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1. Introduction

Urban sprawl is widely regarded as an important environmental and social problem, particularly in the United States but also in Spain and other European countries. In fact, according to a recent independent poll, Americans consider urban sprawl and the way in which urban growth and development impacts on their daily lives the most important issue facing their local community - tied with crime and violence.

Despite this widespread interest, much of the debate about urban sprawl is based on speculation: until now, the data to conduct detailed and systematic measurement of how and where land is built have simply not been available. This article reviews recent research that fills that gap by merging high-altitude photos from 1976 with satellite images from 1992 to create a grid of 8.7 billion 30-metre by 30-metre cells that tracks the evolution of land use across the whole of the United States (except Alaska and Hawaii). These new high-resolution data make it possible to observe the amount of open space in the neighbourhood of every house in every US city. Since there is more open space around a house that is far from its neighbours, development is more scattered as this quantity of open space increases. Thus, we can measure urban sprawl by calculating the average amount of open space in the neighbourhood of a house in each city.

Using these data, we document the evolution of urban development across the United States both in terms of overall quantity and in terms of spatial patterns (i.e., the extent of compact versus 'sprawling' or scattered development). We then address three main questions. First, what can explain increasing per-person consumption of land? Second, what has caused very different spatial patterns of development across US metropolitan areas? Third, does the widely-divulged claim that urban sprawl has worsened the obesity epidemic by discouraging exercise and healthy eating stand up to detailed scrutiny?

2. The evolution of urban sprawl

So is urban sprawl really increasing? In fact, we find that residential development in 1992 is no more scattered than in 1976. For the United States as a whole, the proportion of open space in the square kilometre of land surrounding the average house was 42% in 1976 compared with 43% in 1992. While a substantial amount of scattered residential development was built between 1976 and 1992, overall residential development did not become any more biased towards such sprawling areas. On average, areas that were already densely built up in 1976 experienced little change, largely unbuilt areas in the neighbourhood of earlier development saw some scattered development, while areas with initial scattered development got the highest rate of new development and became more densely built up in the process. As a result, the total amount of developed land grew substantially but the proportions of sprawling and compact development remained substantially unchanged.

Despite seeing no increase in urban sprawl, we observe several important changes in urban development between 1976 and 1992. First, the amount of land built up for housing or commercial buildings or paved for roads has grown substantially over this period, outpacing population growth by a factor of three. Developed land increased at an average annual rate of 2.5%, or a compounded 48% from 1976 to 1992. In contrast, population increased by 18% over this same 16-year period, from 216 million people to 255 million people.

Second, new houses almost never locate far from other houses. In fact, only 0.5% of new residential development was more than one kilometre away from other residential development. This tiny amount of long-distance leapfrogging has, however, significantly reduced peoples' ability to 'get away from it all'. The percentage of US land more than 5 kilometres away from any residential development dropped from 58% in 1976 to 47% in 1992.

Third, areas close to the coast have continued to attract a disproportionate share of development, but with a shift in focus from commercial to residential development. Land within 80 kilometres of the Atlantic Ocean, the Pacific Ocean, the Gulf of Mexico or the Great Lakes already contained 46% of developed land in 1976, despite accounting for only 13% of the US land area. Sixteen years later the figure remained similar, but the type of development located close to the coast had changed significantly. In particular, the share of US commercial land located within 80 kilometres of the coast dropped from 43% to 34%. This reflects that large US manufacturing plants, which historically tended to locate close to ports, have moved inland, while amenities have attracted new residents towards the coasts.

3. How important are demographic changes for urban expansion?

We have just seen that population increased by roughly one third as much as developed land between 1976 and 1992 (18% versus 48%). The same comparison holds if we restrict ourselves to developed land used for housing. If overall population growth only accounts for about one third of residential land expansion, what explains the remaining two thirds? Are new houses large enough compared to older houses to account for the entire difference? In Overman, Puga, and Turner (2007) we conduct a decomposition exercise that calculates the relative contribution of demographic and land use changes to the growth in residential land in the United States. This decomposition reveals a much more complex picture of the components of urban expansion than the one-third/two-thirds back-of-the-envelope calculation would suggest. In this decomposition both population growth and average house sizes play a role, but so do changes in the distribution of population within the United States and the way in which individuals arrange themselves into households.

The first step in our decomposition exercise is to find the relative contributions of population growth and increasing land use per person. The contribution to the expansion of residential land of overall US population growth corresponds to how much the total amount of residential land in the United States would have increased in the hypothetical case that US population had grown as it did over the period 1976-92, but that US residential land per person had remained constant at its 1976 level. This is the one-third figure given above, or more precisely 38% (the result of dividing the 18% increase in population by the 48% increase in residential land).

Similarly, the contribution of changes in US residential land per person corresponds to how much the total amount of residential land in the United States would have increased in the hypothetical case that US residential land per person had grown as it did over the period 1976-92, but that US population had remained constant at its 1976 level. These changes in US residential land per person account for 53% of the actual increase in the total amount of residential land.

The contributions of US population growth (38%) and of changes in US residential land per person (53%) do not add up to 100% because we must also account for the interaction between both types of changes. This interaction captures the fact that the increased population is being housed at the new higher average amount of residential land per person. The contribution of this interaction term is 9% of the actual increase in the total amount of residential land.

The 53% contribution of changes in per-person land use seems large. One possible explanation is that new houses are much larger than older houses. Data from the Census Survey of Construction on the average size of newly constructed houses indicates this could be an important part of the story. In 1992, the average floor area in new one-family houses was 2,095 square feet (195 square metres), up from 1,700 square feet (158 square metres) for houses newly built in 1976.

A fact that has received far less attention than changing house sizes, is the shift of population towards areas where houses have traditionally been larger. Florida is a particularly clear example of this pattern: residential land use per person was almost twice the US average in 1976 and its population subsequently grew at a rate more than three times that of the United States as a whole. If the pattern of population shifting towards areas with particularly large houses holds more generally, it could be that, even if people arriving into an area built houses that were similar in size to those of their neighbours, they would still tend to be larger than the houses they left behind. This could account for part of the growing land use per person.

A final demographic change that is normally not linked to urban expansion is falling household sizes. Between 1976 and 1992 the average number of people in each US household declined from 3 to 2.7 people. Over this period there was a dramatic decline in the percentage of households headed by married couples with children, while the number of households headed by single parents increased. The proportions of single and other non-family households also increased, partly due to an increase in the proportion of the population that is unmarried and childless (as the baby boom cohort moves through the age distribution) and partly due to this group's increased propensity to live alone.

The second step in our decomposition exercise is to take the growth in residential land that cannot be accounted for by nationwide population growth, and see how much is due to individual households using more land on average, how much to the increase in the total number of households, and how much to the shift in population within the United States. Our calculations show that only 24% of the growth in residential land area can be attributed to State-level changes in land per household. Almost as much, 23%, is due to an increase in the number of households over this period. A further 6% is due to the shift of population towards States with larger houses, 38% to the aforementioned overall population growth, and the remaining 10% to interactions between various changes.

4. The causes of sprawl

The nationwide finding that residential development in 1992 is no more scattered than development in 1976 also holds for most individual metropolitan areas. This can be seen in Table 1, which lists the percentage of open space in the square kilometre surrounding an average house in 1976 and in 1992 in each metropolitan area with a population over one million. (Note that the comparison is based on 2000 metropolitan area definitions for both years, but, since we measure open space in the square kilometre surrounding an average house, only land within one square kilometre of houses gets counted in the computation.) Of course, any one household might have seen a great deal of change around their residence over this period. But if we zoom out and look at a given city from a distance, we will see little change, at least in terms of the proportions of sprawling and compact development. The new city is just like an enlarged version of the old city.

However, Table 1 also reveals large differences in the extent of sprawl across metropolitan areas. The square kilometre around the average residential building in Atlanta or Pittsburgh is nearly 60% open space. In Miami, this number is just over 20%. The analysis of Burchfield,

Table 1

Differences in sprawl across metropolitan areas

Metropolitan area	Sprawl index for 1992 residential land	Sprawl index for 1976 residential land
Atlanta	55.57	57.77
Boston	47.64	44.72
Buffalo	39.92	37.87
Charlotte	52.73	51.12
Chicago	31.76	31.21
Cincinnati	47.79	47.45
Cleveland	36.84	36.24
Columbus	41.20	41.59
Dallas	28.08	26.65
Denver	28.63	28.63
Detroit	33.28	30.47
Greensboro	52.94	51.45
Hartford	41.34	42.23
Houston	38.15	38.93
Indianapolis	39.66	37.68
Kansas City	35.32	34.33
Los Angeles	35.41	32.95
Memphis	27.40	28.72
Miami	20.73	20.03
Milwaukee	35.33	33.85
Minneapolis-St. Paul	32.07	31.34
New Haven	39.11	38.68
New Orleans	32.29	33.92
New York	28.75	28.47
Norfolk	40.82	44.07
Orlando	40.02	39.39
Philadelphia	42.51	43.03
Phoenix	27.54	34.94
Pittsburgh	57.70	56.71
Portland	44.90	43.38
Rochester	48.80	48.11
Sacramento	34.93	30.72
Salt Lake City	31.90	32.88
San Antonio	32.77	29.58
San Diego	45.63	45.40
San Francisco	30.48	29.81
Seattle	46.97	45.03
St. Louis	43.44	40.62
Tampa	36.01	34.84
Washington-Baltimore	49.81	50.68

Notes: Each sprawl index measures the percentage of open space in the square kilometre surrounding an average house in each metropolitan area in the corresponding year. The metropolitan areas listed are those with population over one million in 1992.

Source: Burchfield, Overman, Puga, and Turner (2006).

Overman, Puga, and Turner (2006) is largely devoted to explaining these large cross-sectional variations in spatial development patterns as a way to understand the causes of sprawl.

We proceed by estimating the statistical relationship between the percentage of open space in the square kilometre around an average new house built between 1976 and 1992 in each metropolitan area and a host of characteristics for each metropolitan area in 1976.

The first set of characteristics of metropolitan areas that we consider are measures of physical geography. Despite technological progress, the physical environment continues to play an important role in shaping cities. In all, we find that physical geography alone explains about 25% of the cross-city variation in our sprawl measure.

Mountains hindering urban expansion are an obvious explanatory variable. These have been prominent, for instance, in Los Angeles, where the mountains bordering the city have limited further expansion of its sprawling suburbs (a situation described locally as "sprawl hits the wall"). However, in studying the effect on sprawl of mountains more generally, we need to be careful with two features. First, we must focus on mountains in vicinity of earlier development where they truly act as a barrier to further expansion. We therefore restrict calculations for mountains as well as other geographical variables to the "urban fringe", defined as those parts of the metropolitan area that were mostly undeveloped in 1976 but were located within 20 kilometres of areas that were already mostly developed in 1976. Second, we need to be careful to separate large-scale from small-scale terrain irregularities. This is because mountains and hills tend to have opposite effects.

When an expanding city hits a mountain range, further scattered development in the urban fringe becomes very costly. Thus, *high mountains in the urban fringe encourage infilling and lead to increasingly compact residential patterns*. In particular, a one standard deviation increase in the elevation range in the urban fringe (740 extra metres between the lowest and highest point) is associated with a decrease in the sprawl index by 1.6 points (i.e., with a reduction of 1.6 percentage points in the share of open space in the square kilometre around the average house). On the other hand, small-scale irregularities in the urban fringe have the opposite effect. When terrain in the urban fringe is rugged, steep hillsides where development is more costly alternate with flat portions where development is less costly. Thus, *rugged terrain encourages scattered development*. The magnitude of this effect is such that a one standard deviation increase in the ruggedness of the terrain increases the sprawl index by 1.3 points.

Another physical feature with important effects on sprawl is aquifers. Most households in the United States get their water through the nearest municipal or county water supply. However, extending water systems to service new scattered development in the urban fringe requires substantial infrastructure investments, the cost of which is typically borne by developers through connection fees and ultimately reflected in housing prices. In places where water-yielding aquifers are pervasive, developers can instead sink a well at a fraction of the cost of connecting to the municipal or county water supply. A total of 15% of households in the United States get their water from such private household wells. Figure 1 illustrates the relationship between aquifers and sprawl with a map of San Antonio (located in the southwest of the map) and Austin (northeast), in Texas. Development built by the

Figure 1.

The relationship between aquifers and sprawl in Austin and San Antonio

Source: Burchfield, Overman, Puga and Turner (2006).

mid 1970s is marked in pink while more recent development is marked in red. Only parts of San Antonio and Austin overlay an aquifer - the Edwards-Trinity aquifer system - outlined and crosshatched in white. Households southeast of the "bad water line" plotted as a white dotted line cannot safely draw water from a well. The San Antonio Water System charges developers one-time connection fees per dwelling unit that, while low downtown, can reach $24,000 for scattered development in some suburbs. However, developers building in areas overlaying the aquifer can sink a well at a cost of about $4,500 and avoid the water connection fee or even build in areas where a connection to the municipal supply is not available. The map shows that most new development in San Antonio since the mid 1970s has taken place above the Edwards aquifer and that this development is much more scattered than that which does not overlay the aquifer. Austin shows a similar pattern. The presence of aquifers is a particularly interesting dimension of underlying heterogeneity in the physical landscape because of the way it interacts with agglomeration economies: *wherever aquifers underlie the urban fringe, household water can be obtained without the large increasing returns associated with public water systems and this facilitates scattered development.* A one standard deviation increase in the percentage of the urban fringe overlaying aquifers increases the sprawl index by 1.2 points. This implies that controlling access to groundwater is a way to control whether development sprawls or not.

One of the reasons why people are willing to incur the additional commuting and infrastructure costs associated with scattered development is the amenity value they assign to having open space near their home. An immediate implication is that *geographical characteristics that make open space less attractive, extreme climate in particular, reduce sprawl.* A standard measure of extreme heat is cooling degree days, a concept used by engineers to calculate the demand for air conditioning. Extreme cold can be similarly measured through heating degree days, used to calculate fuel demand for heating. A one standard deviation increase in mean cooling degree days reduces the sprawl index by 6.5 points, while a one standard deviation in mean heating days reduces the sprawl index by 5 points. Other climatic variables, such as average precipitation, do not appear to have any effect on sprawl. Variables capturing the percentage of forest or various types of vegetation in the urban fringe have no significant effects either. This is in accordance with the literature on the amenity value of vegetation, which finds very mixed results.

After examining the importance of geographic characteristics, we turn to determinants of sprawl that have been emphasized by urban economic theory. We begin by looking at the most widely-used theoretical construct in urban economics, the monocentric city model. This model studies how residential development around an employment centre is shaped by the trade-off between convenient commuting close to the centre and affordable housing further away. Housing prices should decline with distance to the city centre to offset higher commuting. Competition between developers, who combine land and capital to produce housing, implies that the price of land should similarly decline with distance from the centre. As consumers move away from the centre, they respond to declining land and housing prices by demanding larger dwellings with lower capital to land ratios (i.e., less tall, more spacious units and larger yards). A greater ability to use the car for commuting not only reduces transport costs, but also eliminates the fixed costs associated with public transport. Both these effects facilitate urban expansion and contribute to sprawl. Thus, a key prediction of the monocentric city model is that *lower transport costs within a city will result in more dispersed development.* General equilibrium models of systems of cities built on the monocentric model also show that cities specializing in sectors with stronger agglomeration economies have more expensive land, which offsets the higher wages resulting from agglomeration economies. Higher land prices result in taller buildings with smaller units and yards, i.e., more compact development. Thus, another crucial implication of the monocentric city model is *that cities specializing in sectors where employment tends to be more centralized will be more compact.*

Both these predictions of the monocentric city model are supported by the data. Naturally, cities developed mostly after the advent of the automobile tend to be much more car-friendly than cities built before 1900 around public transit.

We use the number of streetcar passengers per capita in 1902 to get an idea of how car-friendly is each city's historical centre. We find that a one standard deviation increase in 1902 streetcar usage decreases the sprawl index by 1.7 points. Roads, in contrast, have no apparent impact on development patterns, despite commonly held beliefs to the contrary. Taking various measures of road density - miles of road per area, average distance to a road and distance to an interstate exit- we find no relationship with the scatteredness of development. To examine the link between employment centralization and sprawl, we measure the extent to which each city is specialized in sectors, such as business services, that in the average city tend to be very centralized. We find that, consistent with the monocentric city model, cities are more compact if they specialize in sectors that tend to be more centralized in the average metropolitan area. In particular, a one standard deviation increase in centralized-sector employment decreases the sprawl index by 1.3 points.

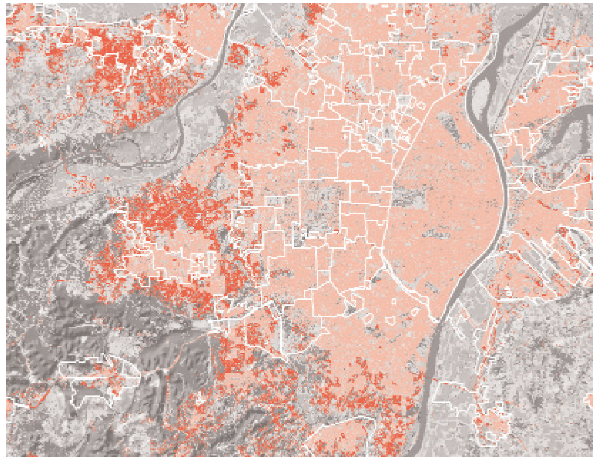
The standard monocentric city model predicts more scattered development, due to large yards, in cities specialized in sectors where employment is less centralized and where it is easier to use a car. However, this model cannot explain leapfrog development where parcels of land are left undeveloped while others further away are built up. Urban economists have followed two strategies to extend the monocentric city model to account for equilibrium leapfrogging. The first is to consider that open space has an amenity value, a feature confirmed by the results on extremely hot or cold climate discussed above. While this is true about both private open space (yards) and public open space (parks), there is one important regard in which public open space differs from private: the control that the residential owner has over subsequent development. If moving is costly, the willingness to trade off commuting costs against access to public open space will depend on expectations of how long that space will stay undeveloped. In areas where population is growing fast, a rational agent anticipates that nearby vacant land will be developed sooner, and thus is not willing to incur large additional commuting costs to gain access to it. Thus, *expectations of sustained urban growth lead to more compact development*. The second strategy that urban economists have followed to account for equilibrium leapfrogging is to consider dynamic urban models where housing is durable and redevelopment costly. The core argument is that it may be optimal to postpone development of certain parcels so that in the future they can be developed in a way that better suits contemporaneous needs. In a context where there are often long lags between the decision to build and the completion of construction, the literature has shown that greater uncertainty about urban growth can encourage developers to leave some parcels undeveloped and develop other parcels further away. Thus, when leapfrogging occurs, it is more prevalent when there is greater uncertainty about future urban growth.

These two predictions about historical population growth patterns are also supported by the data. Developers may expect that cities that have been growing relatively fast in the past will continue to do so in the near future. We therefore capture expected future population growth using the metropolitan area's historical mean decennial percentage population growth for the five decades 1920-70. (Historical population growth rates are indeed a good predictor of population growth between the 1970s and 1990s: the correlation between percentage population growth 1970-90 and mean decennial percentage population growth 1920-70 is 0.60). Our results show that areas that have historically seen high population growth rates do, indeed, experience less sprawl. A one standard deviation increase in the historical mean growth rate reduces the sprawl index by 6.1 points. We interpret this result as telling us something about the value of open space. However, given that historical population growth rates are a good predictor of current population growth rates, this result would also be consistent with fast growing cities using all available land to accommodate their growing population. However, controlling for actual 1970-92 population growth, historical trends still matter. Faster contemporaneous population growth does make cities more compact, but historical population growth rates continue to have much the same impact on sprawl. To test whether greater uncertainty regarding future city growth fosters sprawl, we similarly assume that developers consider future local population growth more uncertain in cities that have had more ups and downs in population growth rates over previous decades. Specifically, our measure of uncertainty is the standard deviation of decennial percentage population growth rates 1920-70. As expected, higher uncertainty leads to more sprawl. A one standard deviation increase in the standard deviation of decennial population growth rates increases the sprawl index by 3.2 points.

We turn finally to political determinants of sprawl. Two of the main dimensions emphasized in public discussions, competition between municipalities of different sizes and the extent of municipal fragmentation, do not matter for sprawl in practice. Figure 2, which depicts development in Saint Louis, Missouri, suggests that municipal boundaries matter, but for different reasons. As in the previous map, development built by the mid

Figure 2.

The relationship between municipal boundaries and sprawl in Saint Louis



Source: Burchfield, Overman, Puga and Turner (2006).

1970s is marked in pink while more recent development is marked in red. The white lines mark municipal boundaries early in the study period. We see that a disproportionate share of 1976-92 development happens in unincorporated areas that were close to existing development but just beyond the municipal boundaries at the beginning of the period. This development is also more dispersed than that on incorporated land. Many other metropolitan areas show a similar pattern. There is a good reason for this: almost every zoning law includes the provision that whenever regulations differ, the most restrictive rules apply. In unincorporated areas, only county and state planning regulations generally apply, while incorporated places add their own zoning restrictions and growth controls. Thus, *to the extent that there are unincorporated areas on the urban fringe, developers can escape municipal regulation by building outside municipal boundaries, and this facilitates sprawl.* A one standard deviation increase in the percentage of the urban fringe incorporated into a municipality reduces the sprawl index by 1.4 points. In all, these results suggest that the failure of municipal and county governments to harmonize land use regulation is an important contributor to sprawl. Developers, it seems, are often leapfrogging out of municipal regulations altogether rather than playing municipalities against each other.

One of the common complaints about urban sprawl is that as development spreads, municipal services such as roads, sewers, police and fire protection are more expensive. It turns out that this concern is well founded. A one standard deviation increase in the percentage of local expenditures that is financed through transfers from other levels of government as opposed to local taxes increases the sprawl index by 1.1 points. This suggests that *when local taxpayers are held accountable for infrastructure costs, they respond by insisting on more compact patterns of development that require less infrastructure spending.*

5. Health consequences: does urban sprawl cause human sprawl?

We have so far described the patterns and possible causes of urban sprawl, but one of the reasons why sprawl has attracted so much attention is that many claim it has pernicious consequences. Glaeser and Kahn (2004) study and dismiss most such claims. Since sprawling development is car-based, it is possible that it leads to longer commutes. However, sprawl often makes commutes shorter because in sprawling areas jobs also become more geographically decentralized. If anything, the car-sprawl connection may be harmful for the poorest because it forces car ownership upon them.

The pollution people are exposed to, has also been reduced with the relocation of large factories away from central cities. In the United States, the global effect on the amount of farmland and forest is also small - although this is likely to be more important in more densely-populated European countries.

One claim about the negative consequences of sprawl that has nevertheless made big inroads into the press and public opinion is that it may be an important cause of obesity. The potential significance of this link cannot be underestimated. The prevalence of obesity in the United States and other countries, including Spain, has increased dramatically over the last two decades. The proportion of medically obese men rose from 12.7% to 27.7% between the late 1970s and 2000. For women, the corresponding rise was from 17% to 34%. Obesity has very serious negative health consequences, including increased risk of cardiovascular disease, hypertension and stroke, and diabetes. As a consequence of these health risks, the United States now spends more on obesity-related illnesses than on those related to smoking and heavy drinking combined.

Obesity has not risen as fast or reached the same levels everywhere in the United States. For instance, between 1991 and 1998 the prevalence of obesity increased by 102% in Georgia but by only 11% in Delaware. And while 30% of men and 37% of women in Mississippi were medically obese in 2000, the corresponding figures for Colorado were 18% and 24% respectively. Such large spatial differences in the incidence of obesity have led many to claim that variations in the built environment, by affecting exercise and diet, may have a large impact on obesity. For instance, compact neighbourhoods may induce people to use their car less often than those where buildings are scattered. Similarly, neighbourhoods where houses are mixed with a variety of local grocery stores and other shops may encourage people to walk more and eat healthier food than those where all built land is devoted to housing. A growing and influential literature studies this connection between the built environment and obesity (see, e.g., Ewing, Schmid, Killingsworth, Zlot, and Raudenbush, 2003). Loosely, its main finding is that individuals living in sprawling neighbourhoods are more likely to be obese than those who live in compact neighbourhoods.

But does urban sprawl really cause human sprawl? Not according to our research. In Eid, Overman, Puga, and Turner (2007) we find no evidence that urban sprawl affects people's weight. What the research does confirm is the commonly reported view that people living in sprawling neighbourhoods tend to be heavier than those living in neighbourhoods where development is compact and there are plenty of shops and amenities within walking distance. But this is not because sprawling neighbourhoods cause people to gain weight. Populations in sprawling neighbourhoods are heavier because individuals with an innate propensity to be obese tend to live in such neighbourhoods. Thus someone who simply does not like walking is both more likely to be obese and to prefer living where one can easily get around by car.

To study the role of this sorting process, we matched the same satellite data we used to study the causes of sprawl and data on the detailed location of retail establishments to confidential survey data that reports the weight and address of a representative sample of nearly 6,000 individuals for six years. The survey is the Confidential Geocode Data of the National Longitudinal Survey of Youth 1979 (NLSY79) of the US Bureau of

Labor Statistics. Since approximately 80% of the people in the sample changed residences during the study period, we can check whether people actually gained weight when they moved to a more sprawling neighbourhood or if they lost weight when they moved to a less sprawling one.

We focus on two key dimensions of the built environment that earlier studies suggest as potential determinants of obesity. First, we use the measure of "residential-sprawl", in the sense of scattered development, described above: the percentage of open space in the square kilometre around the average house in the neighbourhood. Second, we use counts of retail shops and churches in the neighbourhood from US Census Bureau Zip Code Business Patterns data to measure the extent to which a neighbourhood can be characterized as "mixed-use". We define each individual's neighbourhood as a two-mile radius disc around the individual's residence. Obesity is measured through each individual's Body Mass Index (BMI), which allows comparisons of weight across people of different height. This index is calculated by dividing an individual's weight in kilograms by his or her height in metres squared, i.e., in units of kg/m^2.

As in earlier studies, for men, we find a positive correlation between obesity and residential-sprawl and a negative correlation between obesity and mixed-use. That is, men who live in neighbourhoods with more compact development and more shops within walking distance weight less on average. However, the association between obesity and residential-sprawl goes away once we control for sufficiently detailed observable individual characteristics. This tells us that these observable characteristics (including age, race, education, marital status, number of children, smoking habits, and work characteristics) explain both the propensity to be obese and the propensity to live in a sprawling neighbourhood. In contrast, we still see a negative correlation between mixed-use and obesity, even after controlling for these observable individual characteristics.

The fact that the men in mixed-use neighbourhoods weigh less even once we control for the weight effects of detailed observable characteristics does not imply that sprawl causes obesity. If this were the case, then people who move from compact to sprawling neighbourhoods should gain weight, but in fact they do not. We can look at this directly because our data allows us to track people's changes in residence and weight (as well as in observable characteristics) over time. Thus we can estimate the effect of changes in neighbourhood characteristics on a given individual's weight. Once we take advantage of the panel dimension of our data to control for unobserved propensity to be obese in this way, the correlation between men's obesity and mixed-use vanishes: changes in neighbourhood characteristics do not lead to changes in weight.

For women, the cross-sectional correlation between obesity and both residential-sprawl and mixed-use is weaker than for men. However, in some regressions controlling for a small set of observable individual characteristics we do find a negative correlation between obesity and residential-sprawl. As in the case of men, however, changes in neighbourhood characteristics do not lead to changes in weight.

Our results strongly suggest that urban sprawl does not cause weight gain. Rather, people who are more likely to be obese (e.g., because they dislike walking) are also more likely to move to sprawling neighbourhoods (e.g., because they can more easily move around by car). Of course neighbourhood characteristics may still place constraints on the type of exercise that people are able to take or the nature of the diet that they consume. The key point is that individuals who have a lower propensity to being obese will choose to avoid those kinds of neighbourhoods. What if they are not always able to avoid those neighbourhoods because, say, their choice is constrained for financial reasons? Our results suggest that, even then, individuals adjust their exercise and diet to avoid gaining weight. Overall, we find no evidence that neighbourhood characteristics have any causal effect on weight.

Conclusions

By using a novel data set based on satellite imagery and linking it to other sources, we have been able to study urban development patterns across the United States with unprecedented detail. Our results confirm some key prediction of urban economic theory but also contain a few surprises.

Our analysis of the causes of sprawl confirms most of our priors as urban economists. Sprawl is positively associated with the degree to which employment is dispersed; the reliance of a city on the automobile over public transport; fast population growth; the value of holding on to undeveloped plots of land; the ease of drilling a well; rugged terrains and no high mountains; temperate climate; the percentage of land in the urban fringe not subject to municipal planning regulations; and low impact of public service financing on local taxpayers.

The surprises relative to widely-held claims come in three flavours. First, the extent of residential sprawl has not increased between the mid 1970s and the 1990s. Second, while the land used for housing has grown three times as fast as population, larger houses only explain about a quarter of residential land expansion. Just as important are changing demographics leading to smaller households (and hence to a need for more houses to shelter any given population), while internal shifts in population also play a role. Third, the widely-claimed causal link between sprawl and obesity is a mirage. People in sprawling neighbourhoods are heavier because the same characteristics that make them obese (e.g., a distaste for walking) make them prefer to live in sprawling neighbourhoods (e.g., so that they can get around by car and not walk). When people move to a different neighbourhood, their weight is unaffected. As health spending on obesity-related illnesses continues to rise in the United States and parts of Europe including Spain, many suggest that urban planning geared towards active and healthy living could be an important tool to curb obesity. Our results indicate that such efforts are misguided and that the public health battle against obesity is better fought on other fronts.

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