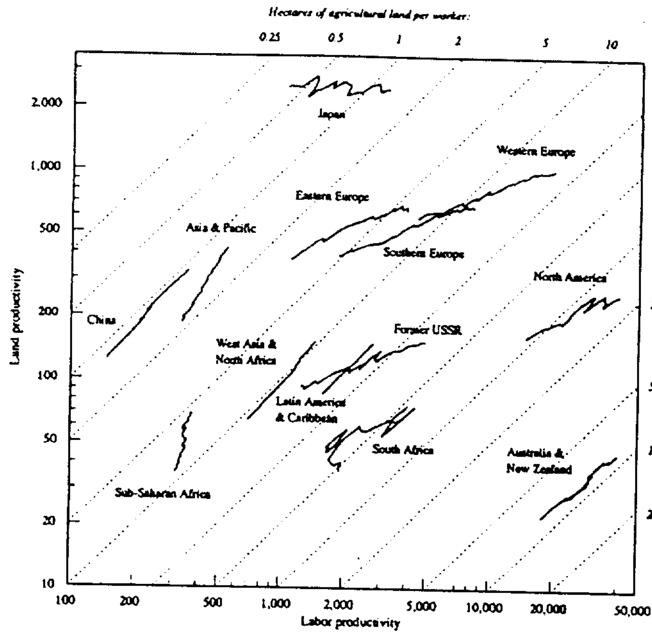


Figure 1. International comparison of agricultural land and labor productivities by region, 1961 to 1990

Source:Craig, Pardey & Roseboom, 1997 A-5

Appendix B: An Instrumental Variable for Transport Infrastructure

As noted above, the best measure of transit infrastructure we have obtained to date is 1980 Census of Transportation on transit seat miles per capita. However endogeneity is a potential issue with this variable. We wish to investigate whether increases in transit infrastructure are positively associated with increasing density. On the other hand, most public transit methods are less costly and more feasible in denser cities. Thus it is quite possible that the transit variable would be correlated with the error term in an equation modeling density.

We adopt the traditional instrumental variable approach. For two stage least squares and similar IV models to work, it is necessary to have some exogenous variables which can used to construct the instrument which do not appear on the right hand side of the other equations. In many studies this is done in an ad hoc way, for example by adding higher power terms of selected exogenous variables. It is better if one can find some exogenous variables that are likely to affect the variable one is constructing an instrument for, but would not necessarily appear on the right hand side of the structural equations of interest.

Our candidates for such a variable are drawn from measures of political and cultural attitudes. Our maintained hypothesis is that political and cultural attitudes are translated most directly into political support for higher spending on transit infrastructure. We would not rule out the idea that, *ex post,* Democrats are more likely to live in dense cities than Republicans. Our suggestion is that the political process is more focused on deciding the level of transportation infrastructure, rather than voting on the density of development *per se.*

Table B1 presents our instrumental variable regression for transit seat miles per capita. Generally the other exogenous variables perform well and as expected. The percent of Democratic votes in the 1992 presidential election is a particularly strong performer, with a t-statistic of about 4.

Appendix B: Transit Seat Miles Per Capita

Dependent Variable: transit seat miles per capita, 1980

Degrees of Freedom	226
Adj R-sq	0.48

Variable Label	**Parameter Estimate**	**Standard Error**	**t-Statistic**	**Prob > |T|**	**Standardized Estimate**
Intercept	0.545	1.471	0.4	0.7115	
Median Value Owner Occupied Units, 1990	0.0000153	0.0000025	6.1	0.0001	0.399
MSA Population, 1990	0.0000004	0.0000001	5.0	0.0001	0.279
Person per households, 1990	-3.225	0.917	-3.5	0.0005	-0.333
Pct Population under 18, 1990	0.176	0.056	3.1	0.0020	0.307
Median Age of Housing Stock	0.066	0.019	3.5	0.0005	0.298
Ann. Growth in MSA Pop, 80-90	22.686	12.455	1.8	0.0699	0.165
Percent Democratic Votes, 1992 Presidential Election	5.360	1.303	4.1	0.0001	0.237
Location Quotient for Manufacturing	-0.440	0.221	-2.0	0.0482	-0.110