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Research Report

Big cities fuel inequality within and across generations

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Abstract

Urbanization has long fueled a dual narrative: cities are heralded as sources of economic dynamism and wealth creation yet criticized for fostering inequality and a range of social challenges. This paper addresses this tension using a multidisciplinary approach, combining social sciences methods with satellite imagery-based spatial pattern analysis to study the US urban expansion over the past century. We examine the impact of physical urban spatial characteristics (size, population density, and connectedness) on equality of opportunity, measured through intergenerational mobility, as well as its association with levels of income, wealth, and social capital. Our findings confirm that contemporary cities, particularly population-dense and expansive ones, are indeed divisive forces—acting as centers for income and wealth generation but failing to deliver equal opportunities for economic mobility. Perhaps surprisingly, this polarizing dynamic is a recent phenomenon. In the past, the most urbanized regions performed well in terms of income creation *and* equality of opportunity. Our analysis supports the hypothesis that the mid-20th century marked a pivotal shift toward more unequal and less inclusive patterns of urban growth.

Keywords: intergenerational mobility, income inequality, wealth inequality, urban sprawl, landscape ecology

Significance Statement

Childhood environment plays a major role in determining economic opportunity within and across generations. This paper presents a framework and database to study childhood environments and intergenerational mobility over long time periods, fusing social scientific methods with satellite imagery-based spatial analysis. We document key physical features of urban areas that are linked to long-term reductions in intergenerational economic mobility since the mid-20th century. Areas fostering economic growth do not necessarily promote more equal opportunity. These findings underscore the potential for evidence-based urban planning to address inequality and drive sustainable development.

Introduction

From 1900 to 2020, the total share of urbanized land in the United States increased 10-fold while the share of Americans living in urban places doubled from 40 to 80% (1). The urban transformation of American society has fueled a clash of narratives. Some laud the triumph of cities, portraying them as our greatest invention as they deliver health, prosperity, innovation, and happiness (2–5). Critics, however, lament a "new urban crisis," pointing to rising inequality and economic immobility, enduring segregation, environmental deprivation, unaffordable housing, and unprecedented economic disparities between regions (6–10). These conflicting narratives present a paradox that may only be explainable with reference to the complexity of cities and the multidimensional nature of inequality (11).

This paper contributes to this conversation by studying the long-term link between intergenerational mobility, income inequality, and the physical aspects of urban expansion. We do so by harnessing multidisciplinary advances from satellite-based image analysis and records of millions of parents and children linked across administrative data sources to describe a century of change in the structure of urban land development and inequality across over 3,000 US counties. We then use these data to explore whether the increased tendency for Americans to live in big, sprawling, and increasingly connected urban areas has reshaped human development and inequality outcomes.

Specifically, how did the expansion of urban areas throughout the 20th century influence patterns of intergenerational mobility and economic inequality? By urban expansion, we refer to three features: physical city size, population density, and connectedness of urban landscapes. Intergenerational mobility is measured as the adult income attainment of children born into low-income households in a given locale and is used widely as an indicator of

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equality of opportunity (12). The last decade of research on this topic has highlighted the hyper-local nature of intergenerational mobility (13, 14), where children's outcomes are increasingly understood to be determined by their places of childhood and linked to local household structure, neighborhood social capital, and residential segregation (15–18). Conceivably, if we could better understand the place-based childhood determinants of intergenerational mobility, policymakers, and planners would be better positioned to improve equality of opportunity at its source.

Alongside the growing focus on neighborhoods, there is a need to better understand the physical urban spaces in which these communities are embedded. One motivation for doing so is that, as the United States has transitioned to being a predominantly urban society, rates of intergenerational mobility have declined (19, 20), and spatial income and wealth inequality have climbed to unprecedented levels (21, 22). Although there are many potential explanations for these changes, including changes in industrial technologies (23–25), there may be explicitly spatial factors at play. Notably, leading scholars of civic and community engagement have argued that the physical structure of modern cities has limited opportunities for community engagement and the building of social capital (26–28), properties that are powerfully linked to sustainable growth (29), intergenerational mobility (15, 30, 31), and inequality in access to essential infrastructure (9). Physical features of cities and regions may therefore be driving unequal outcomes.

The motivation for this study is evident in the correlation of county-level patterns of urban expansion and intergenerational mobility (Fig. 1). In the United States, counties with high shares of urban land tend to have lower average rates of intergenerational mobility ($r = -0.26$). While children who grow up in many rural places and smaller cities, such as Dubuque, Iowa, experience comparatively high levels of upward mobility over recent decades, those in counties with notably large sprawling urban centers such as Fulton, Georgia (Atlanta), rank among the nation's worst performers. Given that larger and smaller places differ in many ways, beyond their form, careful statistical analysis is required.

Nonetheless, existing studies have overwhelmingly examined the social and economic characteristics of childhood neighborhoods with respect to intergenerational mobility, rather than the physical urban structures that may give rise to such contexts. Of the studies that have examined physical urban characteristics with respect to intergenerational mobility (30, 32–36), none have studied the relationship between these processes over time. This is a critical next step. If it is true that urban expansion weakens communities to the detriment of intergenerational mobility, then policy could seek to address the negative aspects of expansion to improve equality of opportunity. Moreover, the structure of urban regions is durable, and its impact on inequality could persist for generations. Our efforts here could thus inform broader efforts aimed at creating more equitable and sustainable cities (7, 37) and planning for neighborhoods to improve well-being (38, 39).

Beyond intergenerational mobility, our study examines two additional dimensions of inequality. First, we investigate "spatial inequality"—the disparities in income and wealth *between* different regions, which have expanded significantly in recent decades (8, 22, 40). While concentrated economic activity might intuitively seem to enhance local economic opportunity and intergenerational mobility, this relationship may not hold if urban economic development increases local income inequality. Thus, our second additional focus is on changes in income and wealth inequality *within* regions, which researchers link to negative outcomes such as decreased support for public goods and lower intergenerational mobility (13, 27, 41). Analyzing economic inequality both within and between regions provides valuable context for understanding shifts in intergenerational mobility rates.

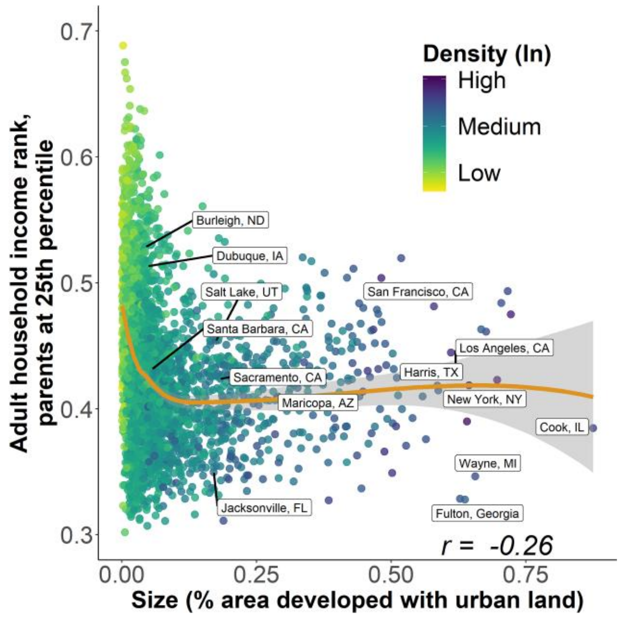

Fig. 1. A scatterplot showing the relationship between the natural log of the share of the county that was developed in 1990 and the county intergenerational mobility level for the 1978–1983 birth cohorts, based on 2014–2015 income attainment. Points are colored according to the population density of the county, with darker shades corresponding to higher density and lighter shades indicating lower density. Labels are added for descriptive purposes. The Spearman correlation coefficient (*r*) between these two variables is −0.26.

Theory on inequality and intergenerational mobility

Research on intergenerational mobility has traditionally been concerned with either societal-scale forces such as industrialization (42, 43) or microscale dynamics like the transmission of resources within families across generations (44). In this work, local contexts (places, communities, and regions) have been relegated to being marginal background considerations in the social stratification process (45). However, research in the last decade has now foregrounded these contextual effects. The mesoscale of analysis is particularly pertinent given high variability in how communities support skill development in childhood (labor supply), the local availability of jobs across space (labor demand), and the implications of spatial mismatch in the supply and demand side for upward mobility.

The recent local turn in the field has been fueled by findings of substantial regional disparities in life chances within the United States. Evidence increasingly suggests that the lifetime economic and educational attainment of children from otherwise similar backgrounds depends heavily on *where* they spend their childhoods (46). Studies based on the analysis of millions of children from lower income households document that disparities in outcomes between US cities are larger than between any pair of countries for which we have reliable data (13). The effects of places on children also appear to vary over time depending on how local conditions change (47). These effects of local context are particularly significant for children from poorer backgrounds, who are particularly vulnerable to family instability, concentrated poverty, racial segregation, school quality, and curtailed interaction within social networks that may otherwise positively support development of aspirations, social mimicking, and role modeling (15–17, 48).

An important nuance in these findings is that the places that best support children's upward mobility are often not those with the most dynamic economies. In fact, many of the regions with the highest rates of upward mobility tend to be in places with high rates of outmigration and low levels of urbanization (e.g. rural Iowa and Minnesota) (30). It may first appear counterintuitive that places with high-wage labor markets often exhibit low rates of intergenerational mobility, but it is less surprising when considering that what matters most are the early-life conditions that support childhood development (46, 49). It follows that early-life conditions play a critical role in later outcomes, and the conditions that support industrial development need not necessarily be conducive to the development of skills early in life.

This raises critical questions about our general expectations regarding how the physical size and structure of urban regions affect children's outcomes. While economic activity tends to be overwhelmingly concentrated in large cities (3), urban size is closely tied to widening income inequality (50), higher residential segregation (51), and an intensification of neighborhood effects on inequality and child development outcomes (11). There is also substantial variance in the size and structure of urban and rural regions in the United States (1, 52), and we know relatively little about how these contexts might differentially structure social interaction, economic inequality, and intergenerational mobility.

The concept of urban sprawl is pertinent here. In the popular view, sprawled urban regions are expansive, low-density regions, where residents are dependent on cars and face long commutes, potentially leading to reduced life satisfaction (53). Yet, urban sprawl has proved to be quite difficult to measure (54, 55). This is because, in reality, some of the most compact major urban regions have long average commute times and low accessibility, while some of the most sprawled exhibit high population density and greater accessibility (34). In this paper, we do not attempt to explicitly operationalize the concept of sprawl (32, 34, 56) but rather to describe how general patterns of urban expansion relate to intergenerational mobility over long periods of time, with potential implications for sprawling and densifying cities.

Figure 2 details the conceptual structure that underlies our work. We are concerned with the urban expansion of US counties across the period from the early and late 20th century, the most pronounced period of urbanization in US history (Fig. 2A). Urbanization was achieved through major transformations of the landscape and has given rise to a wide variety of urban forms, with implications for social and economic outcomes (Fig. 2B). Counties are important units for studying these processes because they are relatively consistent over time, and many health- and poverty-related programs are administered at that scale.

We derive three measures of urban expansion in 1920 and 1990. The first is the share of the total area of a county landscape that is occupied by urban land ("size"). The size of urban development is arguably the most basic indicator of expansion and has previously been shown to be a strong proxy for metropolitan population counts over the 20th century (52). Previous work also shows that the sprawling and car-dependent urban regions of the Sunbelt exhibited the largest growth in total area in the post-war period (1). Importantly, because our measures rely on a generalization of the county boundaries (see Materials and methods), our estimate of size or share of urban development is not seriously affected by irregularities in county boundaries.

The second feature of interest is the population density of the county, which is calculated from the ratio of the census-enumerated population relative to the total land area of the county ("density"). Density is an important variable, as it is one of the most widely used indicators of economic productivity and opportunity, and the so-called urban wage premium (4). Furthermore, density is strongly linked to high rents and a lack of affordable housing for individuals with low incomes (57) and is currently at the center of a contentious debate on the regulation of zoning and urban development (58, 59).

Finally, we measure the cohesion of the urban landscape ("connectedness"). This measure is derived based on the degree to which pixel-based representations of urban land within a county are connected through adjacency. In other words, the degree to which the urban area and associated places within a county are contiguously connected as opposed to fragmented. The connectedness of streets and populations is increasingly an issue of concern (54). This is because expanding cities are understood to fuel segregation, limiting interaction across social groups (60), particularly as segregated neighborhoods are divided by physical barriers in the landscape such as rivers (41). Rising connectivity also occurs as expanding urban agglomerations annex and incorporate smaller settlements.

These metrics were calculated for the developed areas in all counties in 1920 and 1990. These years align with the main exposure periods for the cohorts used to construct the intergenerational mobility estimates (see below). We do not form strong hypotheses regarding their influence on intergenerational mobility, but we note that these characteristics are only moderately correlated across the full distribution of counties.

Our goal is to assess how growing up in a county with a given urban form, as indicated by our three variables, affects adult income attainment for children from lower income backgrounds (Fig. 2C). We measure intergenerational mobility by integrating two main data sources. The first measures the 2014–2015 income attainment of over 20 million adult children from the 1978–1983 birth cohorts from Opportunity Insights, derived from deidentified IRS tax records, and weighted according to the child's length of exposure to their childhood county in the 1990s (14). We complement these data with our newly constructed database measuring the intergenerational mobility of the 1904–1916 birth cohorts based on their 1920 childhood location and their 1950 income attainment (see Table S2 for discussion of age profile differences). We describe the characteristics of these samples in the Appendix S1.

From these data sources, we follow the standard practice in the literature and derive county-level estimates of the average adult income attainment of children growing up in households at the 25th percentile of the national income distribution for the early and late 20th century (13). The 25th percentile of annual income refers to ~$27,000 in 2015 inflation-adjusted dollars. We measure the income positions of parents and children based on the percentile rank within the national income distribution in order to generate estimates that are robust to outliers and lifecycle biases (14). The coefficients from our analysis can be interpreted as estimates of how urban expansion (measured through changes in size, density, and connectedness at the county level) affects the income ranks of children from families at the 25th percentile of the national income distribution.

Our analysis includes several other independent and dependent variables of interest, including many variables capturing features that could confound the relationship between urban expansion and intergenerational mobility. In terms of additional

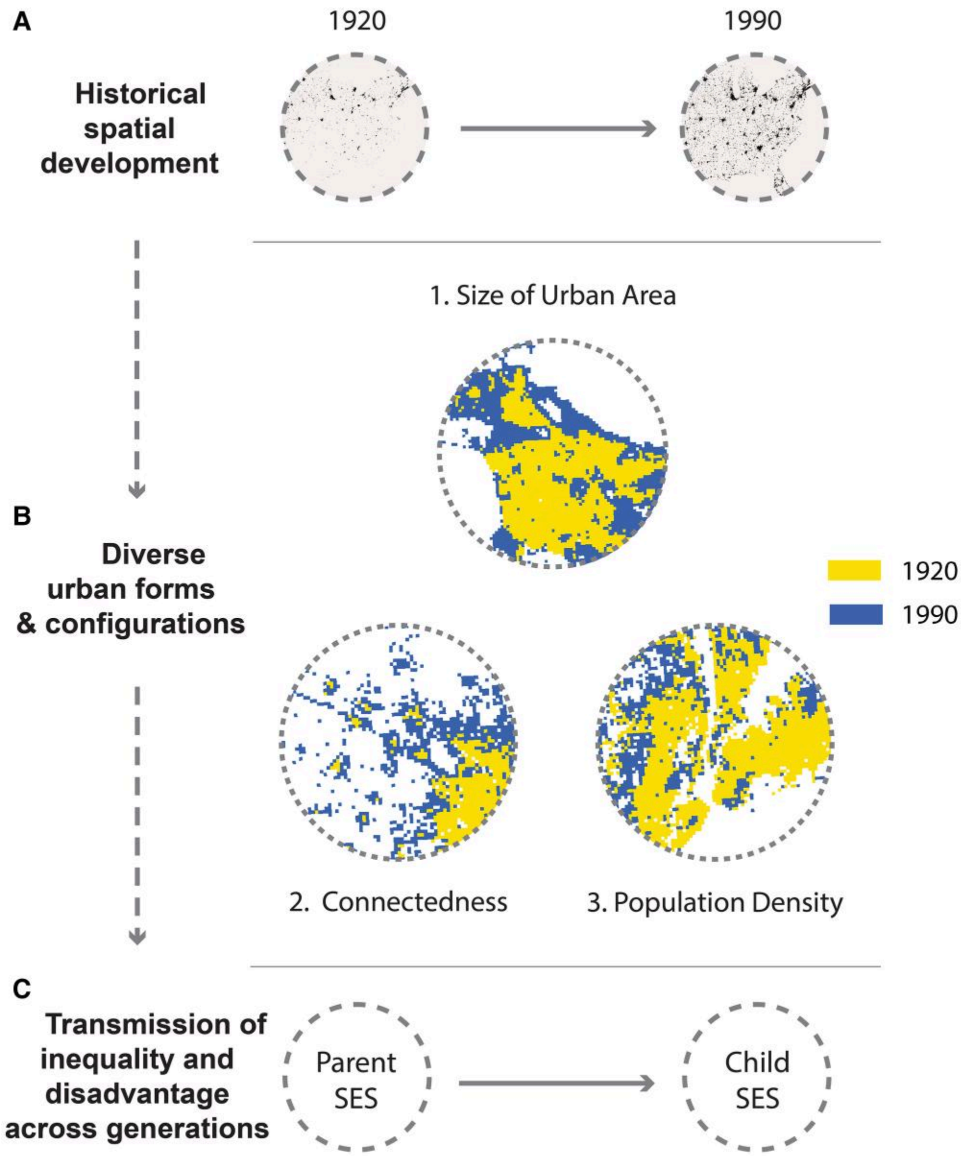

Fig. 2. A figure detailing the three key processes of interest under investigation in this paper. A) The general pattern of increasing urban land or "urban expansion" across the United States between 1920 and 1990. B) A visualization of our three urban spatial configuration metrics of interest: (1) the size of urban area (% developed); (2) the connectedness of the urban landscape; and (3) the population density. B1 shows the developed area for Los Angeles County, CA, a county that scores high in terms of share developed. B2 shows the developed area for Wright County, MN, an area that scores low in terms of connectedness. B3 shows New York County, one of the counties with the highest population density. C) The intergenerational transition of socioeconomic status (SES) from parents to children, the process on which we hypothesize urban expansion to intervene.

outcomes, we include state-of-the-art place-based measures of wealth and income inequality (21) and social capital. Existing evidence suggests that social capital is weakened by urban sprawl (26, 27), making it an important potential mediator through which urban expansion may affect intergenerational mobility (15, 30). Note that we do not make any causal claims regarding the relationship between urban expansion and average income and wealth levels, as urban change is partly driven by local economic development, which also spurs urbanization.

Results

Long-term patterns

We begin by describing long-term patterns of urban expansion and intergenerational mobility rates. Figure 3A presents our new estimates of intergenerational mobility for the early 20th century. These estimates provide an update on those produced previously for the 1920–1940 period (47).

In the early 20th century, intergenerational mobility rates had a strongly identifiable regional geography. Levels of upward income mobility were low throughout the South, the Mid-Atlantic, and in West Texas and New Mexico. Children from poorer households reached higher income levels when growing up in the coastal areas of the Northeast and the Pacific states and throughout the Midwest, Great Plains, and the Mountain regions.

Figure 3B shows that these patterns have some concordance with the geography of urban development in 1920. In the early 20th century, urban development was concentrated in the Northeast, the Midwest, and in smaller pockets along the West Coast around the quickly developing cities of Los Angeles and San Francisco. Although high rates of upward mobility in the

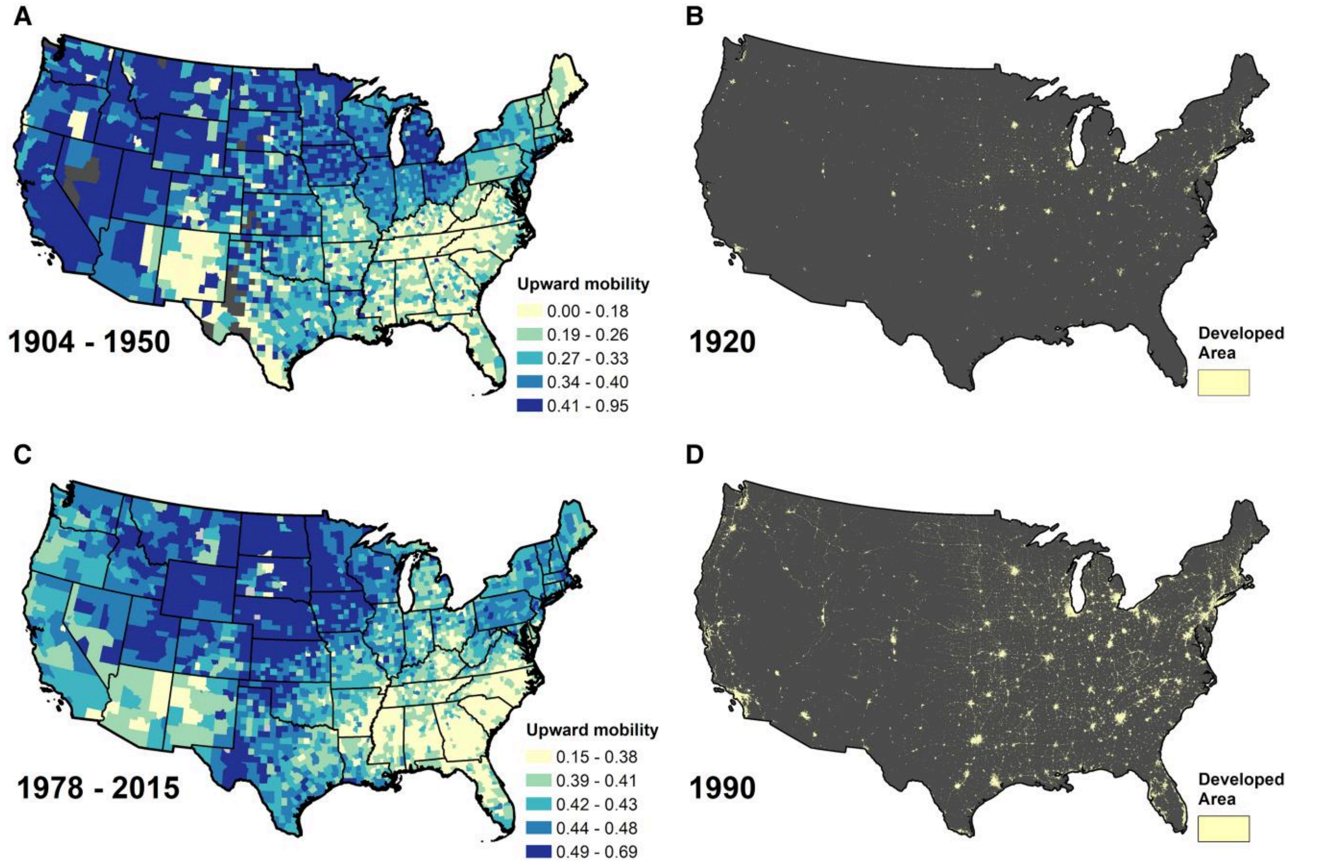

Fig. 3. Maps of intergenerational mobility and urban expansion, early and late 20th century. A figure of four maps showing long-term patterns of intergenerational mobility ("upward mobility") and developed areas in the early and late 20th century. A) Estimates of average adult personal income attainment of children born into households at 25th percentile of the national income distribution for the birth cohorts from 1904 to 1916 where income attainment is observed in 1950. B) 1 km × 1 km pixels of urban developed areas in 1990 from the HISLAND-US database. C) Estimated average adult personal income attainment of children born into households at 25th percentile of the national income distribution for the birth cohorts from 1978 to 1983, where income attainment is observed in 2014–2015. D) 1 km × 1 km pixels of urban developed area in 1920 from the HISLAND-US database. For A and C, darker shades indicate childhood locations that are associated with higher income attainment among children from poorer backgrounds, while lighter shades imply lower levels of upward income mobility.

Great Plains and Mountain states are not consistent with the pattern of urbanization, earlier studies have shown these regions to be both relatively supportive of child development and characterized by high rates of migration to larger metropolitan areas (47, 61, 62).

Figure 3C and D presents the corresponding patterns for the 1978–2015 period. In the late 20th century, there is evidence of both spatial change and stability in intergenerational mobility rates in comparison to the early 20th century. While states in the central and northern regions exhibit rising upward mobility rates relative to the rest of the country, much of the South continues to perform poorly. The geography of intergenerational inequality therefore exhibits some degree of persistence over time. The persistent geographic patterns in intergenerational mobility rates, especially the South's lower mobility, reflect the region's historical legacy of racial inequality (47, 61)—from slavery through subsequent forms of institutionalized discrimination.

There is also evidence of considerable change over time. In this later period, the geography of urban development is much less synchronous with intergenerational mobility. Despite significant urban expansion in the South and along the Pacific coast (Fig. 3D), these regions exhibit low and more mixed intergenerational mobility outcomes, respectively. Moreover, traditionally industrial states of the Midwest—Michigan, Ohio, Illinois, and Indiana—exhibit low levels of intergenerational mobility, despite significant urbanization over the study period. These latter patterns are linked in part to the shock to US manufacturing over recent decades (63), but may also be affected by cross-regional differences in urban expansion.

Figure 3C further illustrates that some of the strongest performing regions in terms of intergenerational mobility are also some of the least urbanized, a phenomenon referred to as the "rural advantage" in intergenerational mobility (30). The fact that some of these more rural states have exhibited high levels of intergenerational mobility over the century (e.g. the Upper Midwest, Utah) may point to more time-invariant and latent place-based advantages with respect to intergenerational mobility (62). The more germane point, however, is the decoupling of urban development and intergenerational mobility over the 20th century.

Panel analysis: main estimates

This section presents the estimates from our preferred regression specification. We stack our county-level observations from the early and late 20th century and estimate how physical urban expansion over the study period is related to changes in intergenerational mobility. These models include two-way fixed effects and adjust for a variety of time-varying county characteristics as

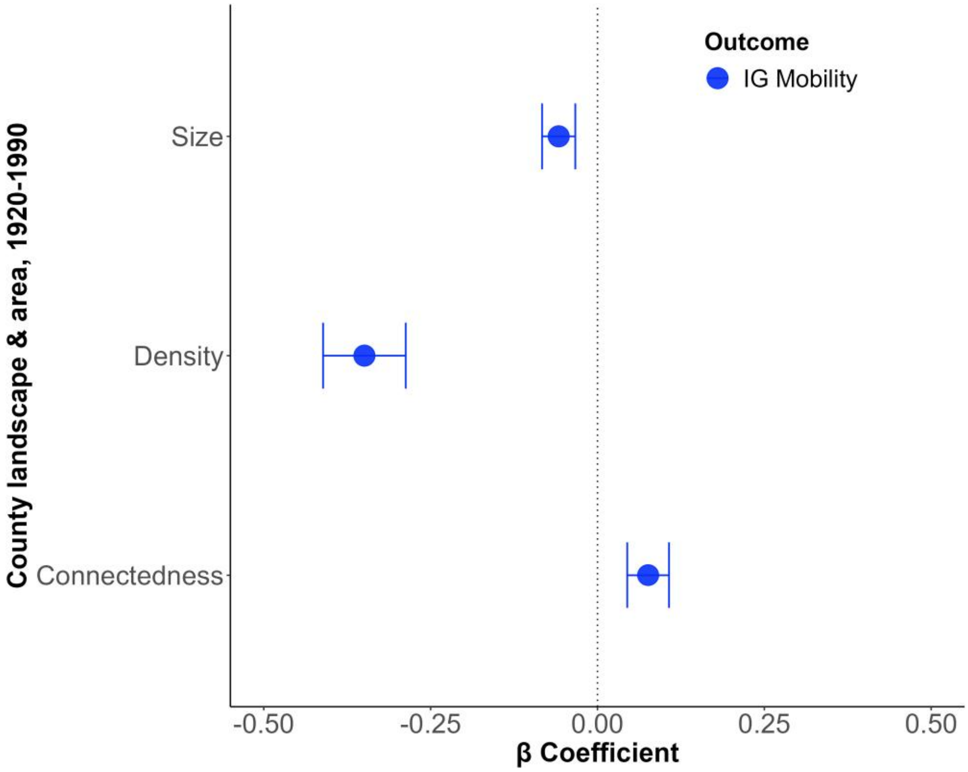

Fig. 4. Estimates from a spatial panel error model linking urban expansion to intergenerational mobility. The spatial panel error model adjusts for spatial and temporal autocorrelation in the error terms of the regression model. These estimates are derived from a dataset of 2,347 stacked county-level observations describing the characteristics of urban land within county areas in 1920 and 1990, and corresponding intergenerational levels that incorporate the periods from 1904–1950 and 1978–2015, respectively. Models are estimated with two-way fixed effects for period and county. Time-varying control variables include the share of single-parent households in a county, the foreign-born population, the share employed in manufacturing, the Black population, mean household income per capita, and the Gini coefficient for mean household income. The independent and dependent variables are standardized to have a mean of 0 and an SD of 1 across the study period.

well as spatially autocorrelated errors. The beta coefficients in Fig. 4 describe how an SD increase in one of the three urban expansion characteristics relates to corresponding changes in intergenerational mobility.

Across all three of our variables of interest—urban size, density, and connectedness—we observe strong and statistically significant relationships. Most notably, increases in population density are associated with significant reductions in intergenerational mobility. A one SD increase in the natural log of population density is associated with almost a half SD reduction in intergenerational mobility. The size of urban expansion within the county is also negatively associated with intergenerational mobility, but to a much more modest degree.

There is a small positive relationship between the connectedness of the urban area and intergenerational mobility. A one SD increase in connectedness is associated with an increase of 0.12 SDs in the intergenerational mobility level of a county. In terms of our preferred intergenerational mobility metric, this corresponds to an average increase of 1.6 income ranks within the national distribution for the low-income population of a county. This finding implies that counties where the urban landscape has become more connected over time have experienced average increases in intergenerational mobility outcomes.

Although our initial estimates suggest that expansions in urban size and densification are associated with unfavorable changes in intergenerational mobility, this relationship may also depend on a county's preexisting level of development. We address this question in Fig. 5 by interacting the urban expansion characteristics with the initial development level in the 1920 base period.

We find that changes in urban size matter most when the county is already developed. The continued expansion of already urbanized counties is associated with lower rates of intergenerational mobility, a pattern consistent with the suburbanization and sprawl of many northern cities. These patterns are also consistent with evidence of negative externalities to growth in places where the housing supply has become inelastic and residents less mobile (64). Conversely, when counties with little prior urban development increase in size, intergenerational mobility tends to rise.

For connectedness, we observe positive associations for counties irrespective of their initial development level. However, the effect of connectedness appears to be particularly strong for counties that have existing urban settlements, suggesting positive returns to urban infill and spatial integration rather than spatial separation. In terms of density, we observe the most negative relationships for counties that were mostly rural in the early 20th century, indicating that newly emerging urban settlements are linked to reduced upward mobility.

Period-specific analyses

Have urban regions become less economically inclusive and more unequal since the early twentieth century? We address this question by examining variability in the relationship between urban expansion and intergenerational mobility over time, as well as the extent to which urban expansion is predictive of other

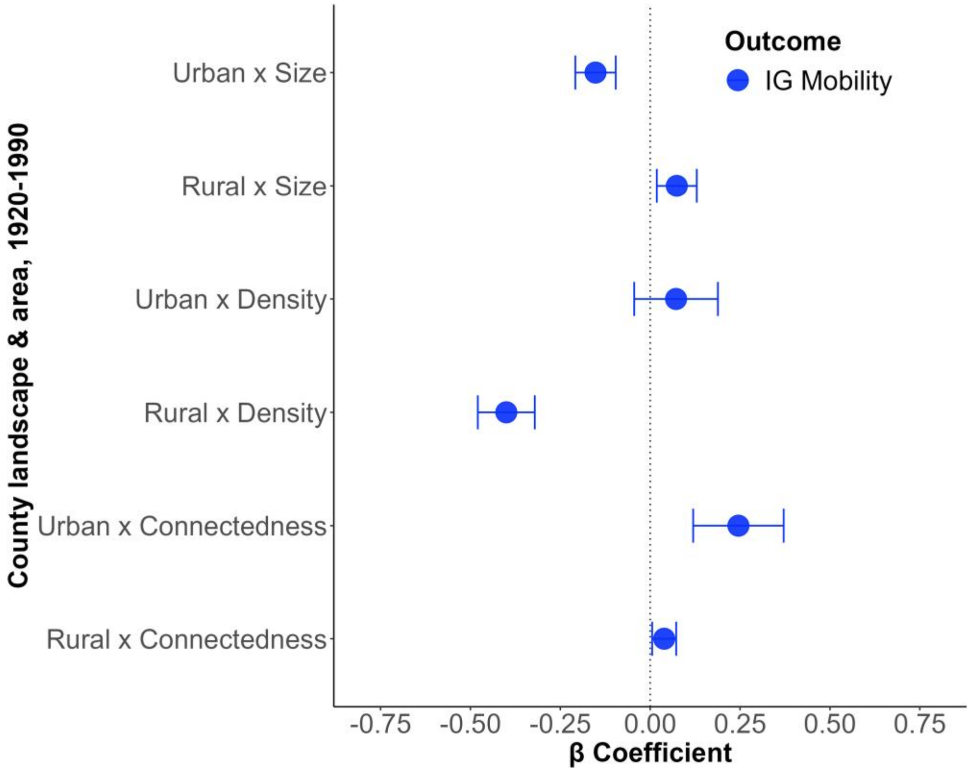

Fig. 5. Estimates from a spatial panel error model with interactions for 1920 urbanization, linking urban expansion to intergenerational mobility (IG mobility). A county is defined to have "Urban" actvitiy in 1920 if at least 1% of the total county landscape area was developed. It is considered fully "Rural" if less than 1% of the total county area is developed. This threshold applies to ~40% of counties in 1920. The spatial panel error model adjusts for spatial and temporal autocorrelation in the error terms of the regression model. These estimates are derived from a dataset of 2,347 stacked county-level observations detailing urban expansion in 1920 and 1990, and corresponding intergenerational levels that incorporate the periods from 1904–1950 and 1978–2015, respectively. Models are estimated with two-way fixed effects for period and county. Time-varying control variables include the share of single-parent households in a county, the foreign-born population, the share employed in manufacturing, the Black population, mean household income per capita, and the Gini coefficient for mean household income. The independent and dependent variables are standardized to have a mean of 0 and an SD of 1 across the study period.

indicators of prosperity and inequality. In the results that follow, we demonstrate that large cities consistently exhibit high average levels of income and wealth but perform increasingly poorly with respect to intergenerational mobility.

Figure 6A presents period-specific estimates of the relationships between urban expansion and intergenerational mobility, as well as social capital. Social capital is measured as the average probability for a county that a person's friends are also friends with each other, as observed from 21 billion Facebook friendship ties (15). While our preferred social capital variable is measured in 2022, our results are consistent when we use other widely used measures from 1990 (Appendix S3) (65).

For the contemporary period, we observe that size, density, and connectedness are all negatively associated with both intergenerational mobility and social capital. Urban expansion appears to be particularly detrimental for social capital as defined by indicators of community and civic engagement, membership in local organizations, altruism, and the density of friendship networks (Appendix S3). While it may be surprising that greater urban connectedness is linked to reduced social mobility, these patterns are consistent with the view that expanding and densifying cities weaken community interactions, potentially limiting intergenerational mobility for youths from lower income backgrounds.

Contrastingly, in the contemporary period we observe a different set of relationships between urban expansion and average household wealth and income levels. The three urban expansion indicators in 1990 positively predict income and wealth levels in the year 2000 (Fig. 6B). The contemporary period is therefore characterized by positive associations between urban spatial development and income and wealth levels but a negative relationship for intergenerational mobility.

This polarized pattern is not observed in the early 20th century. In the past, all three measures of urban expansion were positively associated with both intergenerational mobility (Fig. 6A) and average income levels (Fig. 6B). The absence of reliable data on personal assets and debts in the early 20th century means that we cannot make historical comparisons in terms of wealth. However, we suspect that the same patterns would extend to wealth.

Finally, we turn to the Gini coefficients for income and wealth inequality. Here, we see again a polarized relationship over time (Fig. 6C). For the early 20th century, income inequality tends to be lower in more urban places but this relationship reversed in the late 20th century. In the latter period, urban development is positively associated with both income and wealth inequality at the county level.

Taken together, these time-varying associations tell a powerful story with respect to urban expansion and various forms of inequality and prosperity. In the early 20th century, more developed regions tended to have higher average incomes, higher rates of intergenerational mobility and lower levels of income inequality. In broad terms, urbanization was delivering, to some extent, on inclusive economic development.

Things changed, however, in the second half of the 20th century. Major urban regions continued to generate and even expand their

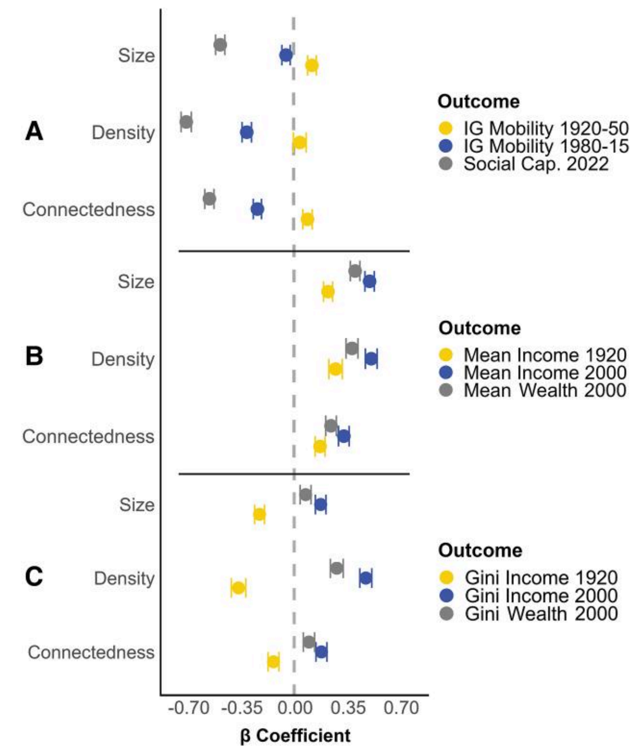

Fig. 6. Period-specific estimates from a spatial autoregressive model linking urban expansion to three outcome variables: A) intergenerational mobility (IG mobility) and social capital, as defined based on the average of a person's friends who are also friends with each other (social cap. 2022); B) mean household income (mean income); mean household wealth (mean wealth); C) the Gini coefficient for mean household income (Gini income) and mean household wealth (Gini wealth). The label "1980–15" refers to the period from 1980 to 2015. Due to data availability, we only model social capital and wealth for the contemporary period. The wealth data were obtained from the GEOWEALTH-US compendium. The data on social capital were downloaded from Opportunity Insights. Control variables include the share of single-parent households in a county, the foreign-born population share, the share employed in manufacturing, the Black population share, mean household income per capita, and the Gini coefficient for mean household income. The latter two control variables are not included when analyzing wealth or income levels or Gini coefficients. The independent and dependent variables are standardized to have a mean of 0 and an SD of 1 for each specific study period.

advantage in terms of income and wealth levels, reflecting the growing prominence of major cities in the contemporary economic landscape (8). At the same time, they fared increasingly poorly in terms of intergenerational mobility for the children growing up in those counties. Unfavorable urban inequality and intergenerational mobility outcomes align with the fracturing of social capital and community life in many of these urban regions. These patterns are consistent with an interpretation that contemporary urban regions support industrial growth (i.e. jobs) but are less favorable for the development of human capital among children from disadvantaged backgrounds. Our findings therefore point to a sea change in the nature of urban expansion and its relationship to intergenerational inequality over the 20th century.

Mechanisms and heterogeneity

The relationship between urban expansion and intergenerational mobility is likely mediated by a large number of local economic and sociocultural influences. In particular, urban form likely matters for intergenerational mobility as a result of its influence on neighborhood and segregation effects (11), as well as the constraints it places on housing markets (66). While we do not conclusively identify these mechanisms here, we do provide an exploratory analysis of these relationships in Appendix S3. Using the data from the contemporary period, we model the relationship between urban expansion and a large set of covariates, conditional on state-level fixed effects.

Unsurprisingly, urban size is strongly predictive of indicators of economic development (Tables S4–S6). Larger size and higher connectedness are associated with higher average income levels and lower poverty rates, and also less affordable home prices and rents. In contrast to other recent work (64), population density is weakly related to housing costs but is strongly positively associated with income inequality and poverty rates. Density is also predictive of many social challenges faced by lower income urban communities, including violent crime, family instability, lower levels of high school funding and completion, longer commutes, and higher levels of racial segregation. Of particular note, density is also associated with reduced social capital, as measured by friendship connections among children from different economic backgrounds ("economic connectedness"; Table S6). This is particularly noteworthy given evidence from Raj Chetty and collaborators (15, 67) demonstrating a strong positive link between economic connectedness and upward mobility.

All of the variables discussed above are notable because of their causal connection to intergenerational mobility, in directions consistent with our findings for urban expansion. For example, urban size and density are predictive of racial segregation, and segregation has been shown to curtail intergenerational mobility (16). Our descriptive analysis thus suggests that recent urban development trends have amplified many of the known determinants of intergenerational mobility.

Using tract-level data, we also demonstrate that population-dense urban regions show greater variation in neighborhood intergenerational mobility rates, indicating that density is associated with increased neighborhood stratification (Table S7). The negative effects associated with density are only statistically significant in neighborhoods characterized by higher poverty rates and Black population shares (Table S13). In contrast, we observe no relationship between density and intergenerational mobility in tracts with low poverty rates or low Black population shares. These findings strongly suggest that the negative effects underlying urban expansion operate through an intensification of localized neighborhood effects on socially and economically marginalized populations. That is, the neighborhood structures of big cities are more internally polarized, leading to greater inequality in intergenerational mobility.

We conclude our analysis by testing for heterogeneity across notable subgroups in the population. Consistent with recent findings of sex-based variability along the rural–urban continuum (30, 68), the negative implications of density appear to be particularly pronounced among White males from lower income backgrounds, who may be more sensitive to household instability. We observe contrasting relationships for women from lower income backgrounds, who experience more upward mobility and lower rates of teen pregnancy in more urban contexts.

Finally, we examine differences in the outcomes of children who left or stayed in their home commuting zones. Children from lower income households are more likely to stay in commuting zones with high levels of population density, size, and connectedness. We also find income benefits associated with migration away from areas with high population density, but this appears to be heavily driven by the low-income attainment of individuals who stay in their home areas. Lower income children from urban neighborhoods may therefore be disadvantaged by being more "stuck in place" than their counterparts elsewhere (69).

Discussion

The last decade of research on intergenerational mobility and equality of opportunity has yielded two major findings. First, the United States is now no longer an exceptional society in facilitating upward mobility for children from lower income backgrounds (19, 20, 70). Second, childhood location matters much more for upward mobility than previously believed (13, 14). In fact, one's place of childhood appears to have increased in importance over time, as economic success has come to depend more on the acquisition of education and skills rather than proximity to jobs (47, 61). The logical extension from these findings is that if we can determine the formula for what kinds of childhood locations promote intergenerational mobility, we will be more empowered to improve outcomes at both a local and national level.

This paper addresses an important topic at the intersection of these findings: the impact of long-term urban expansion on intergenerational mobility outcomes. While there has been much examination of the social, economic, and political determinants of intergenerational mobility, far less attention has been devoted to the physical dimensions of urban environments. The leading studies in this area have been principally concerned with determining whether intergenerational mobility is lower in more sprawled urban regions (32–34).

While the current literature indicates that more compact and less sprawled development may be conducive to intergenerational mobility (71), the cross-sectional nature of the data used in such studies makes it difficult to rule out alternate explanations for these patterns. For example, we cannot be confident that low rates of intergenerational mobility in an urban region like Atlanta are due to urban expansion as opposed to other characteristics of the region that are difficult to measure. We contribute to these efforts by studying these dynamics over a long period of time, a critical step in explaining how urban expansion affects equality of opportunity. Implemented correctly, a longer term approach provides value for identifying how a region's *changing* physical population structure relates to its capacity to generate intergenerational mobility.

We provide two new findings of note. First, increases in the size and population density of urban land within counties have potentially contributed to reduced rates of upward mobility among children from disadvantaged backgrounds over the 20th century. These same characteristics are, however, associated with rising average levels of income and wealth, meaning that urban expansion has likely been positive in terms of overall economic growth but less favorable for equality of opportunity. This is due, in part, to the intensification of neighborhood stratification and its effects on children from economically insecure households, particularly boys. The corollary is that smaller scale urban communities appear to be more conducive to intergenerational mobility. The second finding is that this duality is a *recent* phenomenon: highly developed counties in the past exhibited both economic prosperity *and* equality of opportunity, suggesting a sea change in the nature of urban inequality over the 20th century. This pattern is consistent with the observation that big cities have become increasingly favorable for individuals with high levels of education and economic resources (72, 73).

What accounts for these patterns? Although many explanations have already been advanced (11, 74, 75), the political scientist Robert Putnam highlighted one particularly plausible pathway. In *Bowling Alone*, Putnam argued that automobile-based urban sprawl has particularly deleterious social effects because it weakens community engagement and social infrastructure, exacerbates segregation, and, through increased commute times, reduces the amount of time that people can spend with children, friends, and neighbors (27). Adjacent work on the endurance of urban "neighborhood effects" points to related effects in reducing collective efficacy and exacerbating racial inequality (11). Contemporary urban expansion is therefore synonymous, directly and indirectly, with many of the known causal determinants of intergenerational mobility (15, 16). However, these urban conditions have not just been confined to the archetypical car-dependent cities of the Sunbelt, but increasingly characterize the poorer neighborhoods populating many of America's largest urban regions.

Furthermore, the contemporary, knowledge-based economy values skills and education to a much greater extent than the manufacturing-based economy of the past (23, 76). As a result, early inputs for children's development of skills and aspirations have never mattered more (47, 61). In fact, prior evidence suggests that areas with higher rates of intergenerational mobility have lower salaries conditional on skill (16). This finding is in line with counterintuitive observations that many regions with sluggish economies (e.g. rural regions) manage to generate high rates of upward mobility, perhaps by creating supportive childhood contexts for aspiration and skill development (30). Thus, the negative effects associated with urban expansion on intergenerational mobility likely reflect a mixture of negative effects of urban expansion and its associated neighborhood effects on child development, as well as the growing importance of skills in today's knowledge-based economy.

Our findings complement, rather than supplant, existing explanations for change and stability in the geography of intergenerational mobility in the United States. Prior research has established how the legacies of ethnic settlement patterns, slavery, and structural racism continue to shape mobility patterns, particularly in the South (62, 77) and in areas where there is underinvestment in public goods (41). Relatedly, the nation's changing industrial structure has enhanced opportunities in regions supporting educational advancement while reducing them in former manufacturing centers (47). While accounting for these established factors, our analysis identifies urban expansion as an additional significant force shaping the long-term geography of intergenerational mobility in the United States. It follows that the growth of highly stratified and segregated cities have contributed to the nation's less than desirable levels of social mobility and equality of opportunity.

Our efforts highlight the potential for historical analysis to enrich our understanding of urban systems more generally. There is an active effort among social scientists to establish regularities between city size and a range of human outcomes and activities (73, 78), sometimes leading to a view that large cities can be understood as scaled-up versions of small cities. There is, however, a growing recognition of the importance of historical path dependence and major technological shifts in structuring these relationships (22, 79, 80). Given its dependence on local sociocultural contexts, intergenerational mobility is one such process that is likely to defy simple size-based characterization. There is no neccessary reason why big cities should limit economic opportunity for vulnerable children. Rather, what matters is how we organize communities and neighborhoods within these regions and how we distribute resources across them.

With the growing availability of historical and contemporary land use data and linked census and population records, these and many other problems related to social inequality and human development can now be investigated (81–86). By studying cities through time, we can better understand the mechanisms through which urban space affects intergenerational mobility and inequality, as well as how to potentially attenuate such effects through policy and planning.

Finally, our work holds important implications for urban sustainability science, an area where the science of social and spatial inequality has yet to receive sufficient attention (7, 37). An urban science that addresses these topics is greatly needed, particularly as policymakers are actively considering how they can shape urban landscapes in ways that will generate equitable and sustainable outcomes. Here, we have laid out an approach that harnesses advances from the social sciences alongside satellite imagery-based spatial pattern analysis to study urban expansion, inequality, and equality of opportunity from a long-term perspective. When it comes to both the science and planning of cities, we contend that a long-term perspective is necessary to understand how places change human outcomes, within and across generations.

Materials and methods

Landscape analysis

Our calculations of urban expansion are executed based on high-resolution geospatial data on long-term historical changes in land use and land cover (LULC). The history of LULC for the conterminous United States (HISLAND-US) database provides annual LULC data at 1-km spatial resolution from 1630 to 2020 (87). HISLAND-US was constructed with multi-source data inputs, including historical census data, forestry, agriculture and building records, and high-resolution remote sensing LULC images (81, 88). For our analysis, we extract the "urban" LULC class from the underlying raster database.

We use landscape composition and configuration metrics to describe urban expansion within counties (89–91). To address challenges inherent to studying urban expansion over time, we projected a buffer with a 50-km radius around the urbanized core of each county (circa 1900), which we refer to as "county buffers." By studying development with these consistent buffers, we eliminate biases introduced through the different shapes and sizes of official US county boundaries. This approach also avoids the structural biases introduced by city clustering algorithms that rely on the connectivity of built-up areas to establish urban growth boundaries (92). We adjust for natural constraints on local development during estimation by adjusting for the share over the area of the county buffer that comprises water bodies or steep slopes (>15°) (66).

The metric computations for connectedness were performed at the class level (i.e. urbanized land), using an eight-neighbor conceptualization of connectivity and a parallel-computing pipeline to improve efficiency. For urbanized land within each buffer, the connectedness measure was calculated using the "Cohesion" metric and implemented using the *landscapemetrics* package in *R* (90, 91). For each county *j* in period *t*, the Cohesion metric is defined as:

$$\text{Cohesion}_{jt} = 1 - \left(\frac{\sum_{j=1}^{n} p_{ij}}{\sum_{j=1}^{n} p_{ij}\sqrt{a_{ij}}}\right) \times \left(1 - \frac{1}{\sqrt{Z}}\right)^{-1} \times 100 \qquad (1)$$

where p_{ij} is the perimeter in meters of urban class *i* within the buffer of county *j*, a_{ij} is the area of urban class *j* in square meters, and *Z* is the number of cells in the county buffer. Patch cohesion increases as urban land becomes more clumped, aggregated, and more physically connected in its distribution. For interpretation, Cohesion approaches 0 as the proportion of the landscape comprised of the focal class decreases, resulting in an increasingly subdivided and less physically connected landscape. A known issue exists in which cohesion metrics are of limited insight beyond a particular level of development ("percolation threshold") (93). This is not a major concern here, as only 14 of our counties exceed the 59% threshold.

The size measure is calculated as:

$$\text{Urban size}_{jt} = \frac{\text{Urban}_{jt}}{(\text{Urban}_{jt} + \text{Nonurban}_{jt})} \qquad (2)$$

where the urban size of county *j* in period *t* is calculated by the total urban land within the county buffer over the sum of total land (urban and nonurban) within the buffer. Urban size is thus measured as a proportion with a potential minimum value of 0 and a maximum value of 1.

Density is calculated as:

$$\text{Density}_{jt} = \frac{\text{Population}_{jt}}{\text{Area}_{jt}} \qquad (3)$$

where population refers to the total population of county *j* in period *t*, as measured from the censuses of 1920 and 2000. Note that unlike in the equations above, *area* and *population* in Eq. 3 are measured based on the officially defined county boundaries and not the county buffers. We do this here because total population is not observed for the area covered by the buffer.

Intergenerational mobility data

Estimation of intergenerational mobility rates with low bias requires longitudinal intergenerational observations on parents and children. This allows us to infer location based on place of childhood, reducing concerns that individuals systematically sort across counties based on personality characteristics. Although parents may sort in ways that could influence intergenerational mobility, causal validation of the data suggests that this is of minor concern to the estimates used here (14).

Our intergenerational mobility estimates are based on the integration of two new databases. The first is a database of county-level intergenerational mobility estimates for the early 20th century (1904–1950) and late 20th century (1978–2015), the latter of which were extracted from Opportunity Insights (14). The data on wealth levels were obtained from the GEOWEALTH-US compendium (21) and the social capital data were accessed through Opportunity Insights (14). We generated the early 20th century estimates by constructing a new sample of 416,481 linked fathers and sons as observed in the historical full count census data for 1920 and the recently released 1950 full count census from IPUMS (Appendix S1). These data are published as part of a collaboration between Ancestry.com and the Minnesota Population Center (94).

We constructed our linked sample between the 1920 and 1950 census using the Multigenerational Longitudinal Panel (MLP) crosswalks (82). While all linkage algorithms face trade-offs regarding representativeness and accuracy (95, 96), we use the MLP because it has low rates of false positives, a known challenge in historical census linkage (97, 98). Our primary unit of analysis for intergenerational mobility is based on 2010 county boundaries. We describe our strategy for harmonizing historical and contemporary boundaries in Appendix S2. Further, as income is not observed directly in the 1920 census, we imputed "income scores" based on 1950 data (Appendix S1).

Ideally, our analysis would focus on individual rather than county-level observations. This would increase the power of the analysis and allow detailed decomposition of the population. This is unfortunately not possible because the individual-level data for the contemporary context are subject to strong privacy restrictions. As such, we focus our investigation on county-level aggregates across the study period and, where useful, draw on group-specific county-level estimates of intergenerational mobility by gender, race, etc.

Estimation strategy

Our regression analysis is based on a series of spatial panel error and spatial autoregressive models estimated using the *spdep* package in *R* (99). We use these models to adjust for spatial dependence and bias in the data (100). Econometricians have recently documented inflated *t* statistics in long-term spatial analyses of persistence (101). In our case, there is an explicit form of spatial dependence in that nearby counties interact directly with one another through their shared landscapes. To address this problem, we needed to specify the spatial relationships between counties through a spatial weights matrix (Appendix S2).

We estimate the following spatial panel regression models with two-way fixed effects for period and county (102):

$$Y_{jt} = X_{jt}\beta + \mu_j + \lambda_t + \varepsilon_{jt} \quad (4)$$

$$\varepsilon_{jt} = \rho W \varepsilon_{jt} + u_{jt} \quad (5)$$

where the dependent variable Y is the intergenerational mobility level of county j in period t. X_{jt} is a vector of explanatory variables including our landscape metrics (size, connectedness, and density) and β refers to the corresponding coefficients. μ_j is the fixed effect for county j and λ_t is the fixed effect for period t. ε_{jt} is the error term for county j in period t. In the table and figure notes, we include the respective control variables for each respective regression analysis. W refers to the spatial weight matrix and ρ is the spatial error coefficient. Our cross-sectional estimates are based on the more simplified spatial autoregressive (SAR) models. In Appendix S3, we present robustness tables for alternate specifications, including adjustments for neighborhood effects or "spatial lags" in the independent and dependent variables. These adjustments have no meaningful impact on our core results.

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Supplementary Material

Supplementary material is available at *PNAS Nexus* online.

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Author Contributions

D.S.C., A.F., S.X., J.J., and G.J. conceptualized the study; D.S.C., S.X., J.J., A.F., and P.K. performed the methodology; Y.Y., D.S.C., S.X., J.J., A.F., P.K., T.K., and G.J. provided support on data and visuals; all authors reviewed and edited the paper.

Data Availability

All data and code associated with this manuscript will be made publicly available at openICPSR.

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