

Empirics of Strategic Interdependence:
The Case of the Racial Tipping Point¹

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Abstract: The Schelling model of a “tipping point” in racial segregation, in which whites flee a neighborhood in large numbers once a threshold of nonwhites is reached, is a canonical model of strategic interdependence. Moreover, the idea of “tipping” explaining segregation is widely accepted in the academic literature and popular media. I use census tract data for metropolitan areas of the US from 1970 to 2000 to test the predictions of the Schelling model and find that this particular model of strategic interaction largely fails the tests. There is more “white flight” out of neighborhoods with a high initial share of whites than out of more racially mixed neighborhoods.

¹ I am grateful for comments received from Ingrid Gould Ellen, participants in the CEPR Conference on Macroeconomics and Geography in Modena Italy, those in the NBER Summer Institute on Macroeconomics and Inequality, and those in a seminar at UC-Berkeley.

Models of strategic interaction are common in the economic growth literature, as well as in many other fields. For example, in human capital spillover models, your incentive to acquire human capital depends on the human capital of others. If spillovers take place within neighborhoods, then strategic interactions affect neighborhood formation, human capital of different ethnic groups, and overall inequality (Borjas 1993, 1996, Benabou 1993, 1996, Durlauf 2002, 1999, 1996). These models often feature multiple equilibria and sensitivity to initial conditions. Although the theory is well developed, there has been only limited empirical testing of strategic interactions and sensitivity to initial conditions.²

One of the most famous models of strategic interaction in economics is Thomas Schelling's (1971) elegant model of racial segregation (see its coverage in Dixit and Nalebuff 1991, for example). He shows how only a modest preference of whites to live next to other whites could result in nearly complete residential segregation, because of the instability of intermediate points where one agent's residential location depends on the actions of other agents. In this model, even a relatively small fraction of nonwhites could cause the neighborhood to "tip" from completely white to completely nonwhite. The fraction at which this happens is called the "tipping point."

If there are differences in average human capital between whites and blacks, and there are spillovers within neighborhoods, then residential segregation has important implications for black-white income differences. Hence, Schelling's model is potentially

² Borjas 1993, 1996 shows empirically that outcomes for individuals are affected by "neighborhood capital" and "ethnic capital", but does not test for sensitivity to initial conditions in neighborhood formation.

one of the important building blocks in understanding inequality (Durlauf 2002 cites it in this context).

The tipping view of neighborhood change had been around long before Schelling's piece. In articles described by Schelling (1971) from the 1950s, the tipping process was described as universal, as was the instability of mixed neighborhoods. Once a neighborhood had begun to change from white to black, there was rarely a reversal. The process was very nonlinear. An article in 1960 defined it thus:

*Although the movement of whites out of the area may proceed at varying rates of speed, a "tipping point" is soon reached which sets off a wholesale flight of whites. It is not too long before the community becomes predominantly Negro.*³

The idea of the "tipping point" is very much alive today both in academic literature and in popular folklore. Sociologists Douglas Massey and Nancy Denton (1993) describe how a white "majority still feel uncomfortable in any neighborhood that contains more than a few black residents; and as the percentage of blacks rises, the number of whites who say they would refuse to enter or would try to move out increases sharply." Ellen (2000) sums up the current conventional wisdom similarly: "racially integrated neighborhoods cannot stay that way for long...because as soon as the black population in a neighborhood has reached some "tipping" point, whites move away in droves."⁴

For examples of popular folklore, the recent bestseller called *The Tipping Point* by Malcolm Gladwell defined this point as the moment on the graph when the line (in our case the share of nonwhites in a neighborhood) shoots straight upward. An Atlantic Monthly article by Jonathan Rauch in April 2002 discussed Schelling's model of racial

³ Oscar Cohen quoted in Wolf (1963).

⁴ Ellen (2000) does not share this conventional wisdom, arguing for a more nuanced view of "white avoidance" of integrated neighborhoods for reasons unrelated to race. She argues that racially mixed neighborhoods in 1990 were more common and more stable than the conventional wisdom would have it.

segregation, then went on to apply the same concept to phenomena as diverse as collapsing civilizations, riots, and genocides. The tipping point model is also applied to racial segregation (as well as other kinds of sorting such as by gender) in other venues like schools or private clubs.

A large social science literature studies racial segregation. However, the Schelling model has undergone surprisingly little large-scale empirical testing on residential neighborhoods. There has been extensive empirical testing of the determinants of segregation using survey methods to ascertain people's preferences for segregation, or testing small samples of neighborhoods or school districts, or testing cross-city determinants of segregation, some of which address the Schelling hypothesis (with mixed results).⁵ In a Gallup survey in 1997, 25 percent of whites said they would move if blacks came in "great numbers" into their neighborhood (which was way down from 73 percent in a similar survey in 1966). This seems to indicate an increased tolerance for racial integration among whites over time. However, the researchers who report this survey result (Schuman et al. 1997) still believe in the tipping point model: "the upward trend does not seem to match reality if compared with the exodus of white families that often occurs when large numbers of black families move into a previously white neighborhood" (pp. 152-153).

⁵ See Clark (1991), Galster (1988), Clark (1988), Massey and Gross (1991), Wilson (1985), Farley et al. (1994), Giles (1978), Farley and Frey (1994), Hwang and Murdock (1998), Giles et al. (1975), Wolf (1963), and Schwab and Marsh (1980). Denton and Massey (1991) analyze transition matrices for a large sample of metropolitan census tracts from 1970 to 1980, but do not test the nonlinear dynamic equation implied by the Schelling model. Massey and Denton (1993) extensively discuss neighborhood transitions with census tract data, but do not test the tipping point hypothesis. Crowder (2000) does do a regression of individual level mobility on neighborhood nonwhite share that shows a highly nonlinear relationship as predicted by the tipping point model, but his setup does not lend itself to explicitly testing for a tipping point. Clotfelder (2001) finds the growth of white enrollment in schools declines almost linearly over most of the range of exposure to nonwhites in school districts.

The Multi-City Study of Urban Inequality (O'Connor, Tilly and Bobo 2001) conducted a more nuanced survey in Atlanta, Boston, Detroit, and Los Angeles. They showed whites five different cards indicating neighborhood composition ranging from all-white to majority black and asked them if they would "feel comfortable" in such neighborhoods or would be "willing to move in" to such a neighborhood. The affirmative response by whites falls fairly sharply as the black share rises, which would be more consistent with the tipping point hypothesis (for example, only 30 percent of whites would be willing to move into a neighborhood with an 53 percent black majority, with slightly more "feeling comfortable.")⁶

There has never been a full-scale test of the tipping point hypothesis with nationwide data on American metropolitan neighborhoods.⁷ Such a test has become feasible thanks to the availability of a new database from the Urban Institute and a firm called Geolytics.com, which matches census tract information from the U.S. censuses for 1970, 1980, 1990, and 2000. This is called the Neighborhood Change Data Base (NCDB). The database covers metropolitan areas; it does not include rural areas.

This database confirms that American neighborhoods continue to be highly segregated in the year 2000, despite some decrease in segregation and despite years of rhetoric and legal action in favor of integration. Nonwhites made up 28 percent of the sample population in the NCDB in 2000. Blacks make up 14 percent of the sample population. If each neighborhood were a random draw of whites and nonwhites, with the probability of drawing a nonwhite = .28, the odds against a neighborhood nonwhite share

⁶ Charles 2001, pp. 233-237

⁷ Aaronson (2001) and Ellen (2000) also run regressions for neighborhood dynamics using census tract data from 1970 to 1990, but they do not explicitly test the tipping point hypothesis. Both have indirect results that tend to indicate stability of neighborhood racial composition, which would be in line with this paper's conclusions.

of less than 10 percent would be astronomical. Yet 35 percent of all census tracts had nonwhite shares less than 10 percent. Similarly, the probability that a nonwhite would live in a neighborhood where the nonwhite share exceeds 50 percent would be extremely low if the population were distributed randomly. Yet the median black lived in a neighborhood that was 52 percent black. The Tauber dissimilarity index, a widely used indicator of segregation, was .53 in the year 2000 for America as a whole (the index ranges from 0 if nonwhites are evenly distributed across neighborhoods to 1 if whites and nonwhites are completely segregated). The index can be interpreted as the fraction of either whites or nonwhites that would have to move to achieve even distributions of racial groups across neighborhoods.⁸ I don't attempt in this paper to cover the rich literature on the historical and modern mechanisms determining racial segregation; I am just doing a test of one particular model of segregation.⁹

Of great relevance for the tipping point hypothesis, changes in neighborhoods from majority white to majority nonwhite are common in the dataset. Of the 41,321 urban census tracts in the NCDB that have data for both 1970 and 2000, 3965 neighborhoods had a drop in white share of .5 or greater from 1970 to 2000. Thus nearly 10 percent of the neighborhoods in the sample changed drastically from majority white to majority nonwhite over these 30 years. A weaker definition of tipping, the change from any white majority in 1970 to a nonwhite majority in 2000, reveals 14 percent of the neighborhoods tipped during this 30 year period.

⁸ See the discussion by Cutler, Glaeser, and Vigdor 1999 of different measures of racial segregation. They also present evidence that segregation declined from 1970 to 1990.

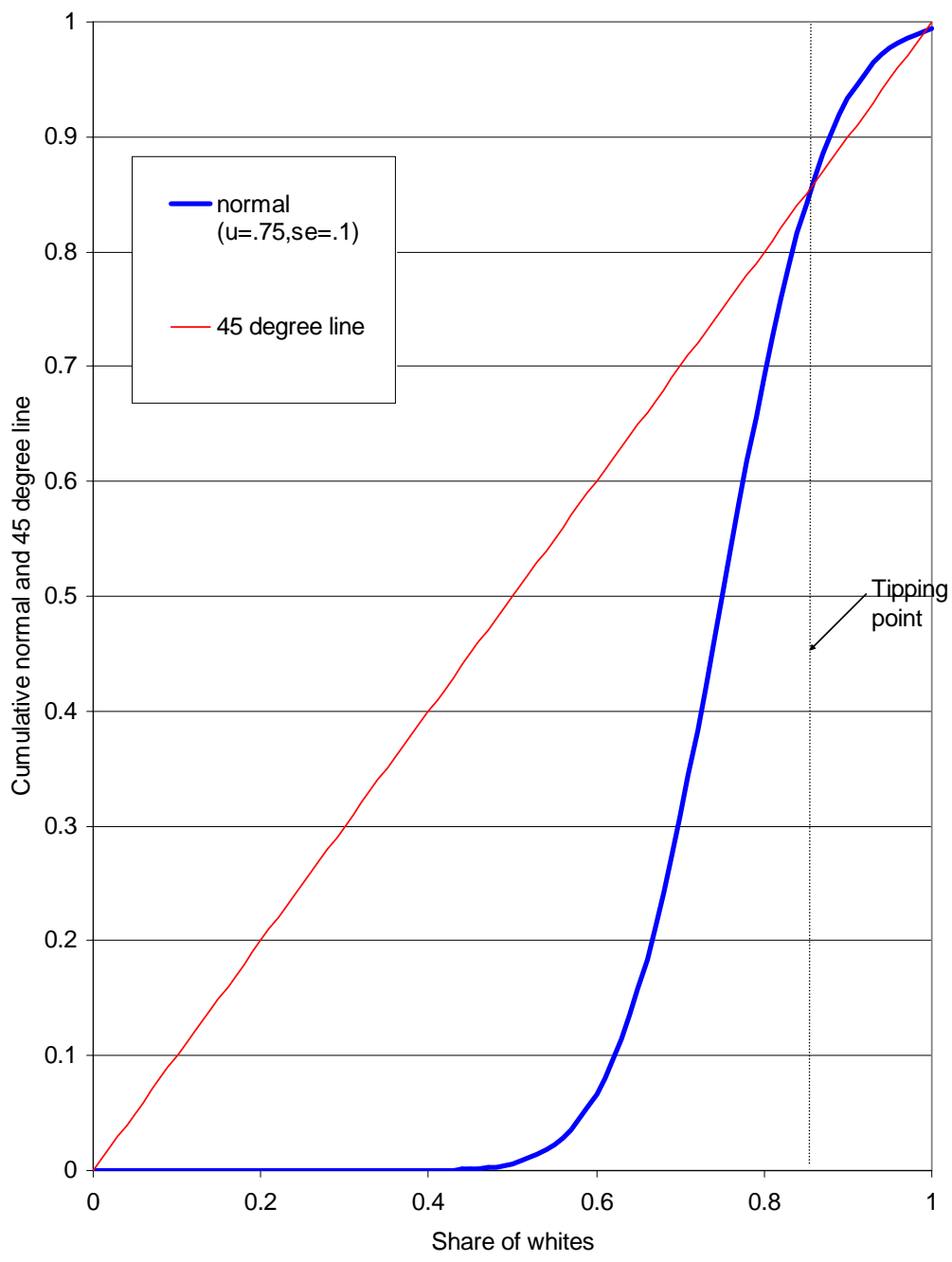
⁹ See Massey and Denton (1993), Ellen (2000), and Meyer (2000) for a richer treatment of the complexities of residential segregation.

This paper uses this database to conduct tests of some of the predictions of the Schelling “tipping point” model. It will ask the fundamental question of whether the high degree of segregation observed in American neighborhoods is a consequence of the dynamic instability of intermediate points due to strategic interdependence, with only weak preferences for living next to your own racial group.

Schelling's model

Schelling's model is simple and elegant. Suppose that whites' preferences for neighborhood segregation between whites and blacks can be summarized as follows: each white individual j prefer to live in a neighborhood that has at least w_j percent of whites. If white individual j finds himself in a neighborhood containing less than w_j percent of whites, then he will exit the neighborhood. As long as the neighborhood contains more than w_j percent of whites, then individual j will stay in the neighborhood. Whites have diverse preferences for racial segregation ranging from integrationist to segregationist, which can be summarized by assuming a normal distribution for w_j across all white individuals. Thus, the cumulative density function of the normal distribution with mean μ and variance σ^2 , $F(w; \mu, \sigma^2)$, gives us the percent of whites that have an w_j less than or equal to w . For example, assuming just for illustration that $\mu=.75$ and $\sigma=.1$, Figure 1 shows the corresponding cumulative density function.

Figure 1: The cumulative normal distribution for racial preferences



The CDF thus shows the percent of whites that will live in a neighborhood that is w percent white – it is all those who have an w_j less than or equal to w . The CDF is highly nonlinear, with flat segments at either end but climbing steeply in the middle. This reflects the characteristics of the normal distribution, with flat tails but steep increases in the number of individuals contained in the middle. The actual fraction of whites who live in the neighborhood is given by the 45 degree line.

To relate the CDF to the whites who desire to live in the neighborhood as a fraction of the neighborhood population, the reasoning seems to be something like this. Suppose that whites have a right of first refusal on the homes in any neighborhood – so all the homes are offered to a representative sample of whites, $F(w)$ of whom accept. The remainder of homes are then occupied by non-whites. Hence $F(w)$ also gives the ratio of whites desiring to live in the neighborhood to the total neighborhood population.

Note that Schelling's basic model assumes the outcome is entirely driven by whites' preferences. This assumption is debatable (and perhaps even offensive), but it reflects the traditional view of neighborhood segregation as mainly driven by whites' behavior. It could be justified by saying that whites have stronger preferences about getting their preferred racial composition than nonwhites, and hence will pay more to live in their preferred neighborhood (note that the basic Schelling model does not have any role for housing prices). Schelling actually did a version of the model that also incorporated nonwhites' preferences for neighborhood composition, but it has not caught on like the original model and it did not dramatically change the predictions of the model.

The point where the cumulative density function crosses the 45 degree line in Figure 1 is where the fraction of whites willing to live in a neighborhood that is w percent white is in fact equal to w :

$$(1) w = F(w; \mu, \sigma^2)$$

This is an equilibrium outcome for racial composition of the neighborhood. Note that this outcome is a higher fraction of whites w than the mean of the normal distribution of white preferences. For example, in the figure the equilibrium point is .86, while the mean of the normal distribution was .75. Any mean of the normal distribution greater than .5 cannot be an equilibrium, because only .5 of whites are willing to live in the neighborhood with the mean of the normal distribution for fraction of whites. The equilibrium always lies above the mean in this case.

Note however, that this equilibrium is unstable. If there is a disturbance such that a few whites leave the neighborhood or a few nonwhites enter and the white share drops below equilibrium, then the fraction of whites willing to live in the neighborhood falls below the actual share. There is a further decrease in white share, and yet a further white exodus. This process does not stop until the neighborhood becomes completely nonwhite – a white share of 0 is a stable equilibrium. The neighborhood has “tipped” from being majority white to completely nonwhite.

Conversely, any deviation of the white share above the equilibrium will lead to a fraction of whites willing to live in the neighborhood that is greater than the actual share. This will cause the white share to increase. A new equilibrium is not reached until the cumulative density function intersects the 45 degree line from above. In the diagram, this happens at a white share of about .992. Hence, the remarkable outcome of Schelling’s

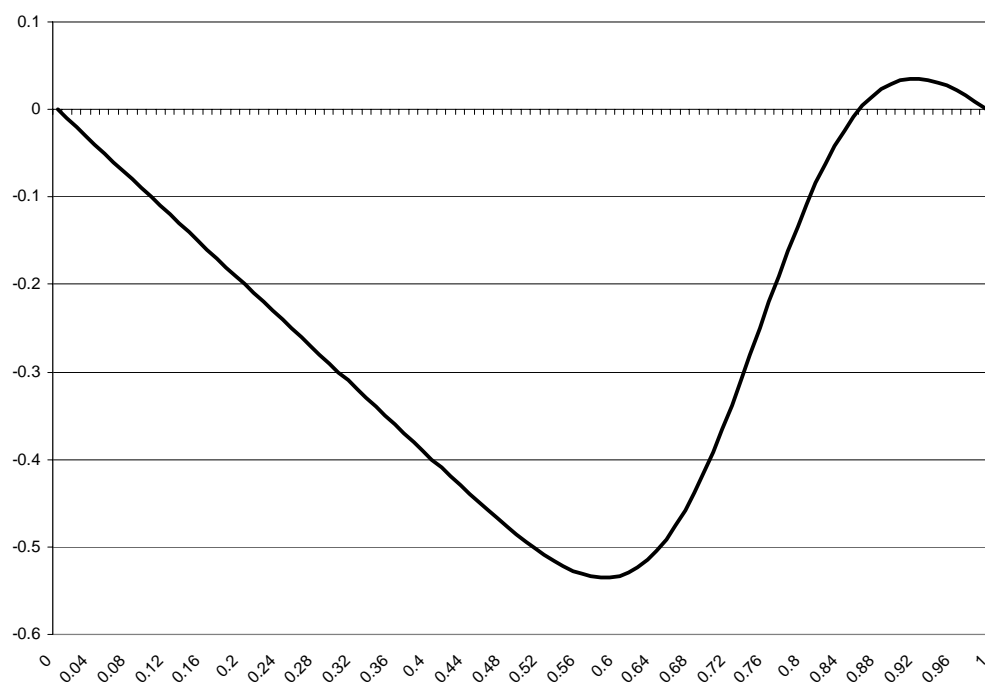
model is that the long run equilibrium is for neighborhoods to be either entirely nonwhite or 99.2 percent white, despite the preferences of the median white for a mixed neighborhood that is 75 percent white and 25 percent nonwhite.

The crossing point of the CDF and the 45 degree line is the tipping point. Any neighborhood that falls below a white share of .86 will tip over to being completely nonwhite. The dynamics of the white share can be specified by giving the change in white share as the distance between the CDF and the 45 degree line.

$$(2) \Delta w = F(w; \mu, \sigma^2) - w$$

Figure 2 shows the predicted change in white share as a function of the initial white share. The relationship is highly nonlinear. Note also that the changes in white share as the neighborhood falls below the “tipping point” white share become very large – there is massive “white flight” even when whites are still in the majority. Note that this exodus does not reflect any expectations about the future composition of the neighborhood; it is simply the myopic individual behavior of whites who find the current composition of the neighborhood to be inconsistent with their preferences.

Figure 2: predicted change in white share with normal distribution with mean .75 and standard error = .1



It is interesting to relate this to some of the rhetoric about segregation. The folklore of the tipping point has historically been linked to racist justifications for segregation. If even a comparatively small number of nonwhites move into a neighborhood, with whom the majority of whites are perfectly content to coexist, there is a risk from the point of view of whites that the neighborhood will tip over to a nonwhite majority neighborhood that whites find unacceptable. Hence, whites acting collectively have historically resisted even modest integration of residential neighborhoods.

Although the tipping point idea is linked historically to racial scare-mongering, Schelling's contribution actually gives quite a different perspective on racial segregation. The point of Schelling's model was that only the strategic interdependence of weak preferences for living next to people of the same race could lead to an outcome of almost total segregation. This contrasts with the view that segregation reflects whites having a very strong preference for having white neighbors. Hence a test of Schelling's model is a test of whether residential segregation simply reflects the instability of strategic interaction.

In the context of scare-mongering, again note that Schelling's model did not have any role for expectations about future neighborhood composition. This may make sense if the individual does not have enough information to see the whole dynamic system. Otherwise, we could get even more extreme tipping from white to black as individuals react to the expected future composition of the neighborhood – there could be “racial panics” as whites suddenly fear being in the minority in their neighborhood at some future date.

The data

The database used in this analysis was originally called the Underclass Database (UDB). It was put together for 1970, 1980, and 1990 by the Urban Institute, a nonpartisan think tank in Washington DC. Given the interests of the Institute, the data covered metropolitan neighborhoods (where “metropolitan” is defined as in the census to include central city, inner suburbs, and outer suburbs). The database has been updated to include the 2000 census by a commercial firm called Geolytics Inc.¹⁰ The unit of analysis in the database is the census tract, a division meant to approximate a “neighborhood”, usually containing between 2500 and 8000 people. The tract boundaries are chosen to capture neighbors with similar social characteristics (which means that measures of segregation based on tract data will tend to exaggerate segregation). Tract boundaries do not cross county, metropolitan area, or state boundaries.¹¹

There are several difficult issues surrounding the data construction. Of those tracts that have data for both 1970 and 2000, two-thirds changed boundaries. Some tracts were merged into a single tract, and some single tracts were divided into multiple tracts. Unfortunately, in the majority of tract changes, there are boundary changes that are not simple mergers or divisions of existing tracts. The constructors of the database addressed this problem in several different ways, depending on what data was available for different census years. They used geographic information software (GIS) to overlay 2000 tract boundaries on earlier tract boundaries. They then used 1990 block data to estimate the proportion of the old tracts in various racial categories that went into the new tract, and then recalculated the 1990 tract data using the 2000 tract boundaries.

¹⁰ The new database is available on CD-ROM from geolytics.com. The description of the data contained here is based on the NCDB Data User’s Guide, including Appendix J on tract matching.

¹¹ Except in New England, some tracts cross metropolitan area boundaries.

Block data located spatially were not available for 1970 and 1980. The 1980 tracts were matched to the 1990 tracts and 1970 tracts matched to 1980 tracts using Census Bureau information on tract correspondence based only on spatial changes in tract boundaries. Hence, the 1970 and 1980 tract matching to 1990 and 2000 is less accurate than the tract matching between 1990 and 2000.

The database includes an indicator of which tracts changed boundaries. The use of the full sample could be justified if we think any errors introduced by boundary changes are random, i.e. uncorrelated with the right hand side variables in my regressions below. However, I will run a robustness check of my results by running them on the sub-sample which did not change boundaries between 1970 and 2000.

Some 2000 tract boundaries include areas that were not covered at all by 1970 data. As long as the covered area is a random sample of the whole tract, with the error term uncorrelated with the 1970 white share, the use of the full sample could still be justified. Nevertheless, I will run another robustness check by omitting these observations from the sample.

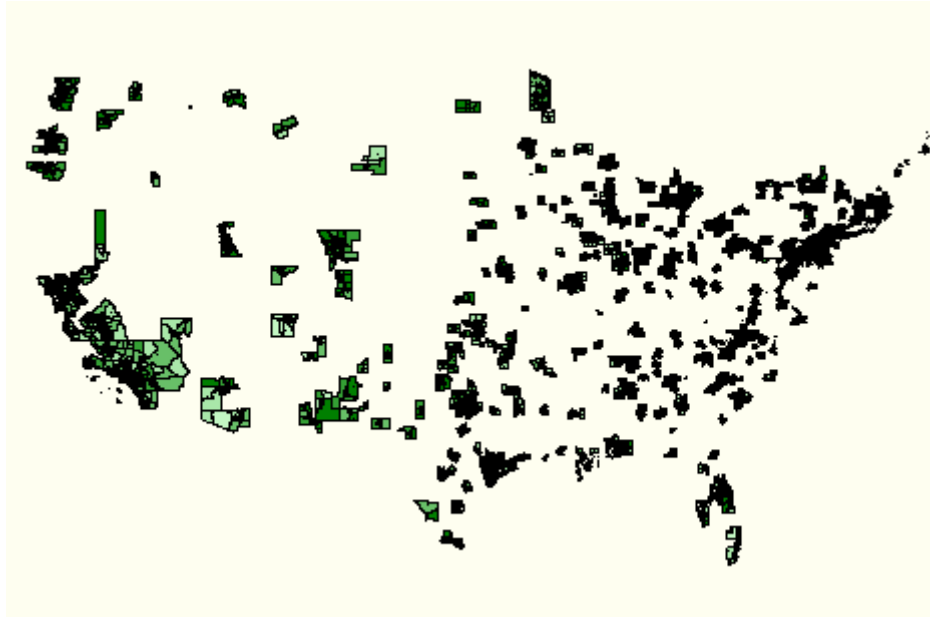
Census data has the commonly known problem that it undercounts the population because some people are harder to reach for enumeration. Of concern for our exercise, the undercount is thought to be proportionally greater for nonwhite populations. The undercount percentage has been falling over time. I do not have any solution to this problem, but hope that it is of small enough magnitude not to distort the results. In 1990, the Census estimated the overall undercount as 2 percent, down from 5 percent in 1950.

The undercount for blacks was estimated at 5.7 percent in 1990, an increase from 4.5 percent in 1980.¹²

Table 1 shows the variable definitions and summary statistics. The sample is all available data in the NCDB, which as I noted is mainly for metropolitan census tracts (Map 1 shows the coverage of NCDB for 1970). Census tracts have a mean population in 1970 of 3,208 people. I eliminated any census tracts with a population of less than 100 in either 1970 or 2000 from the sample so as to avoid extreme outcomes in very small census tracts. The maximum population of census tracts in the sample is 31, 903 in 1970 and 36,146 in 2000.

Map 1: coverage of NCDB in 1970

¹² Another problem was that the 2000 census introduced a change in its racial classification methodology. Racial classification is done by self-identification. In 2000, individuals were allowed to select more than one race to describe themselves, in contrast to earlier years when they could only pick one. 2.4 percent of respondents chose multiple races in 2000. To match 2000 data to earlier years, the NCDB creators used the principle that anyone who selected a nonwhite category, even if it was in addition to white, would be classified as nonwhite. Since this conforms to the social convention for defining nonwhites, which probably influenced individuals' self-classification in prior years, and since the number choosing multiple races is small, I do not think this will overly distort the results. For some reason, the database authors violated this rule only with Native Americans, who were counted as Native Americans only if they did not also choose "white." However, the proportion of Native Americans in the sample is small in any case. Other racial issues arise with classifying Hispanics. "Hispanic" is a national origin classification, which is different than racial classification. There is a category "other" in the racial classification, which in earlier work co-authors and I have found to be strongly correlated with "Hispanic" (Alesina, Baqir, and Easterly 1999).



The restriction of the NCDB to metropolitan census tracts is fine for my purposes, since the tipping model is mainly about urban neighborhoods.

Table 1: Variable Definitions and Summary Statistics

Variable	DSHRWHT70	SHRWHT7	LPOPDENS7	LFAVINC7
Definition	Change in white share from 1970 to 2000	White share of population in 1970	Log of population density in 1970	Log of median family income in 1970
Mean	-0.185	0.894	7.451	9.323
Median	-0.117	0.983	7.851	9.320
Maximum	0.813	1.000	12.394	12.178
Minimum	-1.000	0.001	-2.197	6.957
Std. Dev.	0.207	0.217	1.987	0.318
Skewness	-1.119	-2.739	-0.633	0.340
Kurtosis	4.435	9.740	3.250	4.882
Observations	41321	41321	41321	41284

Empirical testing 1970 to 2000

Note from Table 1 that the mean white share declined considerably from 1970 to 2000, reflecting the faster growth of nonwhite population than white population in metropolitan areas. While the white population only increased by 15% from 1970 to 2000, the nonwhite population nearly tripled over the same period. Both blacks and other nonwhites shared in this rapid population increase. We could think of this influx of nonwhite population as a natural experiment of the Schelling model – predicting that neighborhoods in the vicinity of the tipping point would flip over to nonwhite majorities, while neighborhoods well above the tipping point would have retained stable white majorities.

Using the NCDB, I estimate dynamic equations for the change in white share as a function of initial white share. To accommodate the highly non-linear prediction of the Schelling model, I estimate the change in white share as a function of a fourth-order polynomial of initial white share.¹³ I test first the change in white share from 1970 to 2000, and then I will test the change over each decade. Table 2 shows the basic regression for this fourth-order polynomial. All of the polynomial terms are significant, which does confirm the highly nonlinear dynamics of the white share.¹⁴

¹³ I experimented with a fifth-order polynomial also, but it did not make a difference to the shape of the curve described below.

¹⁴ This is somewhat different from the results of Ellen (2000) for change from 1980 to 1990, who did not find the linear term for black share in 1980 to be significant in a regression for percent change in whites. She specifies the relationship as quadratic, but did not find different results in a spline regression for black share.

Table 2: Regressions of change in white share on nonlinear function of initial white share

	[1]	[2]
Dependent variables: change in white share from 1970 to 2000		
_cons	0.10	-0.11
	<i>10.75</i>	<i>-4.34</i>
White share, 1970	-2.02	-2.09
	<i>-14.86</i>	<i>-20.87</i>
White share ² , 1970,	7.58	7.16
	<i>14.92</i>	<i>17.30</i>
White share ³ , 1970	-12.00	-11.26
	<i>-17.44</i>	<i>-19.10</i>
White share ⁴ , 1970	6.18	5.80
	<i>20.06</i>	<i>21.37</i>
Log (Population/Land Area), 1970		-0.04
		<i>-86.41</i>
Log Family Income, 1970		0.07
		<i>23.29</i>
R squared	0.071	0.226
Number of observations	41912	41284

Figure 3 shows the fitted curve as a function of initial white share. Comparing Figure 2 and Figure 3, the shape of the curve is not very supportive of the tipping point hypothesis. The predicted change in white share at very high levels of initial white share is above the predicted drop in white at intermediate levels of a white share of .6 or below. There is more “white flight” from neighborhoods with large white majorities than there is from mixed neighborhoods! Although the dip in the curve between .6 and 1.0 is consistent with the prediction of the tipping model, the turn up in the curve as the white share falls below .6 is at variance with the tipping model. In the tipping model, the predicted change in white share fell as white share decreased because all whites were

leaving the neighborhood and the fall in white share could not be more than the existing white share. In the estimated curve, the fall in white share at values below .6 is modest and falls well short of all whites leaving the neighborhood. In fact, the only range of the data with a predicted increase in white share is at very low values of initial white share!

Thus, the initial results do not support the “tipping point” story that highly segregated neighborhoods are stable, while mixed neighborhoods are unstable. This does not refute the general notion of an ongoing high degree of segregation – as pointed out in the introduction, the data conclusively refute a random distribution of whites and nonwhites. However, the pattern does suggest that segregation was diminishing from 1970 to 2000, as neighborhoods with high white shares had the biggest drop in those shares. This is confirmed by the aggregate statistics: while the Tauber dissimilarity index for nonwhites was 0.53 in 2000, it had been 0.75 in 1970.¹⁵

We must also distinguish the issue of stability of integrated neighborhoods from that of frequency of integrated neighborhoods. Integrated neighborhoods could be uncommon yet stable.¹⁶ Segregation could reflect a stable process rather than the instability of herd behavior.

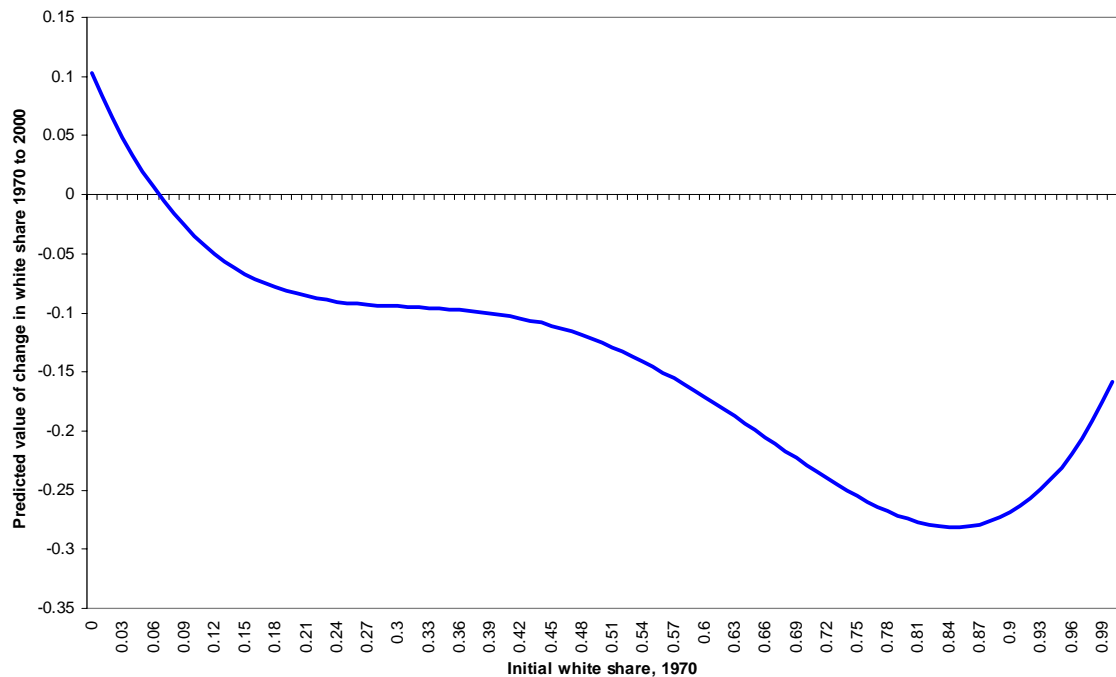
Figure 2 predicted a positive relationship between initial white share and the change in white share over a significant intermediate range of initial white share (this is necessary to get the “tipping point”). In contrast, Figure 3 shows the actual estimated curve has only a small positively sloped segment at very high values of initial white share.

¹⁵ Cutler, Glaeser, and Vigdor 1999 also present evidence that segregation declined from 1970 to 1990, as does Ellen (2000)

¹⁶ Ellen (2000) also finds evidence for stability of many racially mixed neighborhoods.

. What is important for the test of the tipping hypothesis over this period is that the most “white flight” happened in neighborhoods with high initial white shares, contrary to the tipping prediction of accelerating white flight out of mixed neighborhoods.

Figure 3: Change in white share, 1970 to 2000 as function of initial white share



Tipping is not the only factor that could lead to changes in white share during this period, so to test robustness I consider two other controls besides initial white share. One of the most commonly stressed phenomena about neighborhood change is white suburbanization, where the white population is migrating from the central city to the suburbs, and from the inner ring of suburbs to an outer ring of suburbs (one common phrase in the literature is “chocolate city, vanilla suburbs”). Hence, I also introduce the log of initial population density as a control for change in white share, to test the alternative hypothesis that the change in white share reflects a shift in preference among

whites from high density central city or inner suburban neighborhoods to low density outer suburban neighborhoods. This may also have had racial motivations – perhaps segregationist whites perceived that blacks were less likely to live in the outer suburbs and so chose to move there. But this would be a different model than the tipping point hypothesis.

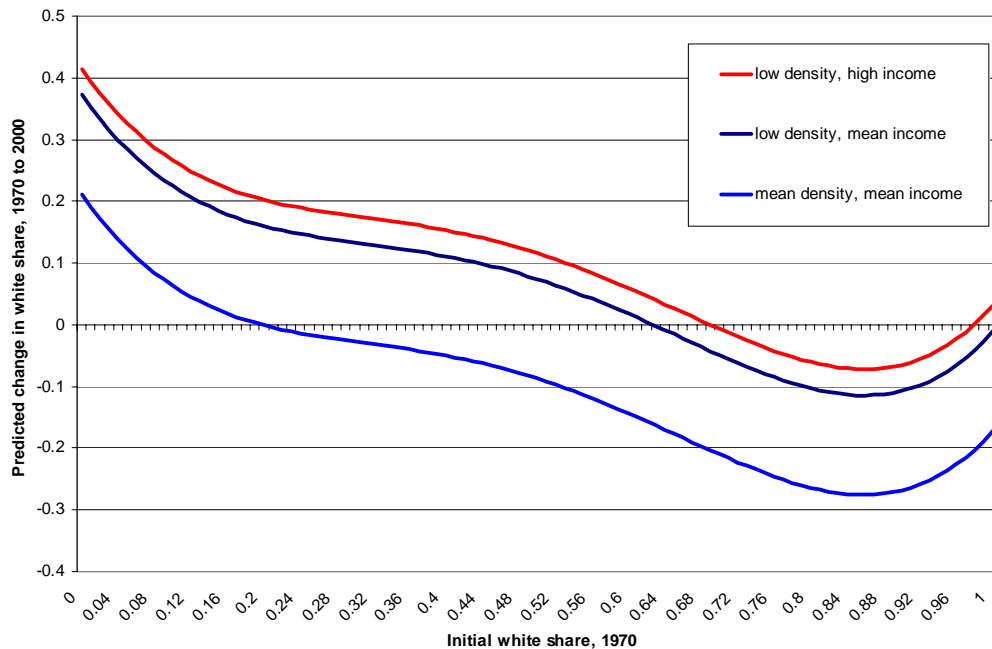
Another obvious control is income. Whites might also have a preference to reside in high income neighborhoods, and might be willing to live in a neighborhood with a lower white share if it has a higher income level. Whites also may be more reluctant to live next to low-income nonwhites than to high-income nonwhites. Hence, I control for the log of initial median family income.

Table 2 also shows the regression of change in white share on these right hand side variables. All of the polynomial terms for initial white share are still highly significant. The population density variable is significant with an extremely high t-statistic, reflecting the large explanatory power of the “white suburbanization” hypothesis for changing white share. Family income is also very significant, reflecting the tradeoff between initial white share and family income in stability of white neighborhoods. All variables together have decent explanatory power for such a noisy variable in a large sample, with an R-squared of .226.

Figure 4 shows the shape of the relationship between initial white share and change in white share at mean values of population density and family income, and then considers shifts in income and

density.

Figure 3: Estimated relationship between change in white share 1970 to 2000 and initial white share 1970



The drop in white share at high levels of initial white share could be reflecting the alternative suburbanization hypothesis mentioned earlier. Figure 4 shows how the curve would look if the initial log population density were two standard deviations below its mean. The predicted drop in white share is much less, and close to zero for white share close to one. If in addition, the log family income were two standard deviations above its mean, then at last we get a predicted increase in white share at high initial values of white share (moving both variables two standard deviations means that this applies to only a small part of the sample). We get an unstable “tipping point” type equilibrium at a white share of around .97. However, this is far from the large tipping over to majority nonwhite envisaged by the tipping point hypothesis. The drop in white share is fairly modest below

.97 and there is a stable equilibrium at a white share of around .7. Below .7, there is a predicted increase of white share which becomes quite large at low initial white share. That is to say, at low density and high income, any neighborhood with low initial white share will rapidly revert to a much higher white share.

To sum up, even controlling for density and income, we don't see anything like the kind of dynamic behavior of neighborhoods predicted by the tipping point model. The change in neighborhood composition does not fit the predictions of a normal CDF for individual preferences for white share.

Further robustness checks

One issue that obviously follows from the white suburbanization hypothesis is that there is a high degree of spatial correlation in the data. A central city neighborhood with a declining white share is not independent of its neighbors, who also often turn out to be neighborhoods with declining white share. If the assumption of independence was violated, as seems certain, that would imply that the standard errors and hence t-statistics were incorrectly estimated in the regressions above.

Hence, I run another set of regressions with clustered standard errors. I use three different definitions of clustering. First, each zip code typically contains a handful of census tracts, and so correcting for clustering by zip code will take into account very local spatial dependence.¹⁷ This yields 8227 clusters. Second, it may be as suggested by the suburbanization hypothesis that tracts in high density and low density areas of each metropolitan area behaved similarly to other tracts in those same areas. Hence, I define a new set of groups that are first broken down by metropolitan area, and then broken down

¹⁷ Zip code boundaries are independent of census tract boundaries, so they will split some tracts into 2 different zip codes. The tract is assigned to the zipcode that accounts for the majority of the tract.

into tracts above median density and those below median population density for the whole sample. This second method yields 404 clusters (i.e. 202 metropolitan areas, with low and high density areas in each one). A third method aims at capturing the same idea with jurisdictional boundaries – whether the tract lies in the central city or the suburbs for each metropolitan area.

Another robustness check I perform is to enter dummies for metropolitan areas, to check that the results are not driven by simple cross-section differences between cities.

Finally, I omit observations that may be questionable for reasons described in the data section. There are two types of problematic observations: 1) those in which the 1970 data apply to only part of the area contained in the 2000 tract boundaries, and 2) those in which the tract definition changed from 1970 to 2000. Note that 1) is a subset of 2). 1) is the most problematic kind of tract change, because there is simply missing information on a part of the tract for the year 1970. For other tract changes, there was an attempt by the database builders to map from the old tract data to the new tract boundaries, as described in the data section above.

Table 3: Robustness checks for metropolitan dummies, clustered standard errors, and restricted sample

	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Constant	-0.113	-0.432	-0.106	-0.112	-0.141	-0.177	-0.303
	-4.34	-10.42	-2.12	-1.11	-1.36	-1.58	-3.63
White share, 1970	-2.089	-1.546	-2.114	-2.082	-2.132	-1.923	-1.426
	-20.87	-12.95	-15.08	-8.96	-8.02	-8.54	-7.77
White share^2	7.163	4.395	7.270	7.154	7.395	6.569	4.344
	17.30	9.82	12.41	6.76	6.29	6.08	5.97
White share^3	-11.260	-6.846	-11.370	-11.252	-11.677	-10.542	-7.747
	-19.10	-11.26	-13.34	-6.87	-6.5	-6.17	-6.86
White share^4	5.802	3.57	5.830	5.795	6.012	5.505	4.458
	21.37	13.09	14.58	7.3	6.97	6.53	7.92
Log (Population/ Land Area), 1970	-0.041	-0.04	-0.040	-0.040	-0.041	-0.047	-0.046
	-86.41	-82.83	-35.95	-10.31	-11.11	-20.12	-13.51
Log Family Income, 1970	0.068	0.11	0.066	0.066	0.072	0.079	0.093
	23.29	33.64	11.94	4.72	4.94	6.12	9.72
Number of observations	41284	41351	41862	41304	31985	32407	11773
R squared	0.226	0.1924	0.2169	0.2155	0.2246	0.2431	0.278
# Clusters	none	none	9099	404	403	431	368
# metropolitan dummies	none	198	none	none	none	none	none
Cluster definition	none	none	zipcodes	metro areas (Low and High Density)	metro areas (Low and High Density)	metro areas (central city and suburbs)	metro areas (Low and High Density)
Excluded observations	none	none	none	none	1970 coverage of 2000 tract<98 percent	1970 coverage of 2000 tract<98 percent	Any changes in tract definitions

The results of clustered standard errors are shown in Table 3. The t-statistics do fall drastically, especially on the population density variable, but also on the initial white

share. All variables remain significant at the 1% level, however. The results (Table 3) are also qualitatively similar with metropolitan dummies, with the plot for predicted change in white share much the same as in figure 3.

Table 3 also shows what happens when observations falling under either 1) or 2) are eliminated. All of the variables are still statistically significant in the smaller, more reliable samples. The coefficients are relatively unchanged for the sample that omits observations in which 1970 data did not cover the whole 2000 tract. The coefficients do change quite a bit in the restricted sample with no tract redefinitions at all. However, the picture of the predicted changes in white share looks qualitatively similar with these coefficients to that shown in figure 3.

I next consider a more extensive set of ancillary variables: percent of population under 18, percent over 65, percent of population who are homeowners, and percent of tract located in the central city. These additional variables are chosen based on what the previous literature considered; I did not do any searching among alternative sets of variables). All of the additional variables are significant, except for percent of population under 18, with intuitive signs. However, they do not alter the coefficients on white share very much and the shape of the curve with these variables is similar to that shown in figure 3.

Table 4: Robustness checks for additional variables with clustered standard errors

	[1]	[2]	[3]
Constant	-0.104	-0.104	-0.104
	-3.09	-0.94	-1.78
White share, 1970	-1.868	-1.809	-1.868
	-19.86	-8.33	-14.8
White share^2, 1970,	5.976	5.765	5.976
	14.72	5.5	10.74
White share^3, 1970	-9.368	-9.141	-9.368
	-15.88	-5.48	-11.31
White share^4, 1970	4.842	4.766	4.842
	17.62	5.76	12.3
Log Family Income, 1970	0.057	0.058	0.057
	16.72	4.56	9.35
Log (Population/Land Area), 1970	-0.036	-0.036	-0.036
	-62.80	-10.89	-32.22
Percent under age 18, 1970	-0.005	-0.006	-0.005
	-0.24	-0.08	-0.14
Percent over age 65, 1970	0.413	0.411	0.413
	15.67	4.52	9.27
Percent of homeowners, 1970	0.102	0.100	0.102
	15.81	2.75	8.35
Percent of tract in central city, 1999	-0.001	-0.001	-0.001
	-27.43	-2.8	-11.91
Number of observations	41139	40533	41139
R squared	0.270	0.2679	0.2696
# Clusters	None	434	9480
Cluster definition	None	metro areas (central city and suburbs)	zip codes

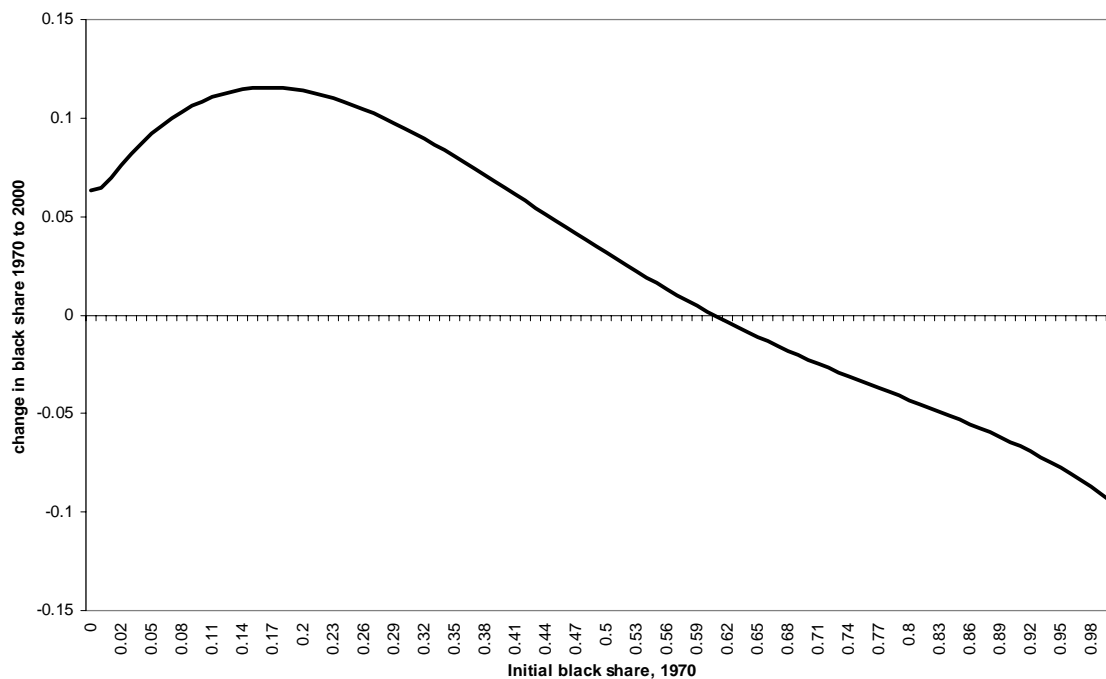
A final robustness check is to regress the change in *black* share from 1970 to 2000 on a polynomial for initial *black* share in 1970. This tests whether the dynamics of tipping are any different when we focus on blacks rather than all non-whites. The tipping point hypothesis would imply a positive relationship between initial black share and

change in black share, peaking at an intermediate level of black share, before declining mechanically because the maximum increase in black share possible is $1 - \text{initial black share}$. The story would predict that neighborhoods with a black share below the tipping point would have a fall in black share, with the tipping point where the curve crosses the x-axis from below.

The polynomial terms for initial black share are all significant (not shown). The implied curve is shown in figure 5. The curve is the mirror image of the white share dynamics in figure 3 above. The relationship between change in black share and initial black share has only a small upward sloping portion. Over most of the range of black share, the line is downward sloping – suggesting that neighborhoods are moving away from the extremes of all black or all non-black, which is just the opposite of the tipping prediction. The change in black share is much larger at low initial levels of black share

rather than at intermediate levels, contradicting the tipping point hypothesis.

Figure 5: Change in black share as function of initial black share 1970 to 2000



Decade to decade changes in white share

The results are similar when I look at the individual decade changes from 1970 to 1980, 1980 to 1990, and 1990 to 2000. Table 5 shows these three regressions.

Table 5: Estimates of dynamic equations for white share 1970-1980,1980-1990, and 1990-2000

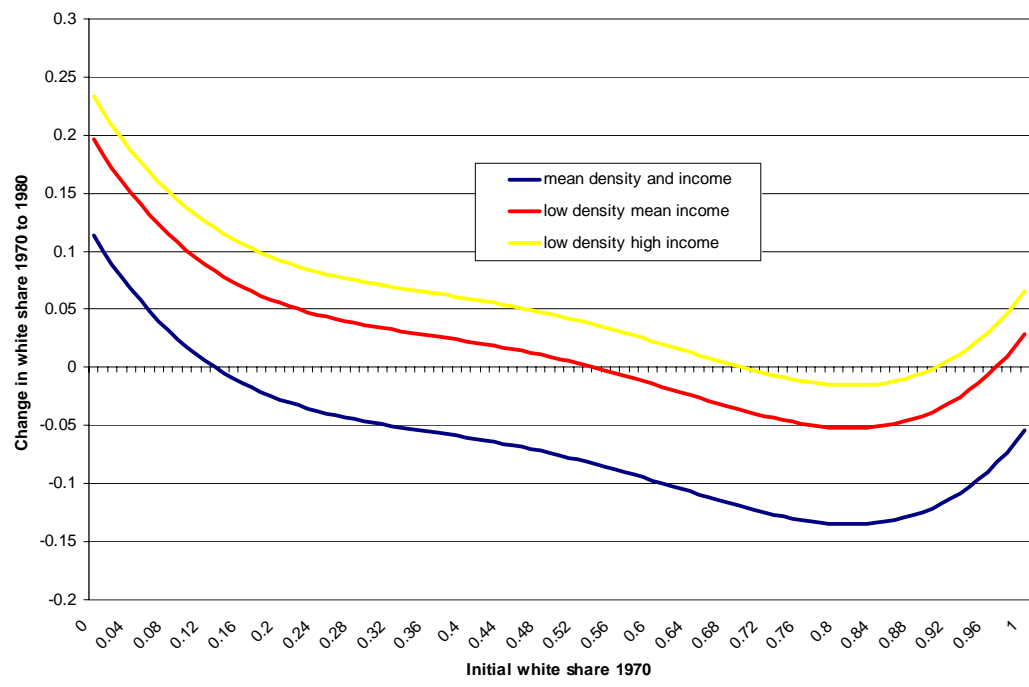
Method: Least Squares

White Heteroskedasticity-Consistent Standard Errors & Covariance

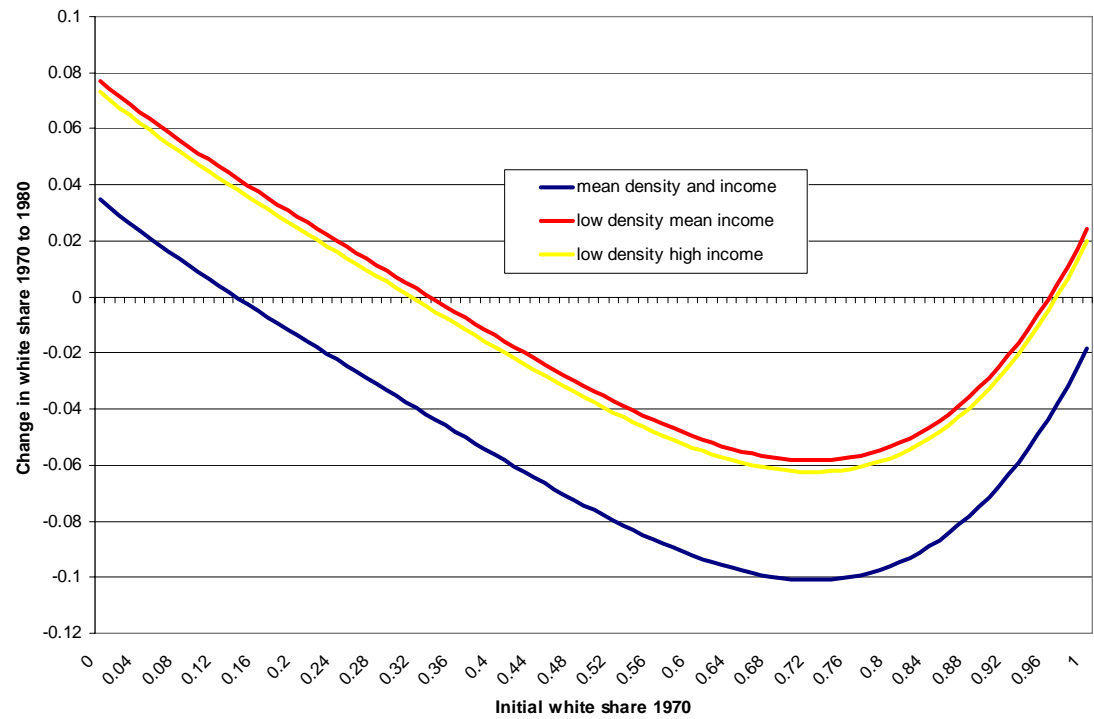
Dependent Variable:	DSHRWHT8		DSHRWHT9		DSHRWHT0	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.280	-15.802	0.069	4.844	0.082	7.711
SHRWHT	-1.307	-17.041	-0.285	-6.513	0.252	6.987
SHRWHT^2	4.083	12.534	0.340	1.864	-1.633	-10.770
SHRWHT^3	-5.957	-12.753	-0.740	-2.845	1.695	7.793
SHRWHT^4	3.014	14.035	0.633	5.287	-0.356	-3.529
LPOPDENS	-0.021	-63.531	-0.012	-43.747	-0.009	-31.776
LFAVINC	0.059	29.660	0.006	3.990	0.000	0.342
R-squared	0.175		0.183		0.193	
Adjusted R-squared	0.175		0.183		0.192	
S.E. of regression	0.118		0.081		0.082	
Mean dependent var	-0.073		-0.050		-0.063	
S.D. dependent var	0.130		0.089		0.091	
Observations	41284		41218		41205	

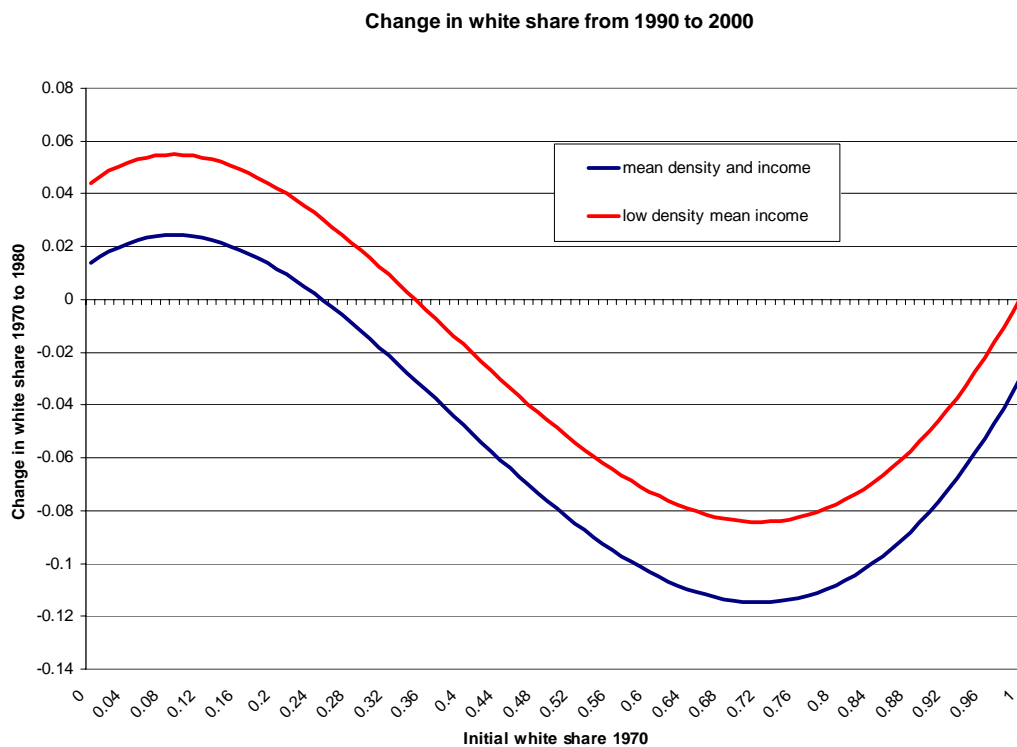
Again, population density is by far the strongest predictor of change in white share. The effect of initial family income is weak in the 1980 to 1990 regression and insignificant in the 1990 to 2000 regression. The nonlinear terms for initial white share are significant, but much less so than density. The following figures show the dynamic curves for each regression, comparing the curve at mean log population density with that with density 1.96 standard deviations below the mean, and then both density and income 1.96 standard deviations away from the mean. The curves are quite different from one decade to the next, but none of them fit comfortably with the picture predicted by the tipping point model. At mean density and income, all of them show the highest predicted drop in white share to be at high initial levels of white share rather than the intermediate levels.

Change in white share from 1970 to 1980



Change in white share from 1980 to 1990





There are multiple equilibria for some low values of density in these graphs, but the lower stable equilibrium is one with a mixed neighborhood. At mean density, all of the neighborhoods with high white share show a decline in white share, with only a modest trough at intermediate values of the white share. (The curvature in this zone is consistent with the predictions of the normal CDF for preferences, but we do not find a tipping point except at low density.)

The curve for changes from 1990 to 2000 comes the closest to fitting the tipping model. At low density, the stable equilibria are a white share equal to one, and a white share equal to about .4. This captures the idea that neighborhoods could tip from homogeneous white neighborhoods to minority white neighborhoods. However, the lower equilibrium of .4 is much higher than in the typical view of the tipping point. And the tipping point itself is implausibly high – any white share less than .99 will tip over to

the minority white neighborhood. While providing some support for the tipping point view, these parameters do not portray a very plausible tipping story.

It would be nice to have data from earlier decades to assess tipping. It may be, as the survey evidence suggests, that whites' behavior and attitudes have changed in the course of the 20th century. It is possible that "tipping" is a good description of neighborhood change before 1970. Unfortunately, we do not have the data to assess this conjecture.

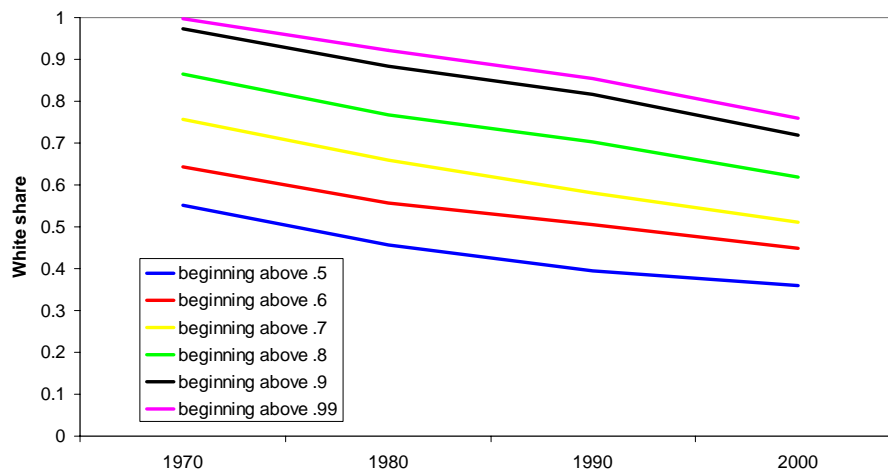
Episode analysis of the tipping point hypothesis

Another way of testing the tipping point hypothesis is to look at those neighborhoods that actually started to "tip." The tipping point hypothesis suggests a particular profile of such a neighborhood: it will start in an intermediate range of white share, and it will experience an accelerating decline in white share as it moves from majority white to majority nonwhite, winding up almost totally nonwhite.

This prediction is tested by considering what subsequently happens to neighborhoods that have a decrease in white share in the first decade, from 1970 to 1980. The tipping point hypothesis would suggest that those above the tipping point would remain stable, while those around or below it would tip over to a nonwhite majority. The latter would show the accelerated decline in white share characteristic of the tipping model. Figure 7 shows the pattern of evolution for neighborhoods beginning at different white shares in 1970, all of which experience a drop in white share between -.05 and -.15 from 1970 to 1980. The different subgroups are defined as those above the white share indicated in the legend and below the white share in the next category up. The lines in Figure 7 are almost parallel and linear – we see a steady decline in white share in all

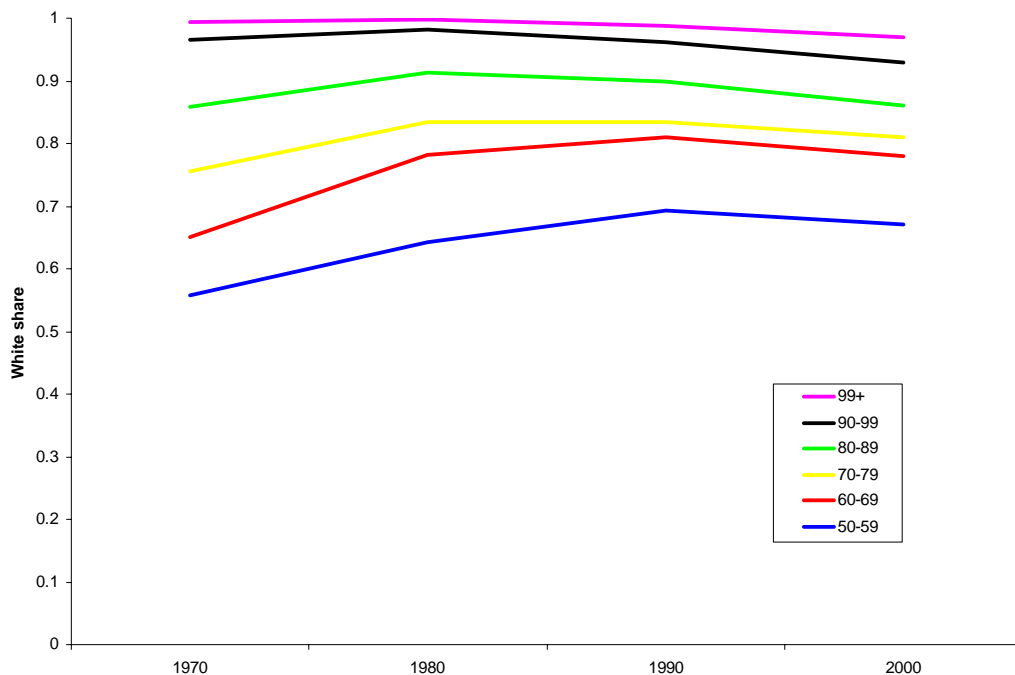
neighborhoods. Those that began with higher white share end up with higher white share, but all neighborhoods have white share decline by about the same amount. There is no discernible breakpoint at which neighborhoods tip or do not tip. There is no accelerated decline for any of the subgroups, regardless of the starting point.

Figure 7: Trajectory of white share with initial fall between -.15 and -.05 from 1970 to 1980 for different starting points in 1970



A complementary exercise is to examine the dynamics of neighborhoods that had an initial increase in white share from 1970 to 1980. The tipping point hypothesis would now predict that neighborhoods around the tipping point would tip over towards being all-white. In contrast, the prediction for neighborhoods well below the tipping point is that they would resume their movement towards being predominantly nonwhite after the initial increase in white share. Figure 8 shows the actual outcomes for neighborhoods with an initial increase white share. No bifurcation is noticeable around any hypothetical tipping point. The neighborhoods that began with a white share between 50 and 59 percent or between 60 and 69 percent actually maintained a larger increase in white share through the year 2000 than those with higher initial white share.

Figure 8: Evolution of white share after increase 70 to 80 at different initial white shares



Conclusions

Although a significant fraction (about 10 percent) of the sample of urban American neighborhoods did change from majority white to majority nonwhite over 1970 to 2000, they did not do so as the “tipping point” hypothesis suggests. The main factor in neighborhood change was a movement of whites from central cities and inner suburbs to outer suburbs in metropolitan areas. The relationship between change in white share and the initial white share does not fit the “tipping point” model. Episodic analysis does not show evidence of “tipping” at intermediate levels of white share. In this dataset, the dynamics of neighborhood composition do not suggest the instability of strategic interdependence as modeled by Schelling.

Models of strategic interdependence are very slippery creatures to test. It could be that there were other long-run factors not captured by the empirical analysis that determined changes in white share, and that conditional on these other factors there was still strategic interdependence that would lead to tipping. I have sought in the robustness checks to explore some of the obvious candidates, but the list of possible third factors is endless. I can only say that the simplest tests of the tipping model, conditional on the seemingly most obvious third factors, fail to confirm the model.

This is not to say that strategic interdependence and multiple equilibria are not important phenomena in other contexts. Schelling's model remains a classic theoretical milestone for understanding instability of interdependent behavior. As far as racial segregation goes, however, research should seek to understand more the stable fundamentals that determine the high degree of racial segregation.

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