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Can the Rise of Dual-Earning Households Explain Gentrification of US Central Cities?

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Abstract

The last four decades have seen a return of high-earning households to central cities. The consequences are urban renewal on the one hand and soaring inner-city rents on the other. In this paper I extend a monocentric city model of income sorting and urban rents to examine whether increases in the number of two-earner households can explain recent patterns of gentrification. I then present evidence from Washington DC that, among the young and married, the rich are shortening their commutes while the poor are lengthening theirs. However, among the unmarried, no such trend is discernible. These facts support the model's prediction that two-earner households have reshaped the landscape of urban income group sorting.

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1 Introduction

The spatial structure of urban housing prices in the United States has undergone substantial change in recent decades. In 1980, homes within 2 miles of the city center carried lower prices on average than homes 10 miles distant. By 2010, housing prices were decreasing nearly monotonically with distance from downtown (Edlund et al. 2015). The change in central city prices was accompanied by a demographic shift. While low-income residents had been leaving the inner city for almost three decades, by the turn of the millennium the college-educated were flowing back into the city center (Baum-Snow et al. 2016).

These phenomena—which are referred to collectively as "urban renewal" or "gentrification" depending on normative intent—demand a positive explanation. During this period, female labor force participation has risen steadily (McGrattan 2008). A household with two earners will have more cash on hand, but fewer hours of non-work time compared to a single-earner household. This will induce dual-earners to pay higher rents in order to avoid long commutes by locating more centrally. But, if low-skill workers occupy the city center already, will it be the poor dual-earners or the rich dual-earners who end up renting the inner-city apartments? To think about this question rigorously, we need an economic model. In this paper, I use a model of urban housing prices to explain how a transition from single-earning to dual-earning households explains why skilled workers are shortening their commutes.

The standard neoclassical approach to studying housing prices across space is the theory of spatial equilibrium (Glaeser 2010). This theory suggests that if individuals are free to move to whichever location they wish, then prices will adjust so that utility for each group is equal across all locations. More productive cities might offer higher wages, but they will also carry higher housing rents or more severe traffic congestion.

Spatial equilibrium theory can also explain price variation among districts within a single metro. The Alonso-Muth-Mills "Monocentric City" model (Duranton et al. 2015) uses the assumption that all workers commute to the city center to predict two outcomes. First, because transportation costs are lowest near the city center, inner zones will experience higher land prices than outer zones. Second, whether high-income residents occupy the inner city or the suburbs depends upon whether the principal cost of transportation is time or money.

Applications of spatial equilibrium theory to gentrification are still emerging. Edlund et al. (2015) tell a human capital story. As returns to skill rose in the 1980s and 90s, educated workers supplied more labor. Thus, leisure time decreased and the marginal value of leisure rose. In this way, high-income households bid up the prices of homes close to the city center in order to cut down on increasingly costly commute time. Their analysis of tract-level Census data finds evidence that increases in city-wide skilled labor demand were associated with greater home price increases close to the city center. Furthermore, the increases in college-educated population that accompanied labor demand rises were largest in the inner city.

However, Gyourko et al. (2013) propose that national shocks also drive gentrification of entire metros. In their framework, some cities have relatively elastic housing supplies and some have inelastic housing supplies. Furthermore, some cities are more "desirable" to live in than others. When aggregate demand for housing rises nationally, the desirable cities with the least elastic housing supplies should experience the greatest rent growth, which will price out the poor. Thus, gentrification also involves the flight of low-income residents from housing-inelastic cities to housing-elastic cities in response to rising numbers of high-income households. The authors express these ideas in a two-location spatial equilibrium model. They test the model's implications with a panel of city-level Census data. Their evidence suggests that even heterogeneous price growth across different cities can be explained by increases in national housing demand. From this perspective, gentrification is driven by rises in national demand, whose local effects depend upon the elasticity of the local housing supply.

Other cross-city work is gaining momentum (Diamond 2016, Chetty 2014). Diamond (2016) in particular derives a several-city structural model which explains how metro-wide changes in amenities and labor demand lead to changes in the distribution of college-educated workers across different cities. However, Diamond's theory does not model this distribution across space within a metro. Indeed, Section 2 will show that changes in the spatial sorting of income groups within Washington DC have been substantial.

Rappaport (2014) uses a fully structural spatial equilibrium model that considers both inter-city and intra-city decision-making. This model numerically simulates realistic population and rent gradients in a general equilibrium setting. Even traffic congestion and highway construction are explicitly modeled. Rappaport's model has a very broad scope, but is not built for answering questions of gentrification because workers all share one skill level.

Any study of gentrification must inevitably confront the puzzle of consumption amenities. All of the above-mentioned studies acknowledge the importance of local differences in quality of life. Amenities matter a great deal (Hwang et al. 2016, Gyourko 2013). But, how exactly they matter is not known because the very term "amenities" is an ad hoc concept meant to capture whatever local idiosyncrasies a model does not explicitly consider. To complicate the problem further, amenities probably both attract and are attracted by high-income residents. The endogeneity makes amenities difficult to ignore since they are correlated with everything and will be a never-ending source of bias in most empirical studies.

Simulations can address this concern. Rappaport (2008) calibrates a computational two-city model of population and quality-of-life. He finds that differences in consumption amenities are associated with compensating variation equal to 30% of consumption expenditure can account for observed differences in population among US cities. The computational result is highly suggestive. Yet, we lack sharp statements on how local amenities might confound study of local labor demand (e.g., Edlund et al. 2015) because closed form solutions are lacking.

Nevertheless, as salient as amenities are, it seems plausible that they follow and magnify existing gentrification instead of causing it in the first place. As Edlund et al. (2015) put it, centrality is the most important amenity. They argue that rising skilled labor demand induces the rich to work longer hours and shorten their commutes relative to the poor.

However, this explanation does not mesh well with economic theories of housing price change. Traditional models predict that the rich prefer the suburbs because they like to use their greater buying power to purchase more land (Duranton et al. 2015). These models predict that rental prices in central areas are high enough to transfer any savings from short commutes to landlords. Thus, it seems that if the rich experience an increase in wage, they may purchase more housing by moving outward, purchase more leisure by moving inward, or purchase more leisure by working fewer hours. In other words, a movement inward is one of a host of theoretically feasible responses on the part of the skilled to an increase in their wages.

Married women have driven the majority of increased labor supply on the part of the skilled in recent years (McGrattan et al. 2008). Edlund et al. (2015) claim that increasing returns to skill have driven both increases in two-income households and gentrification. I propose that an increase in two-income households alone can explain gentrification, even if returns to skill were to remain constant. In fact, my model suggests that increasing returns to skill may accelerate or arrest gentrification. But, transitioning from single to dual-earner households will almost always accelerate gentrification and is thus a better explanation.

To show this, I will propose an extension of the traditional Alonso-Muth-Mills (AMM) model, drawing primarily upon theory from Duranton et al. (2015), Glaeser (2008), and Rappaport (2014). The key assumption of the AMM theory is that as distance from the city center rises, transportation costs rise. Rents per square foot must therefore be lower in the suburbs in order to compensate outer residents for their extra commuting costs. The assumption that commute times are what exogenously differentiates the inner city from the suburbs enjoys some empirical support. For example Glaeser et al. (2008) find that much of the historical sorting of income groups across "old cities" was probably driven by access to public transportation.

Simulating AMM models can be challenging because including even a small amount of complexity can compromise tractability (Glaeser 2008). To keep the model tractable, I will use a work hours restriction from Rappaport (2014). Unlike Rappaport, I will introduce a reservation location and make wages exogenous. Although I lose general equilibrium, these changes allow me to continuously simulate rent and incomes at all locations in the city instead of discrete rings.

The structure of this paper is as follows. In Section 2, I present stylized facts to motivate a study of gentrification in Washington DC. In Section 3, I develop a simple model of spatial income group sorting which suggests that increasing prevalence of two-earner households can plausibly explain patterns of gentrification in approximately monocentric cities. In Section 4, I present evidence from Washington DC suggesting that among high-earners, the married young are shortening their relative commutes while the unmarried are not. I conclude in Section 5 that both the theory and the evidence argue persuasively that inner cities gentrify partially because of a transition from single-earning households to dual-earning households.

2 Stylized Facts

In order to calibrate and evaluate my model, I must ground it in appropriate empirical data. In this section, I will use maps constructed from Census microdata to argue that Washington DC is an ideal setting to study gentrification. The following stylized facts will show that the DC metro approximately meets the assumption of monocentricity made by the AMM models and appears to be experiencing gentrification.

2.1 Summary Statistics

My data come from the Integrated Public Use Microdata Series (IPUMS) maintained by the Minnesota Population Center at the University of Minnesota (Ruggles et al. 2015). The data are drawn from the 5-percent and 1-percent samples of the American Communities Survey, which is conducted by the US Census Bureau. I make use of census data covering the Chicago and Washington DC metropolitan statistical areas. The data are from the years 1980, 2000, and 2010.

The raw data provided by IPUMS are at the individual level. My variables of interest are monthly gross rent,[1] yearly personal wage income, educational attainment, commute time, transport method, and the number of bedrooms in the home.

For the motivational maps in Figures 1-12, I aggregated repeated cross-sections of individuals from 2000 and 2010 into a panel at the level of the Public Use Microdata Area (PUMA).[2] PUMAs are geographic areas. They tend to be much larger than census tracts and are required to have populations over 100,000 in order to preserve anonymity. I aggregated the variables as follows. I took gross rent for individuals living in 2-bedroom rented dwellings and wage income for individuals reporting

[1]Gross rent includes contract rent as well as fuel and utilities costs.

[2]Since PUMAs are not consistent outside of this decade, I did not make maps for 1980.

greater than zero income at their medians. For the portion of individuals reporting at least one year of college, the portion married, the portion under 35 years of age, and the portion both married and under 35 years of age, I computed percents for each PUMA. I took the minutes of commute time for individuals who commuted by auto, truck, or van at the mean and called this the "auto" commute time. All dollar amounts are in constant 2017 USD. All aggregations made use of the individual sample weights provided by IPUMS. The data included 234,000 observations before aggregation and 44 observations after aggregation.

Tables 1 and 2 provide summary statistics for the aggregated PUMA-level data for Washington DC in 2000 and 2010 respectively. These tables also show how many individuals were aggregated over for each variable in each year. Since commute times were restricted to auto drivers, wages were restricted to earners, and rents were restricted to 2-bedroom dwellings, the sample sizes for these variables are smaller than for the demographic variables.

2.2 Motivational Maps

The AMM models assume that cities are monocentric. In other words, commute cost and time increase with distance from the city center. This stipulation is more realistic for some cities than others. Figure 1 shows commute time quartiles in Washington DC PUMA's during 2010. The darker the color, the higher the quartile. I ask the reader to consider the central square containing DC proper and Arlington to be the "inner" city. Notice that commute times are clearly shorter in the inner city than the broader metro. Compare this to Figure 2 of Chicago in 2010. Commute times are very high in downtown Chicago relative to the rest of the city. Thus, monocentricity seems to be a reasonable stylization of Washington DC and an unreasonable stylization of Chicago.

Figures 1 and 2 showed that Washington DC appears to be relatively monocentric. In order for it to be a good choice for my study of gentrification, we must have evidence that it is indeed gentrifying. First, consider Figure 3, which shows percent change in median inflation-adjusted gross rents for 2-bedroom dwellings in Washington DC from 2000 to 2010. Notice that the inner square experiences rapid real rent growth compared to the rest of the metro. Similarly, Figure 4 shows that the inner square experienced the fastest wage growth over the same period.

Can the increase in the rent and income rankings of the central zones in the Washington DC metro be explained by demographic change? First, consider Figure 5. The portion of the population under 35 is growing rapidly in almost all of the inner city and declining in most outer zones. Figure 6 shows that the married population is declining throughout the metro, but rising in the inner city. According to Figure Figure 7, the college-educated are also centralizing.

The skeptical reader may wonder whether these five trends are recent phenomena or simply the longstanding historical trends of Washington DC. Unfortunately, my PUMA-level data only go back to 2010. To shed light on this question, I have included maps in Figures 8-12. These maps show absolute levels of rent, income, college education rates, age, and marriage rates in 2000 and 2010. The takeaway from these maps is that levels are much less concentrated in the inner city than changes are. This is evidence that the close concentration of changes in the inner city shown in Figures 3-7 emerged relatively recently.

These maps suggest that Washington DC is approximately monocentric and seeing its inner core become relatively more expensive, richer, more educated, more married, and younger than its outer zones. Which changes are causes and which are consequences? To explain the relationships among these movements, we need some economic theory.

3 Theory

In this section I will define and calibrate a model of urban incomes and housing prices across space. The model is an extension of the Alonso-Muth-Mills models described in Duranton et al. (2015) and Glaeser (2008). It makes the standard assumption that commute costs rise with distance from the city center. Its mission is to show that a city of one-earner households will have a poor inner core and rich suburbs while a city of two-earner households will have the reverse.

3.1 Model

The model describes the behavior of two agents: the landlord and the household. Each landlord owns a single apartment at some location in the city and will rent it to the highest bidder. Thus, housing supply is assumed to be perfectly inelastic and the goal of the model will be to determine the price that each income group is willing to pay for housing at each location in the city.

Moncentricity is a major assumption of this model. That is to say, the farther a household lives from the city center, the longer its commute distance x. Thus, if a household lives x miles from the city center, it must pay a commuting cost of $\tau(x)$ goods and $\sigma(x)$ hours. Thus, work hours N are equal to total time endowment T minus leisure ℓ minus commute time $\sigma(x)$.

Following Rappaport (2014), I restrict work hours N for single-earner households to 40 hours per week. This lends the mathematical derivations tractability and makes the time cost of commuting more salient. The units of housing h are quality-square-feet. So, a larger or nicer apartment is considered "more" housing.

3.1.1 The Maximization Problem

Each household seeks to maximize its utility subject to a budget constraint. The utility function is increasing in housing h, leisure time ℓ, and non-housing goods consumption c. But, the household must not exceed its income, which is equal to hours worked N times wage w. Consumption is the numeraire good, so the price of consumption is implicitly 1. The price of housing is denoted p.

Thus, the household's problem is to pick $\{x, c, h\}$ to maximize utility subject to its budget and time constraints.

$$\max_{x,c,h} \quad U(c, h, \ell) \tag{1}$$

$$s.t. \quad c = wN - ph - \tau(x) \tag{2}$$

$$\ell = T - N - \sigma(x) \tag{3}$$

We can write this maximization problem as a Lagrangian. We know that under maximization, the derivatives of the Lagrangian with respect to c and h will equal zero. This gives us two first-order conditions.[3]

$$\mathcal{L} = U(c, h, \ell) + \lambda(w(T - \ell - \sigma(x)) - c - ph - \tau(x)) \quad (4)$$

$$c: \quad 0 = U_c - \lambda \quad (5)$$

$$h: \quad 0 = U_h - \lambda p \quad (6)$$

Combining equations 5 and 6 gives us:

$$\frac{U_h}{U_c} = p \quad (7)$$

Notice that $\frac{U_\ell}{U_c}$ does not necessarily equal the wage! This is because the household cannot choose its work hours.

3.1.2 The Alonso-Muth Condition

I will now introduce the axiom of spatial equilibrium from (Glaeser 2008). According to this principle, housing prices p adjust until expected utility is equal at every location x. Thus, the derivative of utility with respect to x is zero.

$$0 = \frac{\partial}{\partial x} U(c, h, \ell) \quad (8)$$

If we substitute both budget constraints into Equation 8, we have:

$$0 = \frac{\partial}{\partial x} U(w(T - \ell - \sigma(x)) - ph - \tau(x), h, T - N - \sigma(x)) \quad (9)$$

Next, we totally differentiate. Since work hours N are fixed, $N_x = 0$. We can substitute in Equation 7 and solve for p_x.

$$0 = U_c(wN_x - p_x h - ph_x - \tau_x) + U_h h_x + U_\ell \ell_x \quad (10)$$

$$0 = U_c(0 - p_x h - ph_x - \tau_x) + U_c ph_x - U_\ell \sigma_x \quad (11)$$

$$p_x = -\frac{\tau_x + \frac{U_h}{U_c}\sigma_x}{h} \quad (12)$$

Equation 12 is an extended version of the Alonso-Muth Condition from Duranton et al. (2015). If we define a utility function, we can easily take its derivatives and obtain the housing demand, transforming Equation 12 into a first-order ordinary

[3]There is no need to derive the first order condition with respect to x because the spatial equilibrium introduced in the next section renders the x decision moot.

differential equation. The solution to this differential equation tells us the housing price p that any household with wage w will be willing to pay at distance x from the city center. This solution $p(x, w)$ is called the bid-rent function.

The intuition behind the Alonso-Muth Condition is this: commute cost savings from moving inward are exactly offset by extra housing expenditure. Clearly, housing prices decrease monotonically with distance from the city center. Since utility is even throughout the city and housing is a normal good, this means that housing consumption increases with distance from the city center.

The Alonso-Muth Condition can make predictions regarding the sorting of the rich and poor across space. Suppose that housing price bidded by the poor and the rich are equal at some point $\hat{x}$.[4] Then, whichever income group has a steeper p_x at $\hat{x}$ will occupy the inner city. The group with shallower $\hat{x}$ will occupy the outer city.[5]

Since housing is a normal good, h will be larger for higher income groups, implying a shallower p_x. However, since work hours are fixed, both income groups experience the same ℓ. Since the rich consume more h and c, U_c will be lower for the rich and U_l will be the same or higher for the rich. Thus, both the numerator and the denominator will be greater for the rich and which group occupies the city center is ambiguous. Thus, in order to make predictions regarding gentrification, we must calibrate the model and then numerically estimate the solution of the Alonso-Muth Condition for each income group.

3.2 Functional Forms

In order to numerically estimate Equation 12, we must first define a utility function. I choose to follow Rappaport (2014) and use a nested constant elasticity of substitution form.

$$U(c, h, \ell) = \left(\eta \ell^{\rho} + (1-\eta)\left(\delta c^{\gamma} + (1-\delta) h^{\gamma}\right)^{\frac{\rho}{\gamma}}\right)^{\frac{1}{\rho}} \tag{13}$$

[4] If wages are equal in the city and the reservation location, then the expected commute distance in the reservation location will be such a $\hat{x}$.

[5] Since both bid-rent functions are decreasing monotonically in x, parameter sets with multiple $\hat{x}$ are quite rare.

An engaging exercise in calculus and algebra yields the following housing demand:

$$h = \frac{wN - \tau(x)}{\left(\frac{p\delta}{1-\delta}\right)^{\frac{1}{1-\gamma}} + p} \tag{14}$$

The predictions of the model are somewhat sensitive to the choice of functional forms for transportation costs.[6] For parsimony, I use linear forms for $\tau(x)$ and $\sigma(x)$.[7]

The Alonso-Muth Condition tells us how households hold utility constant throughout the city. But, in order to find its solution, I must specify what the level of utility is that households are holding constant. To do this, I give city-dwellers the option of moving to a reservation location. The price and commute distance in the reservation location are meant to represent the expected price and commute for the resident if they rolled a die and moved to a random location elsewhere in the country. I then set utility at all points in the city equal to reservation utility.

To restate this in mathematical terms, in order to numerically simulate the differential equation $\frac{\partial p}{\partial x}$ we need to fix a $p(0)$. I set $p(0)$ equal to the price that equalizes utility in the reservation location and utility with no commute. Price and commute distance in the reservation location are the national means. With $p(0)$ pinned down, the Alonso-Muth condition can tell us the prices bid at all other points in the city.

It is the reservation location that allows us to understand how it is that the poor can outbid the rich for an apartment. Intuitively, a member of the super-rich would not be willing to move into a tiny apartment in a bad part of town, even if rent were zero. This is because the rich have better options–in the reservation location. If the tiny apartment were the only housing in the world, then the super-rich would have the maximal bid. But, since the wealthy face the opportunity cost of the reservation location, the poor will outbid them in some locations.

[6] In general, increasing goods costs or decreasing time costs will steepen the bid-function of the poor relative to the rich, increasing the likelihood that the poor will occupy the inner city.

[7] The linear functional forms for commute costs imply constant speed and cost per mile. In reality, commutes are likely to be slower and more expensive close to the city center. I do not address how much slower and more expensive in this paper and choose the linear forms to avoid over-fitting.

3.3 Parameters

I follow Rappaport (2014) once more to choose parameters for the utility function. I set the elasticity of substitution between housing and all other goods to 0.33. I set the baseline elasticity of substitution between leisure and the composite of housing and consumption to 0.75.[8] Next, I fix η such that college-educated residents in the reservation location choose to work 40 hours per week. Finally, I fix δ such that poor residents in the reservation location commit about 40 percent of their expenditure on housing.[9]

I calibrate parameters for the budget constraints using the census data detailed in the next section (Ruggles et al. 2015). The median hourly wage for workers with a high school diploma only was \$11.24 in 2010.[10] For workers with a bachelor's degree, the median hourly wage was \$26.34. Finally, I use the mean national rent for a one-bedroom dwelling \$896 as the housing price in the reservation location.

Next, I calibrate transportation costs per mile. The Internal Revenue Service (IRS, 2010) allowed individuals to deduct \$0.56 per business mile driven in 2010. I use this as a rough approximation of auto commute costs. Thus, $\tau(x) = 0.56x$. Since my data do not include commute distance, I draw on a document published by the Bureau of Transportation (2003) which states that the mean commute in the United States in 2003 was approximately 15 miles in 26.4 minutes. I use this to fix expected national transportation speed at 34 miles per hour $\sigma(x) = \left(\frac{26.4/60}{15}\right) x$. It is important that I use mean national transportation costs because utility in the city is "anchored" to the expected utility of a random move to anywhere in the United States.

Finally, I make some simple assumptions. Households are made up of two adults, so total time endowment per day is $T = 48$ hours. Work hours are $N = 8$ if one partner works and $N = 16$ if both partners work. If both partners work, commute costs naturally double.

[8] Subsection 3.5 shows that my results are not sensitive to the choice of these elasticities.

[9] Rappaport (2014) uses a much smaller number: 17 percent. In this case I am guilty of a bit of parameter-seeking. The model starts to predict very high housing prices at low housing expenditure. Furthermore, 40 percent is a more reasonable portion if we are considering expenditure of the urban poor (Castner et al. 2010).

[10] All dollar values are in 2017 dollars.

3.4 Results

The model yields a stylized story of where the poor and the rich choose to live in a metro with only one-income households versus a metro with only two-income households. Figure 13 shows that if $N = 8$, then low-income households will outbid high-income households for the inner city. Consequently, the rich occupy the suburbs. In order to understand how it is possible that the poor are willing to pay more than the rich for centrality, we must consider carefully what the transportation costs mean for each group. Since one partner does not work, both groups have a substantial amount of hours available for non-work activities each day. But, cash is in relatively short supply. Transportation costs are a larger portion of income for the poor, so they are willing to pay more rent per square foot to avoid costly commutes.

Figure 14 shows that everything changes when both partners work. Now hours are in short supply and cash is abundant. Naturally, the extra cash causes all groups to bid up rents everywhere. But, now that time for non-work activities is scarce, the rich use their extra buying power to move closer to the central business district. The rich experience lengthy commute times more acutely than the poor because their marginal utility of leisure is higher. The image that should come to mind is of the time-starved professional couple who elect not to move to the suburbs when a baby comes because they simply do not have time for both partners to commute half an hour twice a day.

This model is highly stylized. In reality there are a continuum of income groups, these groups mix to a degree, and there were no discrete jumps from cities of one-income households to cities of two-income households. Moreover, the rents in Figure 14 are rather high[11] and the poor occupy an unrealistically large land area in Figure 13. Nevertheless, these simulations make the case that an increase in the prevalence of two-income households is an internally consistent explanation for recent patterns of gentrification.[12]

[11] This is probably because no city is actually made up entirely of two-income households. If this were the case, $10,000 per month for a two-bedroom downtown apartment in a super-city might not be unheard of.

[12] For the curious reader, Figures 15 and 16 show the simulated housing demand, portion of expenditure on housing, goods consumption and leisure time for the single and dual earner households. Notice that in Figure 16 as rent approaches zero at around 17 miles, the model becomes unstable

3.5 Robustness

Following Rappaport (2014) to choose the elasticities of substitution for the utility function may not be fully justified. For instance, Rappaport chooses elasticities to match population-weighted mean of the Frisch elasticity. But, since my model has no notion of population, using Rappaport's parameters seems arbitrary.

To test the sensitivity of my qualitative results to parameters, I performed the following experiment 50,000 times. First, I chose the elasticity of substitution between housing and consumption $\frac{\gamma-1}{\gamma}$ by drawing at random from the uniform distribution between 0.01 and 3. Second, I did the same for the elasticity of substitution between leisure and other goods $\frac{\rho-1}{\rho}$. Third, I drew the parameters η and δ at random from the uniform distribution between 0.01 and 0.99.

With the four randomly chosen parameters in hand, I used equation 12 to compute the slopes of the bid-rent functions for the rich and the poor at the intersection point[13] for $N = 8$. I then took the percent difference in slopes.[14] Next, I computed the percent difference in slopes of the rich and the poor for $N = 16$. Finally, I compared the difference in differences between rich and poor for $N = 8$ and $N = 16$.

In 99.76% of the 50,000 trials, the rich bid-rent function steepened relative to the poor bid-rent function when work hours increased. This means that in nearly all cases, increasing work hours caused the rich to increase their bids for inner city housing relative to the poor. Thus, I conclude that the increase in the slope of the rich relative to the poor shown in Figures 13 and 14 to be almost totally insensitive to choice of parameters for the utility function.

4 Empirical Analysis

Edlund et al. (2015) found that the rich are shortening their commutes nationwide relative to the poor. They argue that this is because increasing returns to skill have increased skilled work hours. In this framework, increasing returns to skill can also explain the rising labor force participation of women and the rising prevalence of

[13] Since the wage is equal in the city and the reservation location, the bid-rent functions for the rich and the poor intersect at the expected commute distance in the reservation location.

[14] Recall that whichever group has the steeper slope will occupy the city center.

two-income households. My theory from the previous section suggested that, in fact, a city that transitions from one-income households to two-income households will see the rich shorten their commutes and the poor lengthen them, even if wages are constant.

If increasing returns to skill really were driving gentrification in Washington DC, we would expect the rich, married and unmarried, to shorten their commutes in relative terms. This section will show the contrary. The married rich are increasing their commutes relative to the poor, while the unmarried rich are not.

4.1 Summary Statistics

The raw data underlying the analysis in this section is the same IPUMS census data as Section 3 (Ruggles et al. 2015). However, here I keep the data at the individual level and use the years 1980 and 2010. Tables 3 and 4 display simple summary statistics for commute time and wage income disaggregated by age and marital status. Keep in mind that I included only individuals reporting a positive commute time and personal wage income. The N column counts the individuals in the age-marriage category before restriction. Commute times are in minutes and incomes are in 2017 dollars.

4.2 Gentrification and the Married

In this subsection I present evidence that strongly suggests that it was primarily young, married, high-income couples who drove gentrification in Washington DC between 1980 and 2010. I do not have a well-identified natural experiment that can confirm the causal mechanisms of these changes. However, the following figures and regressions show that any causal explanation of gentrification must account for the fact that it was not the young and skilled, but the young, skilled, and married who were the primary gentrifiers in Washington DC.

The goal of the following procedure is to determine which groups increased their commutes relative to others between 1980 and 2010 in Washington DC. For each year, I gave each auto-commuting, income-earning individual their percentile rank in the income and commute time distributions in the years 1980 and 2010. Then, I found the mean commute time percentile for each income percentile group. Since these plots can be difficult to read, I took a moving average over the income percentile distribution. The outcome is Figure 17.

Figure 17 shows that commute times tend to rise with income. This is consistent with Figure 13. But, the top fifth of the income distribution has shortened its commute times relative to the bottom four-fifths since 1980. Since Figure 1 leaves no doubt that commute time is strongly correlated with centrality in Washington DC, Figure 17 strongly suggests that the rich are moving relatively inward and the poor are moving relatively outward.

Which populations are driving this trend? To find out, I partitioned the DC auto-commuting, income-earning population into four groups according to marital status and age. If an individual is legally married and their spouse is present, they are considered "married." If an individual is 35 years of age or younger, they are considered "young." Cutting along these lines yields four disjoint groups that together make up the entire auto-commuting, income-earning population of Washington DC.

Figure 18 shows the relationship between income percentile and commute time percentile for those over 35 and married.[15] Their trend appears to be almost identical to the population in general. The richest fifth are shortening their commutes and the rest are lengthening theirs.

Now consider the plot for the young and married (Figure 19). Young, married individuals in the bottom fifth of the DC income distribution are lengthening their commutes relative to the rest of the population, while young, married individuals in the top four-fifths are shortening their relative commutes. In fact, the farther up the income distribution we go, the greater the shortening effect. Thus, it appears that the young and married are gentrifying to a greater degree than the rest of the population.

Is it the young and not the married that drive this trend? Figure 20 presents evidence to the contrary. Among this population, the rich do not appear to be shortening their commutes.

[15]The percentile rankings correspond to the entire population, not of the partition.

Finally, among those over 35 and unmarried (Figure 21), the trend is exactly the opposite as those under 35 and married. The old and unmarried in the bottom fifth of the income distribution are actually shortening their commutes, while the richer individuals are lengthening their commutes. The fact that the young and married exhibit the exact opposite trend as the old and unmarried is good evidence that partitioning the population in this way reveals meaningful differences in trends.

To summarize, Figure 17 suggests that the rich are shortening their commutes relative to the poor. Figure 19 suggests that the married, in particular the young and married are driving this trend. The young and unmarried have no discernible trend and the old and unmarried are opposing the trend.

4.3 Statistical Significance

A skeptic might note that the figures have been smoothed and wonder whether the trends that Figures 17, 19 and 21 purport to show are statistically significant. They may point out that since the unsmoothed figures are unreadable, the variance might be too high to say for sure that these trends are as meaningful as they appear.

This skeptic would be wrong. Consider Table 5. This table shows five Ordinary Least Squares regressions on auto commuters in Washington DC. The dependent variable in each case is commute time percentile. The independent variables are income percentile, a dummy variable which is 1 in 2010 and 0 in 1980, and the interaction between the dummy and income percentile. Model 1 includes all income-earning auto commuters in Washington DC in 1980 and 2010.[16] Model 2 restricts to those married and over 35. Model 3 restricts to those unmarried and over 35. Model 4 restricts to the unmarried under 35. Model 5 restricts to the married under 35. The reader should keep in mind that the data are in repeated cross sections, not a panel.

The coefficient on Decade x Income tells us how the effect of income on commute time differed between 1980 and 2010. For the entire population (Model 1), a 1-point increase in income percentile[17] is associated with a .24 point increase in commute

[16] This is a repeated cross section, not a panel.

[17] When I say "increase" in income percentile, I mean observing a different individual in a higher percentile. The data are repeated cross sections, not a panel.

time percentile in 1980. In 2010, this weakened to a .20 point increase. Moreover, this is a statistically significant change. This confirms my interpretation of the gentrification trend in Figure 17.

Turning to Model 2, we find that for those older than 35 and married, a 1-point increase in income percentile is associated with a 0.29 point increase in commute time percentile in 1980. But, in 2010 this dropped to a 0.22 point increase. Since the coefficient on Decade x Income is negative and statistically significant, my interpretation of Figure 18–that gentrification among the old and married was similar to the population at large–is confirmed.

In Model 3, we see that among those older than 35 and unmarried, a 1-point increase in income percentile is associated with only a 0.07 point increase in commute time percentile in 1980. In 2010, this actually jumped up to a 0.14 point increase. Once again, the change is statistically significant. This is the opposite trend and it matches my interpretation of Figure 21 that the old and unmarried are anti-gentrifying.

Model 4 shows that, for the unmarried young, a 1-point increase in income rank implies a 0.2 point increase in commute time rank in 1980. But, in 2010, there is no statistically significant change in this relationship. This belies the fact that Model 4 has a larger sample size than Models 3 or 5, which do have statistical significance. This confirms my interpretation of Figure 20 that the young and unmarried do not appear to be gentrifying.

Finally, Model 5 shows that, for the young and married, a 1-point increase in income percentile is associated with at .23 point increase in commute time percentile in 1980. In 2010, this dropped to a mere 0.16 point increase. Not only is this drop statistically significant, it is the largest in magnitude of any group. This supports my interpretation of Figure 19 that the young and married appear to be gentrifying more than any other group.

In summary, larger incomes are associated with longer commutes. But, between 1980 and 2010 this relationship weakened. For the young and married, the change was the starkest. For the old and married, the change was typical of the population at large. For the young and unmarried, there was no measurable change. Finally, for the old and unmarried, the relationship actually strengthened. Taken together, this is evidence that the married, especially the young, make up most of the gentrification in Washington DC between 1980 and 2010.

4.4 Including All Transport Modes

I have focused on auto commutes thus far because the theoretical model in Section 3 considered only one transportation mode. However, it is important to check whether the empirical results from Section 4.2 and 4.3 hold in general.

Figures 22-26 correspond to Figures 17-21, but no longer restrict to auto commuters. I now include walkers, bicyclers, and those who take public transportation. A glance at these figures confirms that the main results of Figures 17-21 remain in essence, but are a bit noisier. Most commutes are lengthening, except those in the top quintile. The young and married experience a stronger trend, the young and unmarried experience no discernible trend, and those over 35 and unmarried experience the opposite trend.

Table 6 tests the statistical significance of these trends in the same OLS regression technique as in Table 5. The sign and significance of the critical Decade x Income coefficient is unchanged in Models 2-5. I do lose significance in the disaggregated Model 1, however.

About three quarters of the individuals in my sample commute by car or truck. The trends outlined in subsections 4.2 and 4.3 seem to be mostly driven by auto commutes. When I add the other transport modes, the signal becomes noisier, but is still discernible. This is evidence that, regardless of whether the signal is local to auto commuters, it is strong enough to dominate the entire sample and is therefore worthy of documentation.

5 Conclusion

Increasing incomes and rents in central cities remains a national trend (Hwang et al., 2016). Explanations for this reversal of suburbanization range from consumption amenity growth (Baum-Snow, 2016) to increasing returns to skills (Edlund et al., 2015). Yet, sorting out the relative importance and causal relationships among these forces remains a challenge.

In this paper, I propose an alternative narrative. Consider two high-earning households: one single-earning and one dual-earning. The single-earner household has less cash to pay the high urban rents but more time to sacrifice to long suburban commutes. But, a time-starved professional couple is more likely to shell out a high rent to delay a move to the remote suburbs. Thus, the high-wage household with two earners is more likely to use its extra buying power bid up central city rents than a high-wage household with only one earner.

I have argued that a transition toward two-earner households can explain the demographic changes that have accompanied rising urban rents. An extended AMM model suggests that this is a feasible hypothesis. Indeed, in the approximately monocentric Washington DC, it is the married rich, not rich in general, who are shortening their commutes.

There are of course, many limitations to this analysis. My model assumes only two income groups and is somewhat sensitive to the choice of transportation costs. Moreover, while the empirical analysis is highly suggestive, it has no causal identification strategy. Thus, this paper should be considered an argument that identifying an exogenous increase in dual-earning households in an urban area would shed a great deal of light on the causes of gentrification in the United States.

References

[1] Baum-Snow, N., Daniel H. (2016). Causes and Consequences of Central Neighborhood Change, 1970–2010. University of Toronto Working Paper.

[2] Bartolome C., Ross S. L. (2003). Equilibria with local governments and commuting: income sorting vs income mixing. Journal of Urban Economics. 54(1), 1-20. http://dx.doi.org/10.1016/S0094-1190(03)00021-4.

[3] Behrens, K., Combes, P., Duranton, G., Gobillon, L., & Robert-Nicoud, F. (2013). Household sorting in the city. Manuscript in progress, University of Pennsylvania, Wharton School.

[4] Castner, L. & Mabil, J. (2010). Low-Income Household Spending Patterns and Measures of Poverty. Mathematica Policy Research. Submitted to USDA, FNS. Mathematica Reference Number: 6408-600.

[5] Chetty, R., Nathaniel H., Patrick Kline, and Emmanuel Saez. (2014). Where is the Land 34 of Opportunity: The Geography of Intergenerational Mobility in the United States. Quarterly Journal of Economics, 129: 1553-1623.

[6] Diamond, R. (2016). The Determinants and Welfare Implications of U.S. Workers' Diverging Location Choices by Skill: 1980–2000. American Economic Review, 106:3 479–524.

[7] Duranton G., & Puga D. (2015). Urban Land Use. In Handbook of regional and urban economics; 5 (p.p. 467-560). Elsevier, 2015. doi:10.1016/B978-0-444-59517-1.00008-8

[8] Edlund L, Machado C, Sviatchi M. (2015). Bright Minds, Big Rent: Gentrification and the Rising Returns to Skill. NBER Working Paper w21729. http://www.columbia.edu/ le93/w21729.pdf

[9] Glaeser, E. L., Kahn, M. E., & Rappaport, J. (2008). Why do the poor live in cities? The role of public transportation. Journal Of Urban Economics, 63(1), 1-24. doi:10.1016/j.jue.2006.12.004

[10] Glaeser, E. (2008). Cities, agglomeration, and spatial equilibrium (Lindahl lectures). Oxford: Oxford University Press.

[11] Glaeser, E. L. (2010). Agglomeration Economics: Introduction. The University of Chicago Press. Retrieved from: http://www.nber.org/chapters/c7977

[12] Gyourko, J., Mayer, C., & Sinai, T. (2013). Superstar Cities. American Economic Journey Economic Policy, 5(4), 167-199.

[13] Hwang, J., Lin, J. (2016). What Have We Learned About the Causes of Recent Gentrification?. Federal Reserve Bank of Philadelphia Working Paper no. 16-20.

[14] Internal Revenue Service. (2010). IRS Announces 2010 Standard Mileage Rates. Retrieved on: April 2nd, 2017. Retrieved from: https://www.irs.gov/uac/irs-announces-2010-standard-mileage-rates

[15] McGrattan, E. (2008). Changes in the Distribution of Family Hours Worked Since 1950. Federal Reserve Bank of Minneapolis Research Department. Staff Report 397.

[16] Rappaport, J. (2014). Monocentric city redux. Working papers / Federal Research Bank of Kansas City, Economic Research Department, 14-09; Research working papers, Federal Reserve Bank 14-09. Kansas City, Mo: Federal Research Bank of Kansas City, Research Division. http://www.kc.frb.org/publicat/reswkpap/pdf/rwp14-09.pdf

[17] Rappaport, J. (2008). Consumption amenities and city population density. Regional Science and Urban Economics, 38(6), 533-552, http://dx.doi.org/10.1016/j.regsciurbeco.2008.02.001.

[18] Ruggles, S., Genadek, K., Goeken, R., Grover, J., and Sobek, M. (2015). Integrated Public Use Microdata Series: Version 6.0 [dataset]. Minneapolis: University of Minnesota, 2015. http://doi.org/10.18128/D010.V6.0.

[19] US Department of Transportation, Bureau of Transportation Statistics. (2003). From Home to Work. Omnibus Household Survey. 3 (4).

6 Tables

PUMAS: Washington DC (2000)

VARIABLE	Units	Mean	Median	Std. Dev.	Min	Max	Individuals
Mean Auto Commute	Minutes	30.7	30.8	3.6	24.0	38.9	95,418
Mean Mass Commute	Minutes	52.8	51.3	12.2	32.5	78.8	13,423
Median Wages	$ (2017)	47,456	48,254	9,661	27,372	71,914	129,347
Median Rent	$ (2017)	1274	1323	235	791	1869	21,419
Mean Age	Years	34.9	34.5	2.54	30.9	41.1	230,508
College	%	44.8	36.0	13.2	17.5	75.7	230,508
Married	%	36.9	40.2	8.7	15.8	48.6	230,508

Table 1: Summary statistics for Washington DC in the year 2000 aggregated at the PUMA level. There are 22 PUMA's. Wages are only for individuals who made nonzero incomes. Rents include utilities and are only for individuals who paid nonzero rents and rented two-bedroom dwellings. Data Source: Ruggles et al. (2015)

PUMAS: Washington DC (2010)

VARIABLE	Units	Mean	Median	Std. Dev.	Min	Max	Individuals
Mean Auto Commute	Minutes	30.9	30.8	3.9	23.7	40.1	21,327
Mean Mass Commute	Minutes	52.9	51.6	12.5	32.1	81.5	3,741
Median Wages	$ (2017)	50,903	49,318	13,030	22,417	80,703	29,677
Median Rent	$ (2017)	1,589	1,570	292	1064	2466	4,607
Mean Age	Years	36.7	36.6	2.3	30.8	41.4	53,811
College	%	49.3	49.5	12.6	25.2	77.4	53,811
Married	%	35.4	37.3	8.5	9.2	50.2	53,811

Table 2: Summary statistics for Washington DC in the year 2010 aggregated at the PUMA level. There are 22 PUMA's. Commute times only for auto commuters. Wages are only for individuals who made nonzero incomes. Rents are only for individuals who paid nonzero rents and rented two-bedroom dwellings. Data Source: Ruggles et al. (2015)

Individuals: Washington DC (1980)

Year	N	% Auto	Mean Auto Com.	Mean Com.	Median Income
All	35,174	71.9	26.7	28.4	41,248
Married, Over 35	11,244	79.3	28.3	29.9	60,881
Unmarried, Over 35	4,790	65.8	26.0	28.9	46,929
Married, Under 35	6,940	76.2	27.9	29.5	43,090
Unmarried, Under 35	11,264	64.8	24.0	26.0	27,796

Table 3: Summary statistics for individuals in Washington DC in the year 1980. Data Source: Ruggles et al. (2015)

Individuals: Washington DC (2010)

Year	N	% Auto	Mean Auto Com.	Mean Com.	Median Income
All	25,527	80.9	32.5	34.2	58,276
Married, Over 35	11,222	86.9	33.8	35.7	80,690
Unmarried, Over 35	5,695	77.3	32.0	34.7	61,638
Married, Under 35	2,328	84.0	33.2	34.58	56,034
Unmarried, Under 35	5,702	71.6	29.3	30.5	30,819

Table 4: Summary statistics for individuals in Washington DC in the year 2010. Data Source: Ruggles et al. (2015)

Automobile Commute Time and Income

	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	Married $>$ 35	Unmarried $>$ 35	Unmarried $\leq$ 35	Married $\leq$ 35
Decade x Inc	-0.0387***	-0.0685***	0.0675***	0.00392	-0.0689**
	(0.00928)	(0.0143)	(0.0246)	(0.0240)	(0.0319)
Decade	2.423***	4.078***	-1.818	1.806*	2.435
	(0.537)	(0.957)	(1.485)	(0.924)	(1.704)
Income	0.240***	0.293***	0.0721***	0.200***	0.230***
	(0.00622)	(0.0102)	(0.0188)	(0.0139)	(0.0162)
Constant	33.35***	30.59***	40.09***	33.11***	36.83***
	(0.360)	(0.699)	(1.165)	(0.577)	(0.882)
Obs.	45,958	18,664	7,554	11,390	7,223
R-Squared	0.048	0.066	0.013	0.027	0.032

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5: These Ordinary Least Squares regressions test whether the change in the relationship between income and commute time between 1980 and 2010 is statistically significant. These regressions consider only auto commuters. Only those unmarried and over 35 years of age experienced no meaningful change. The purpose of the regressions is only to test whether measurable changes occurred at all. No causal inference can be made.

Commute Time and Income for All Transport Modes

	(1)	(2)	(3)	(4)	(5)
VARIABLES	All	Old Married	Old Unmarried	Young Unmarried	Young Married
Decade x Inc	-0.0101	-0.0390***	0.0991***	-0.00646	-0.0609**
	(0.00813)	(0.0131)	(0.0208)	(0.0199)	(0.0282)
Decade	0.798*	2.780***	-4.489***	0.450	2.104
	(0.470)	(0.885)	(1.248)	(0.780)	(1.542)
Income	0.200***	0.271***	0.00794	0.162***	0.200***
	(0.00527)	(0.00914)	(0.0153)	(0.0112)	(0.0138)
Constant	35.80***	31.60***	45.71***	35.83***	38.04***
	(0.305)	(0.633)	(0.939)	(0.469)	(0.777)
Obs.	60,701	22,466	10,485	16,966	9,268
R-Squared	0.038	0.062	0.006	0.017	0.026

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6: These Ordinary Least Squares regressions test whether the change in the relationship between income and mass transit commute time between 1980 and 2010 is statistically significant. Groupwise sign and significance on interaction term is the same as for the auto commuters. The purpose of the regressions is only to test whether measurable changes occurred at all. No causal inference can be made.

7 Figures

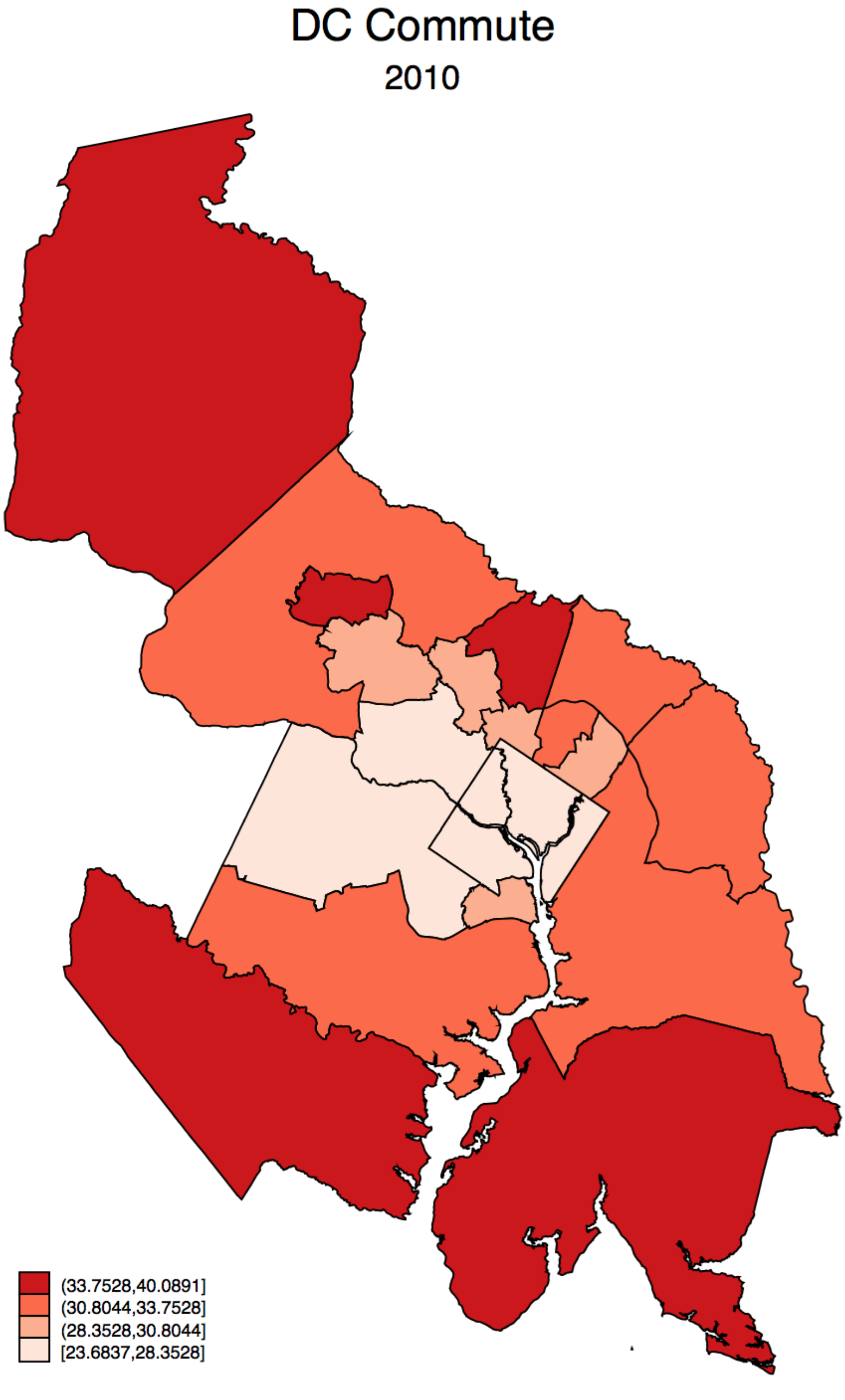

Figure 1: In the Washington DC metro, the central city has the shortest automobile commute times. The map for mass transit times is nearly identical

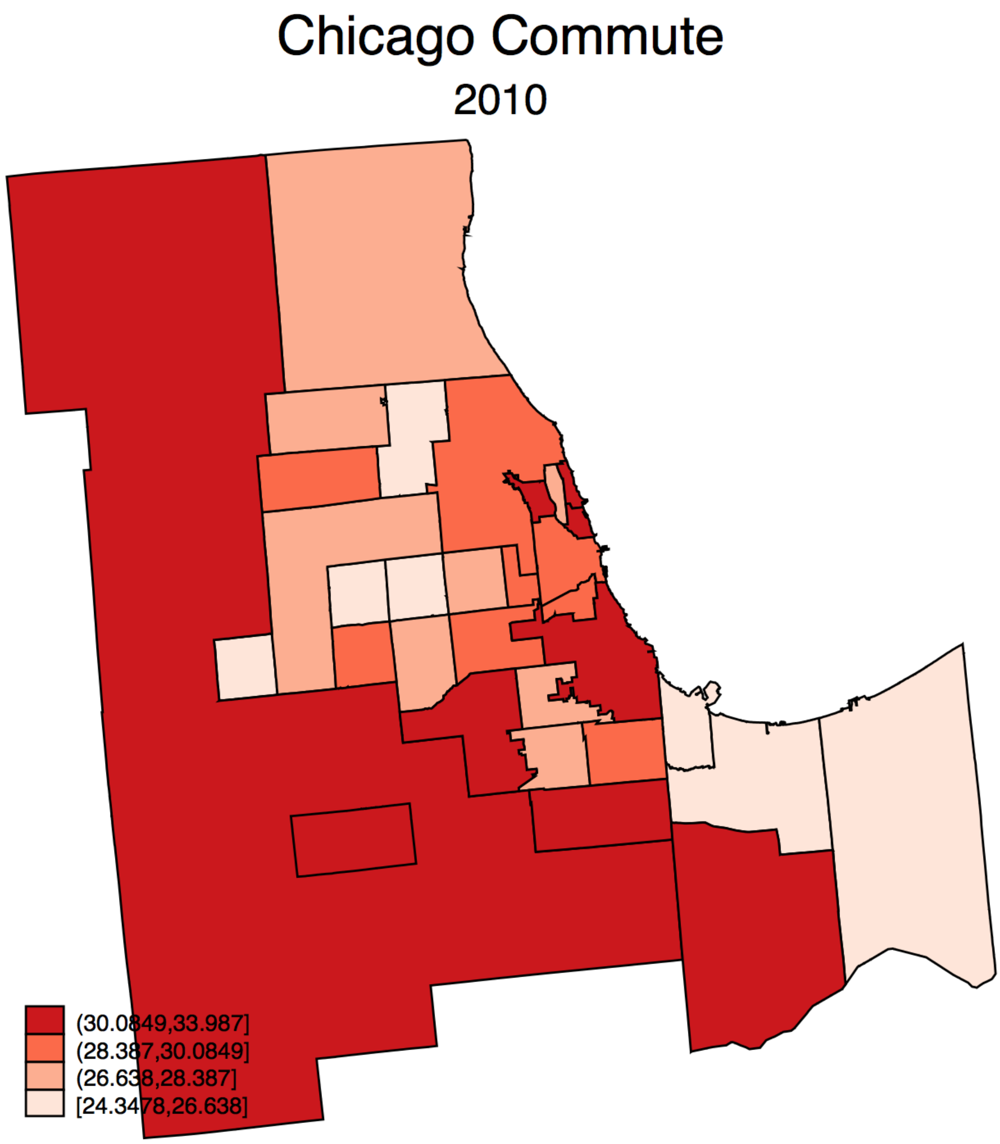

Figure 2: In the Chicago metro, commute times are high in the central city.

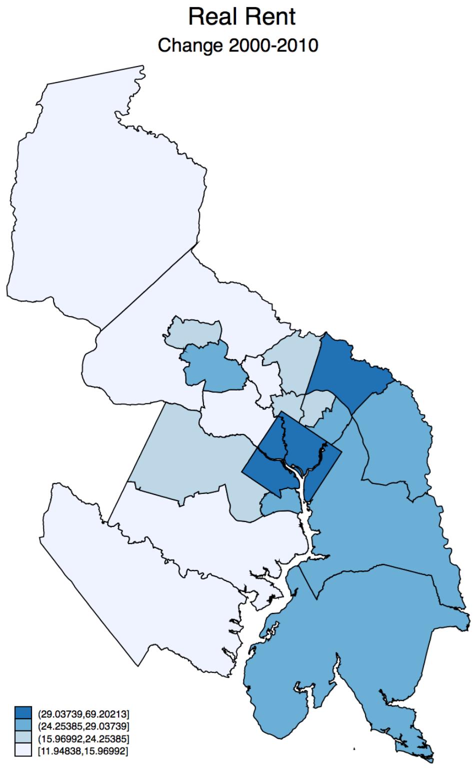

Figure 3: Concentration of Rent Growth

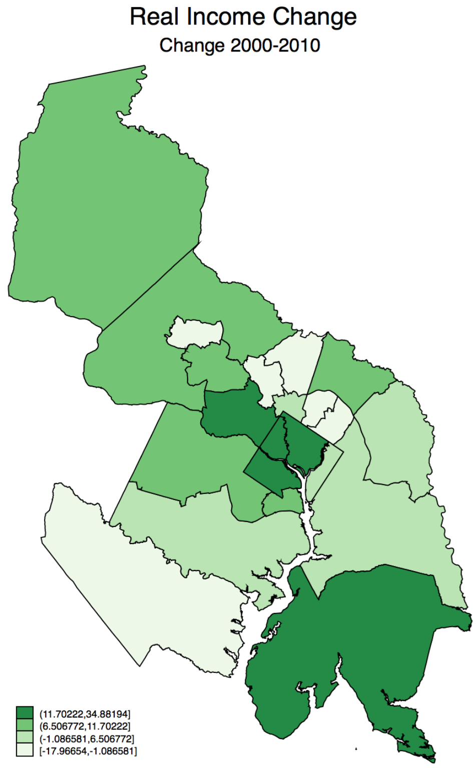

Figure 4: Concentration of Income Growth

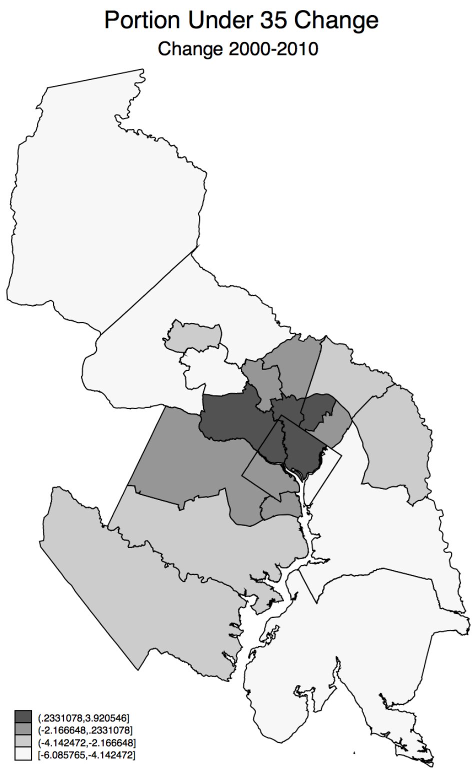

Figure 5: Congregating Young

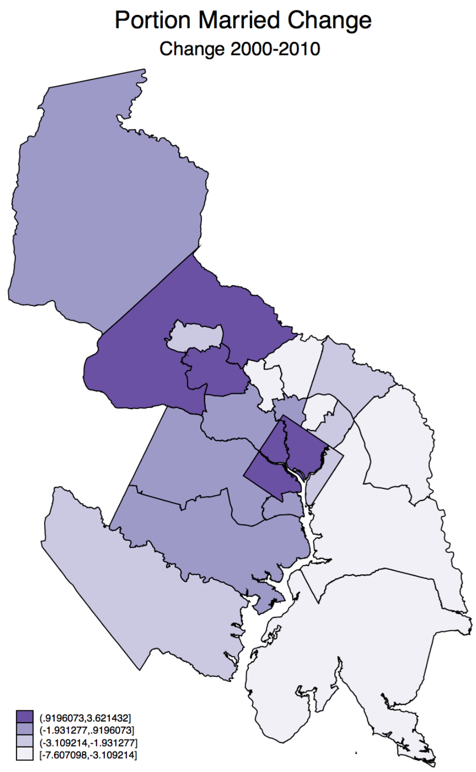

Figure 6: Congregating Couples

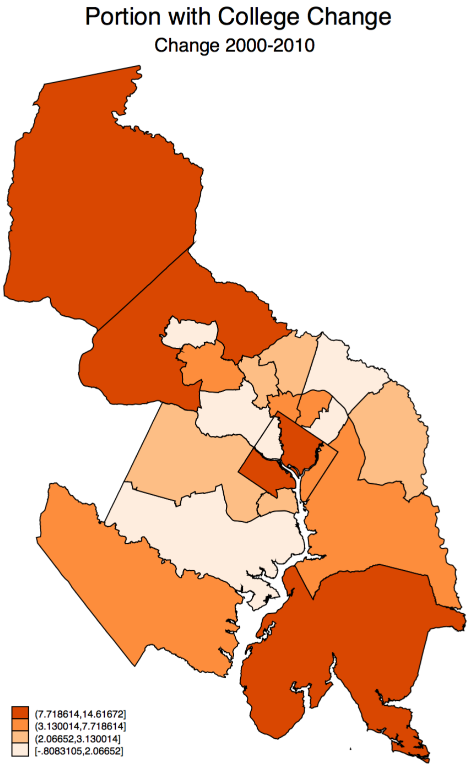

Figure 7: Congregating College-Educated

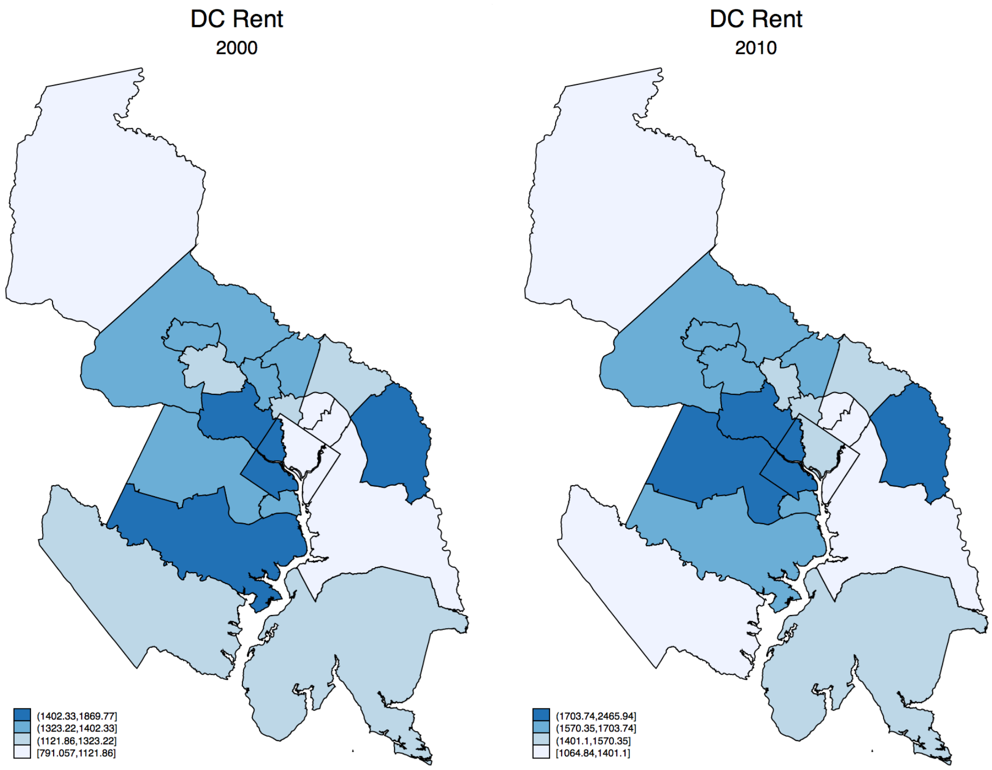

Figure 8: Median real rent levels for 2-bedroom rented dwellings

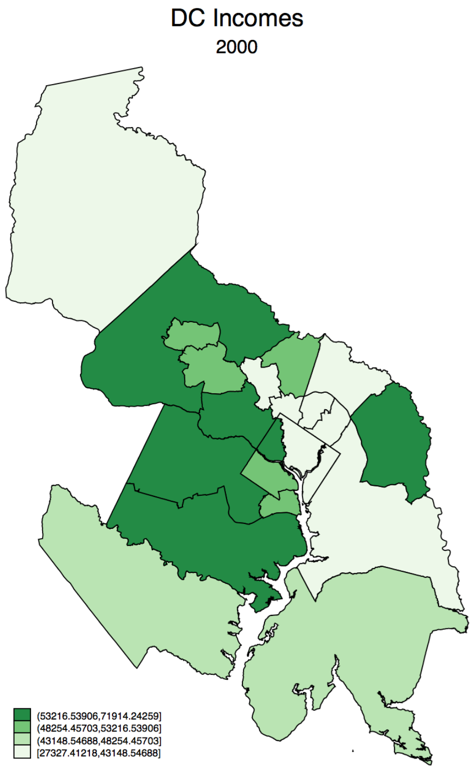

Figure 9: Median real annual personal wage income levels

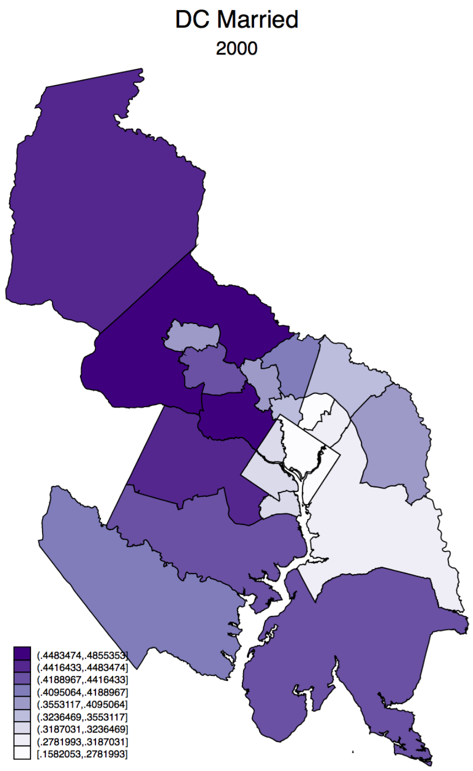

Figure 10: Portion married levels

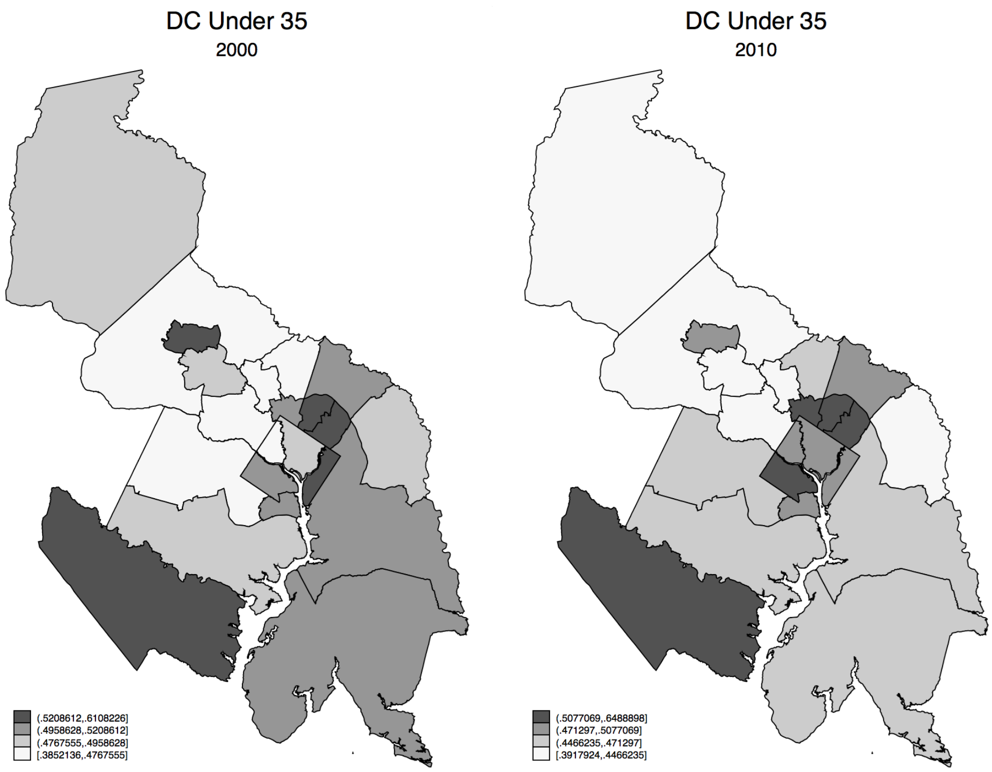

Figure 11: Portion under 35 levels

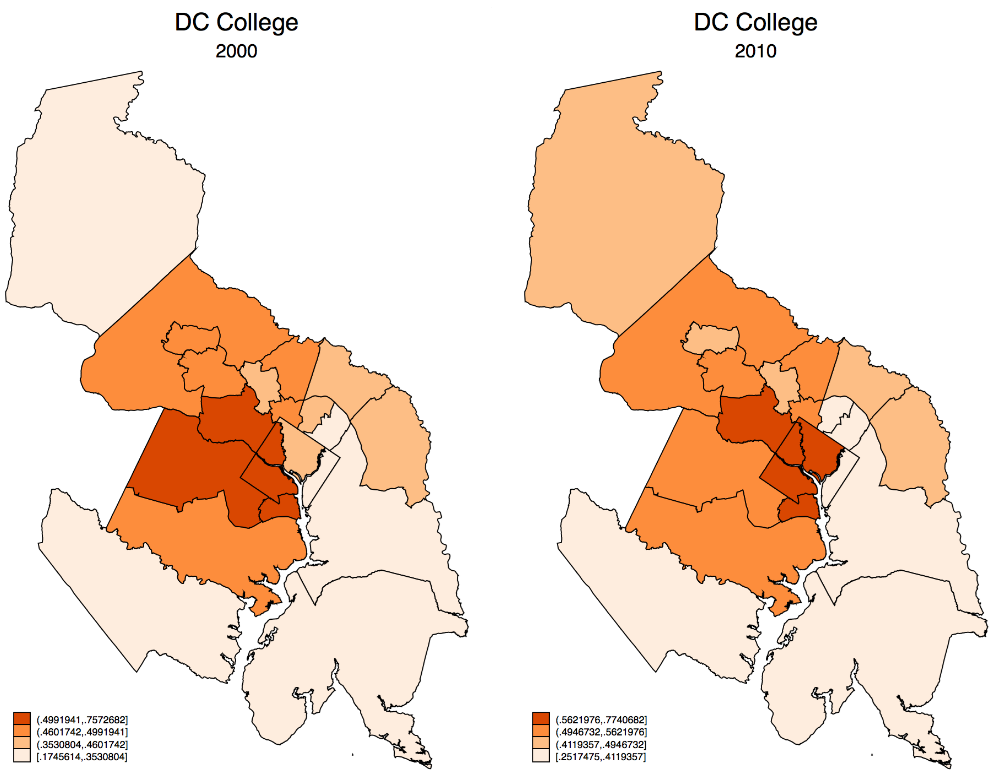

Figure 12: Portion with any college education levels

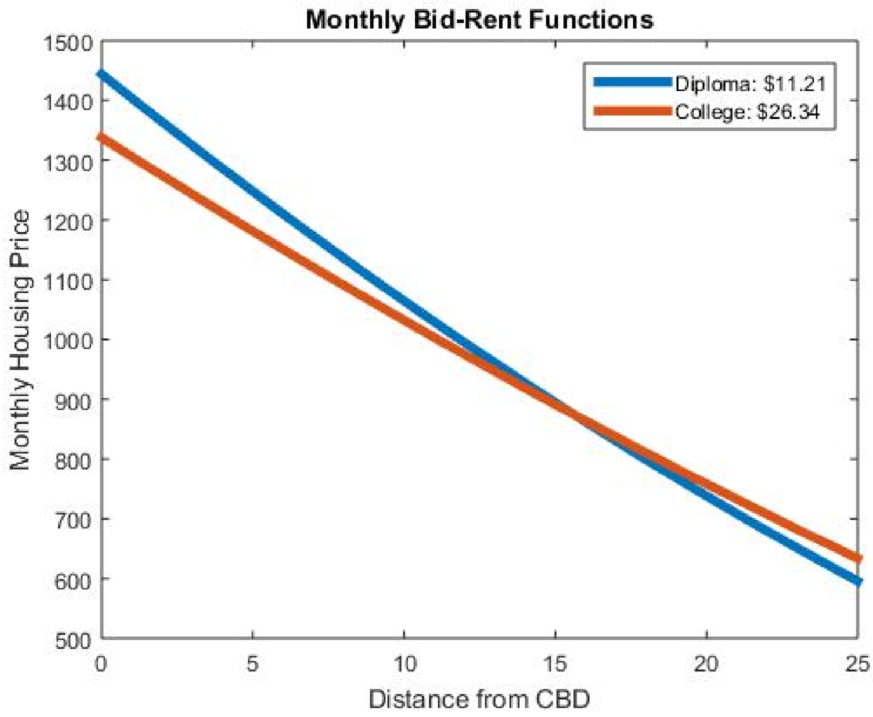

Figure 13: One worker: Simulated rent offered over distance for college-educated (red) and not college-educated (blue).

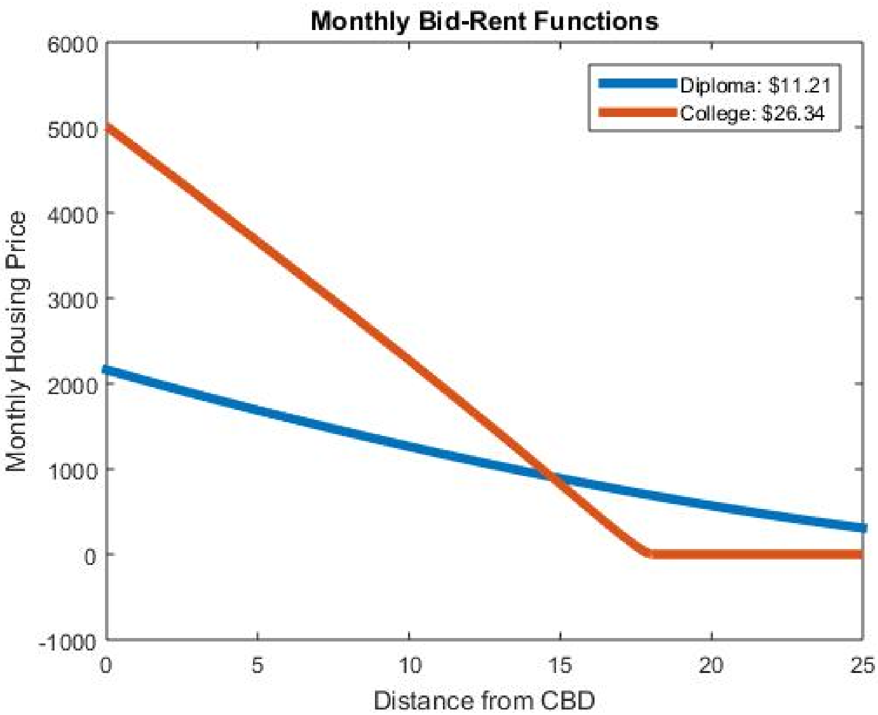

Figure 14: Two workers: Simulated rent offered over distance for college-educated (red) and not college-educated (blue). The model becomes unstable once rent approaches zero.

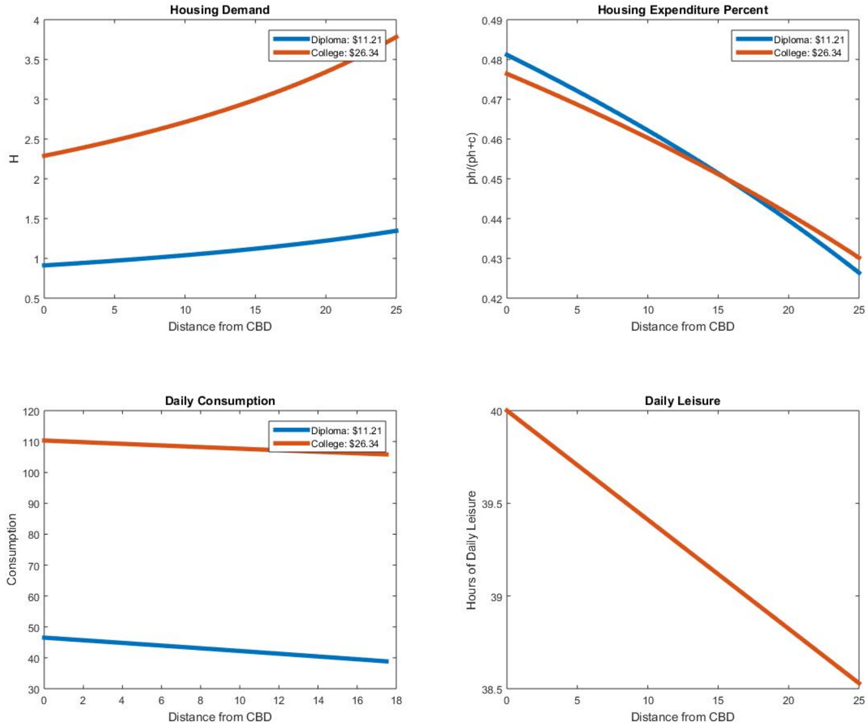

Figure 15: Simulated variables for single-earner households.

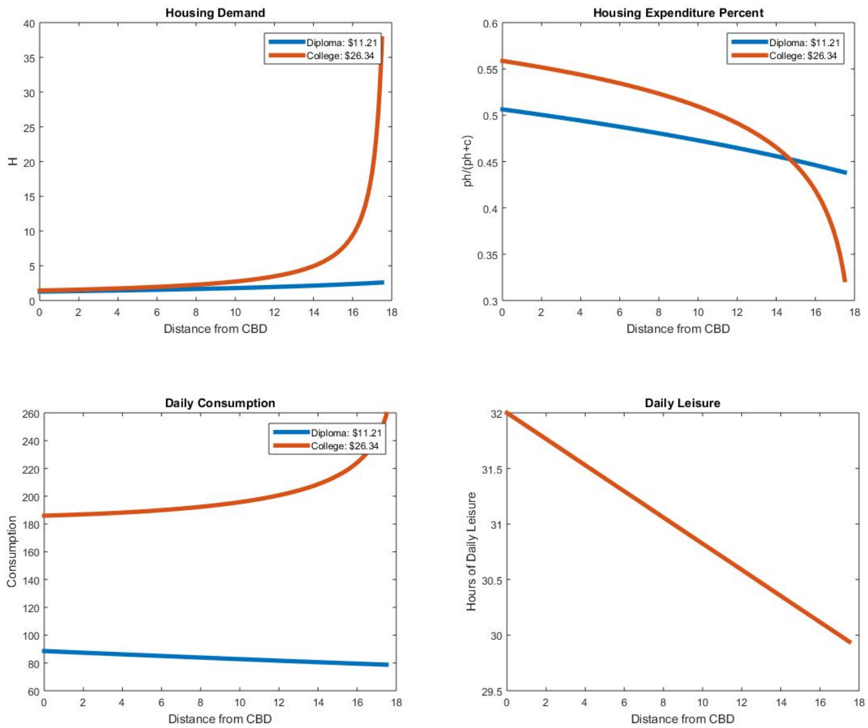

Figure 16: Simulated variables for two-earner households.

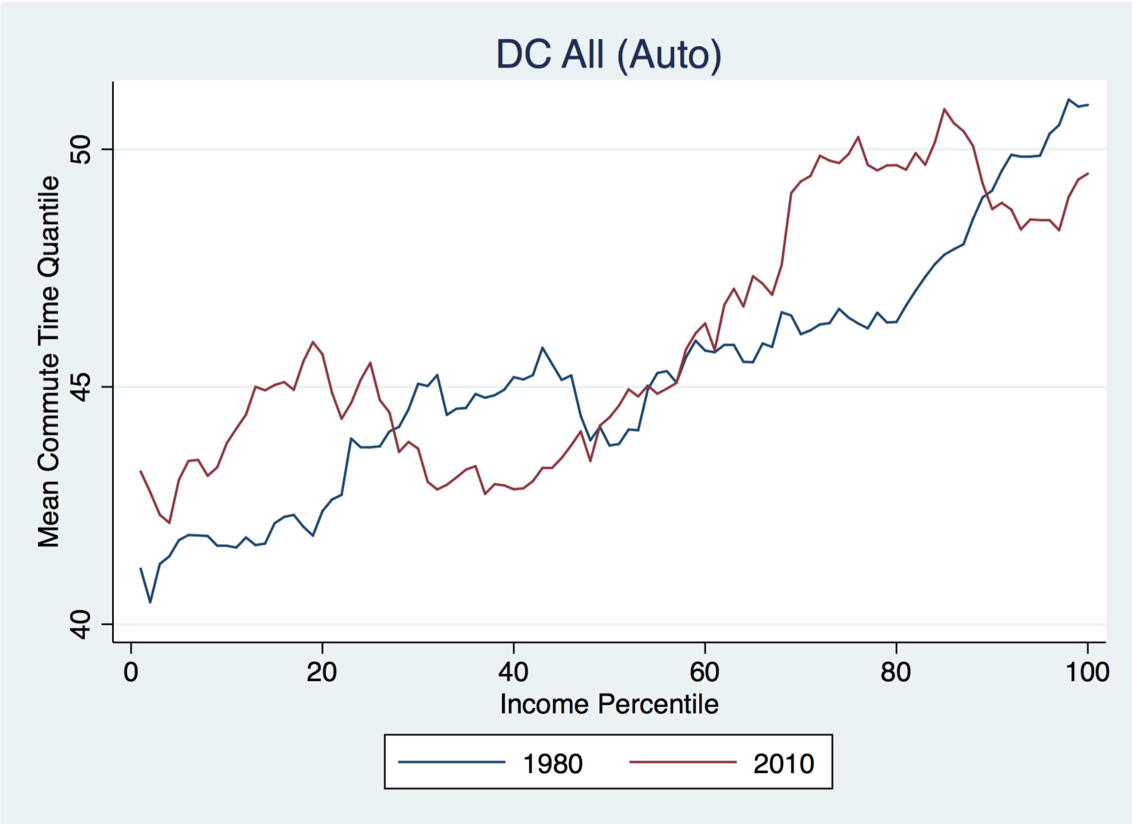

Figure 17: Auto commute time and income (smoothed).

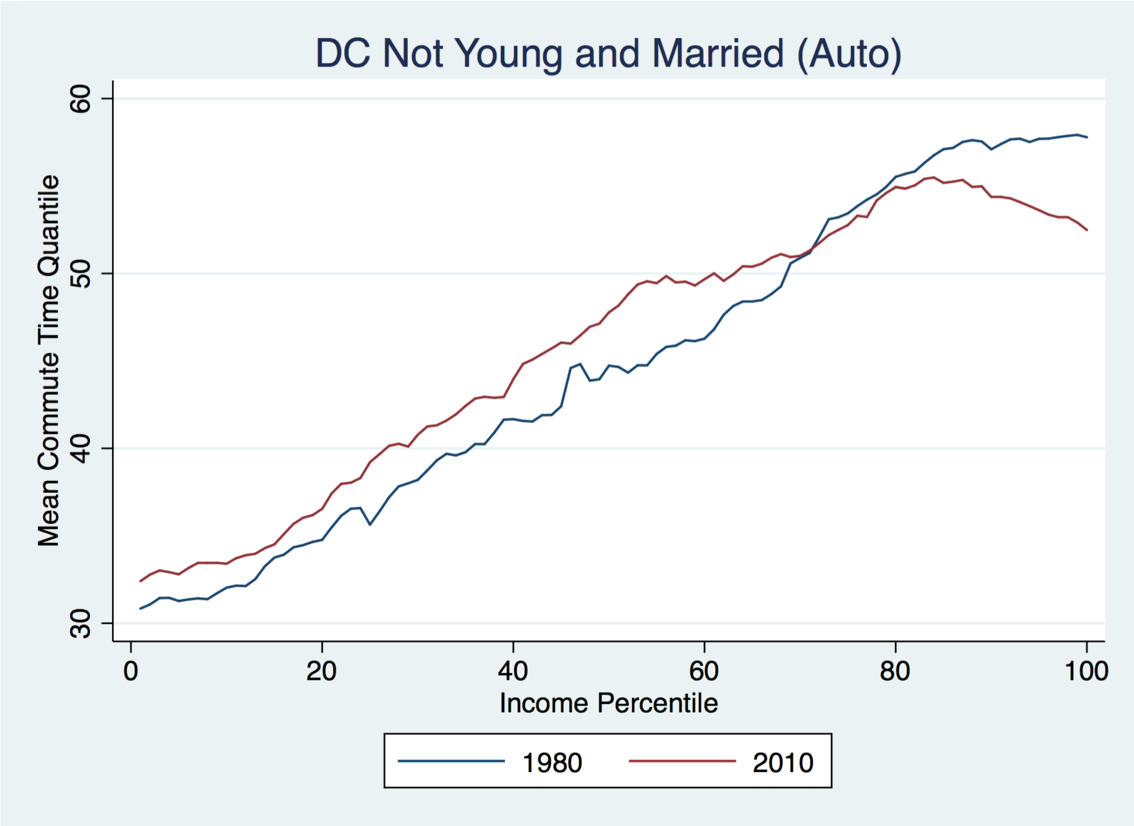

Figure 18: Auto commute time and income for the married over 35 (smoothed).

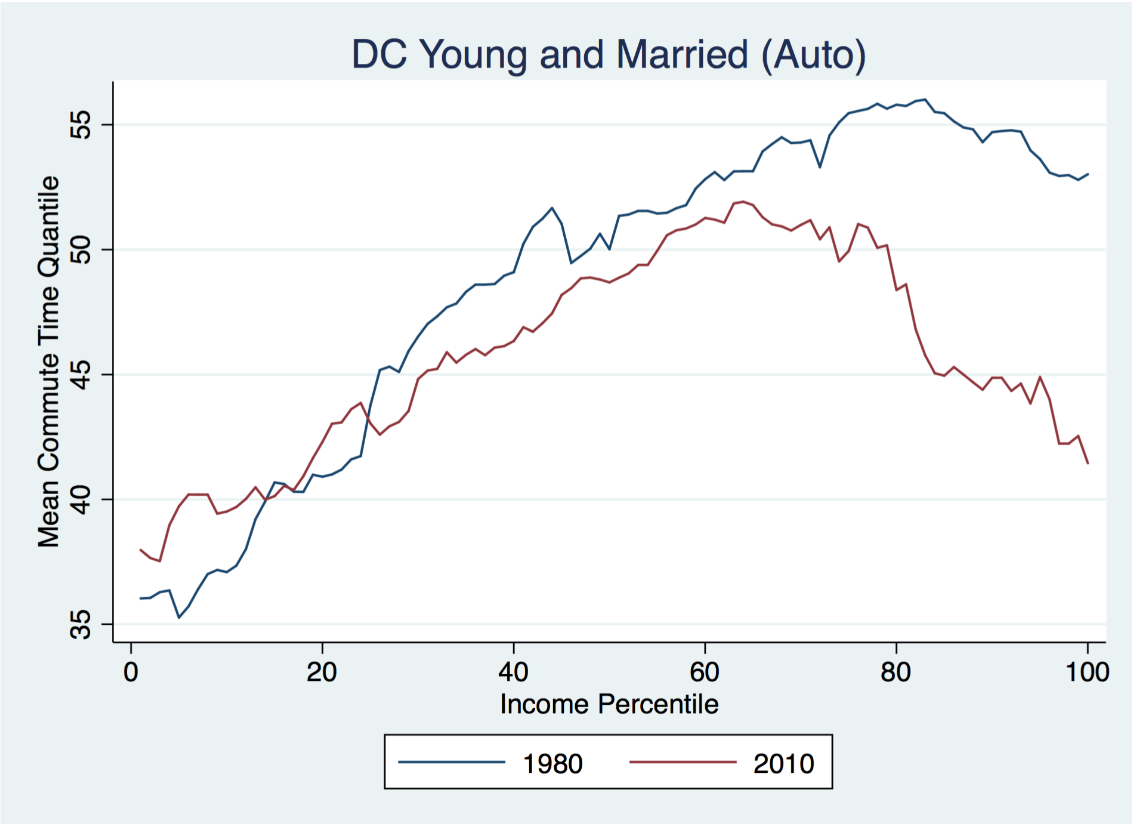

Figure 19: Auto commute time and income for the married under 35 (smoothed).

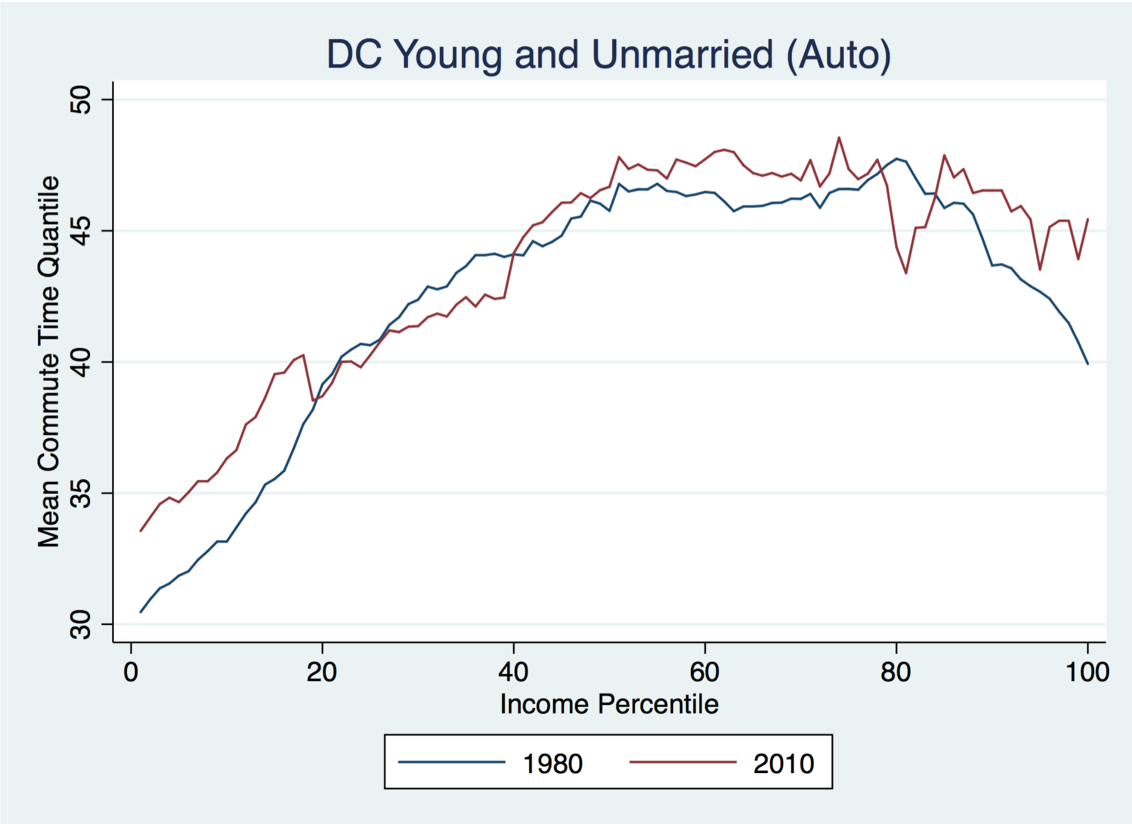

Figure 20: Auto commute time and income for the unmarried under 35 (smoothed).

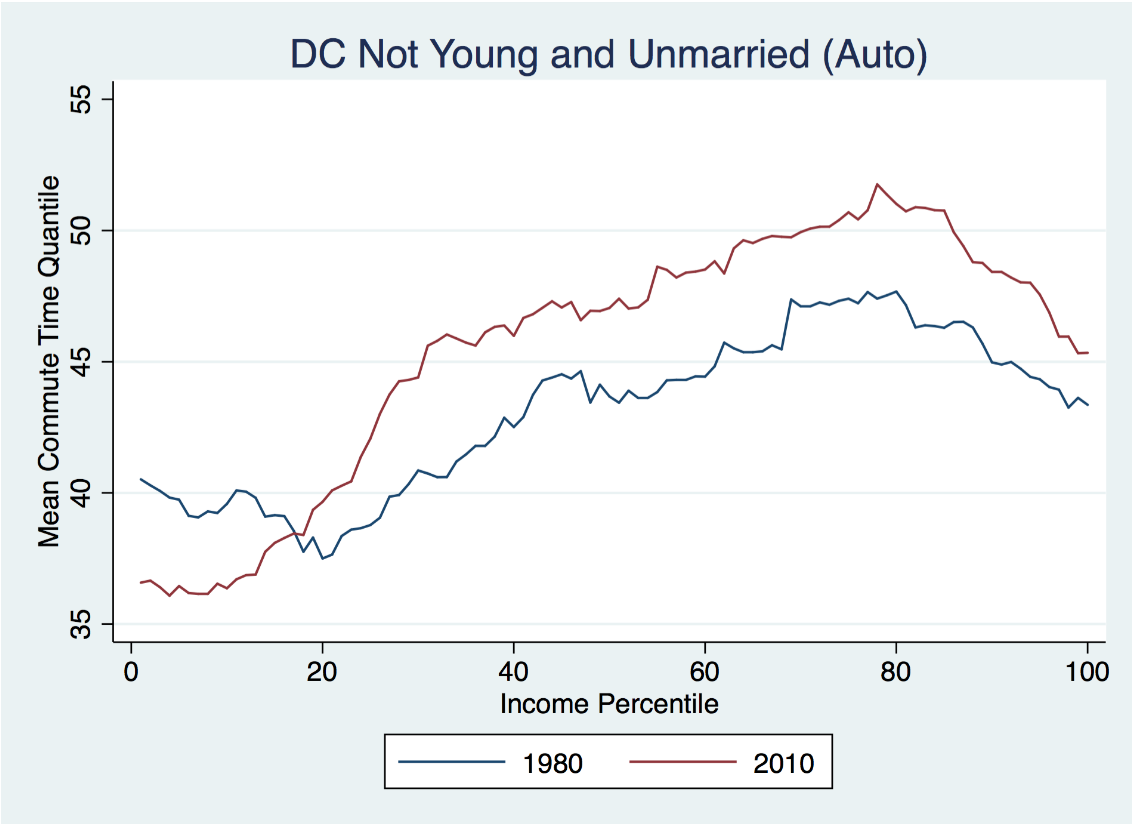

Figure 21: Auto commute time and income for the unmarried over 35 (smoothed).

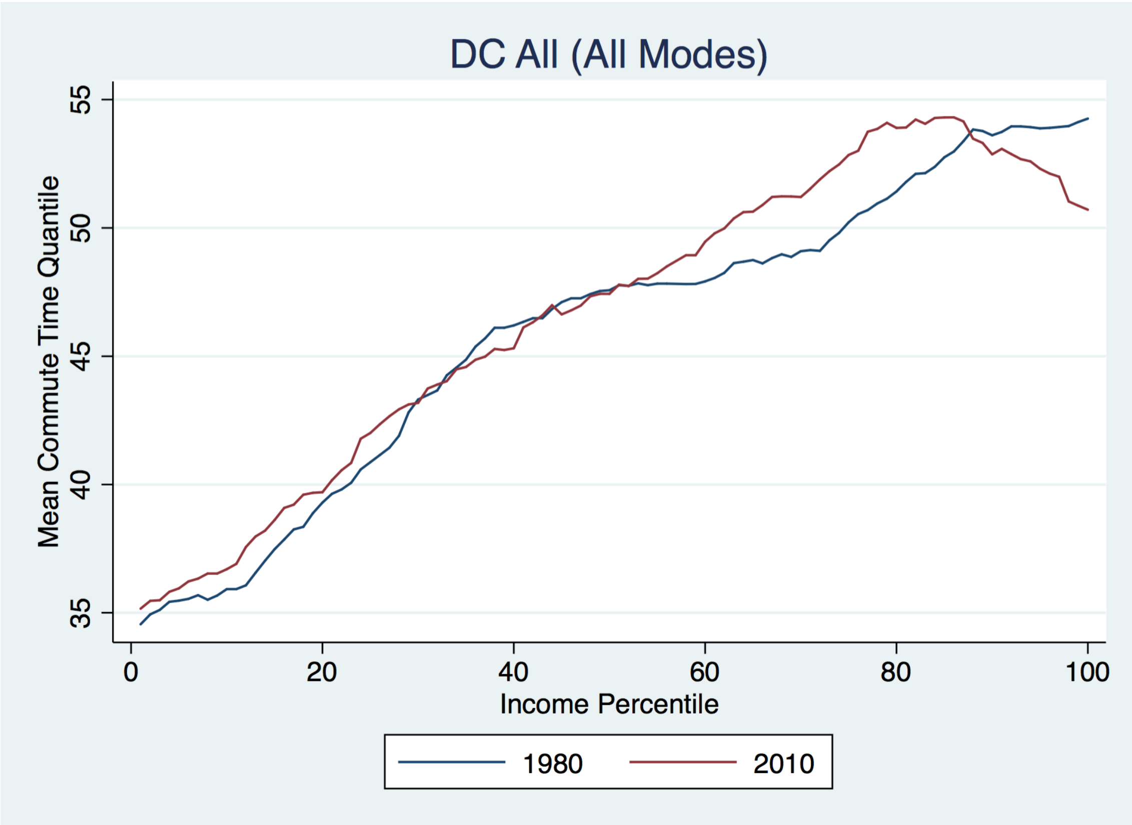

Figure 22: Commute time and income for all transportation modes (smoothed).

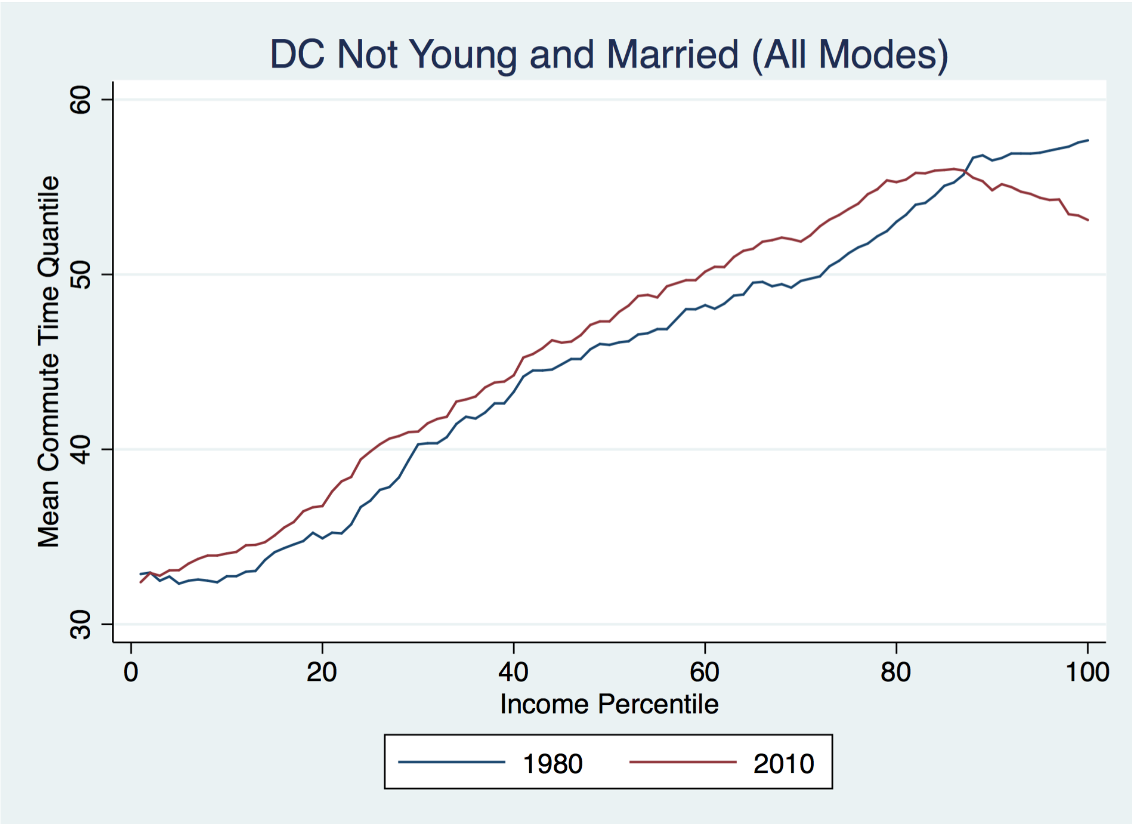

Figure 23: All-mode commute time and income for the married over 35 (smoothed).

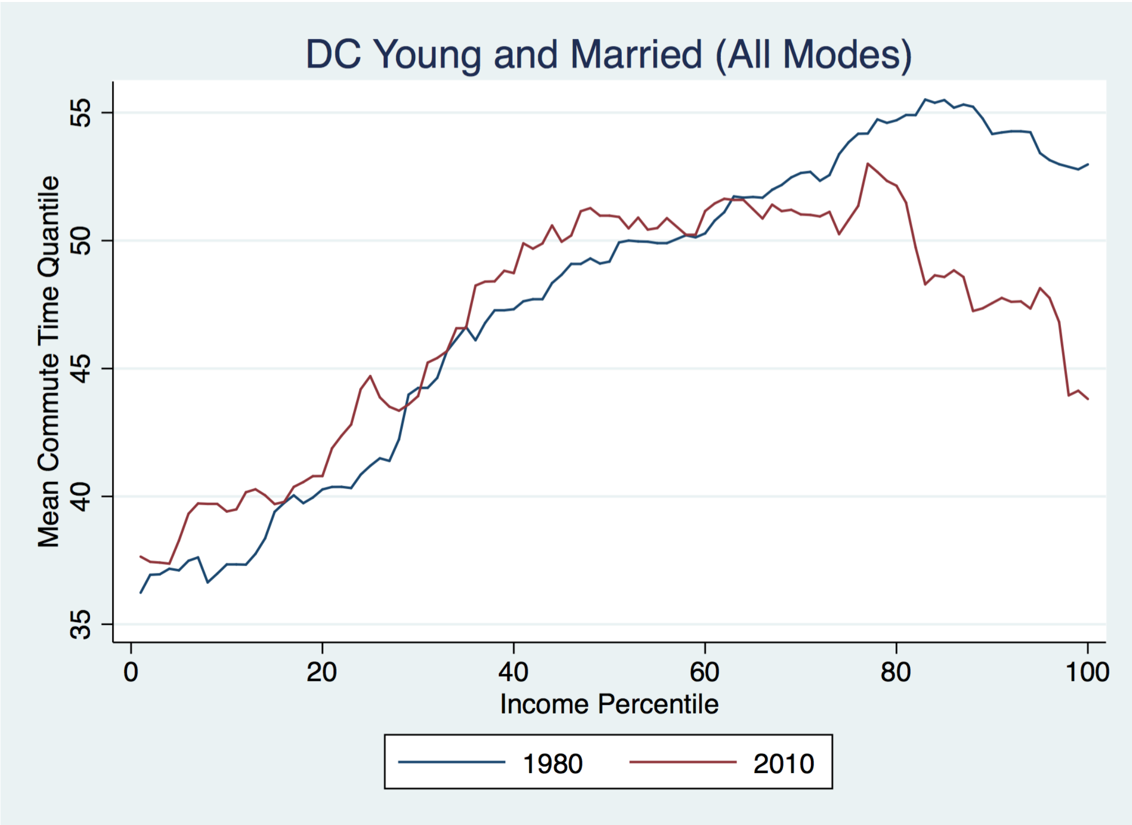

Figure 24: All-mode commute time and income for the married under 35 (smoothed).

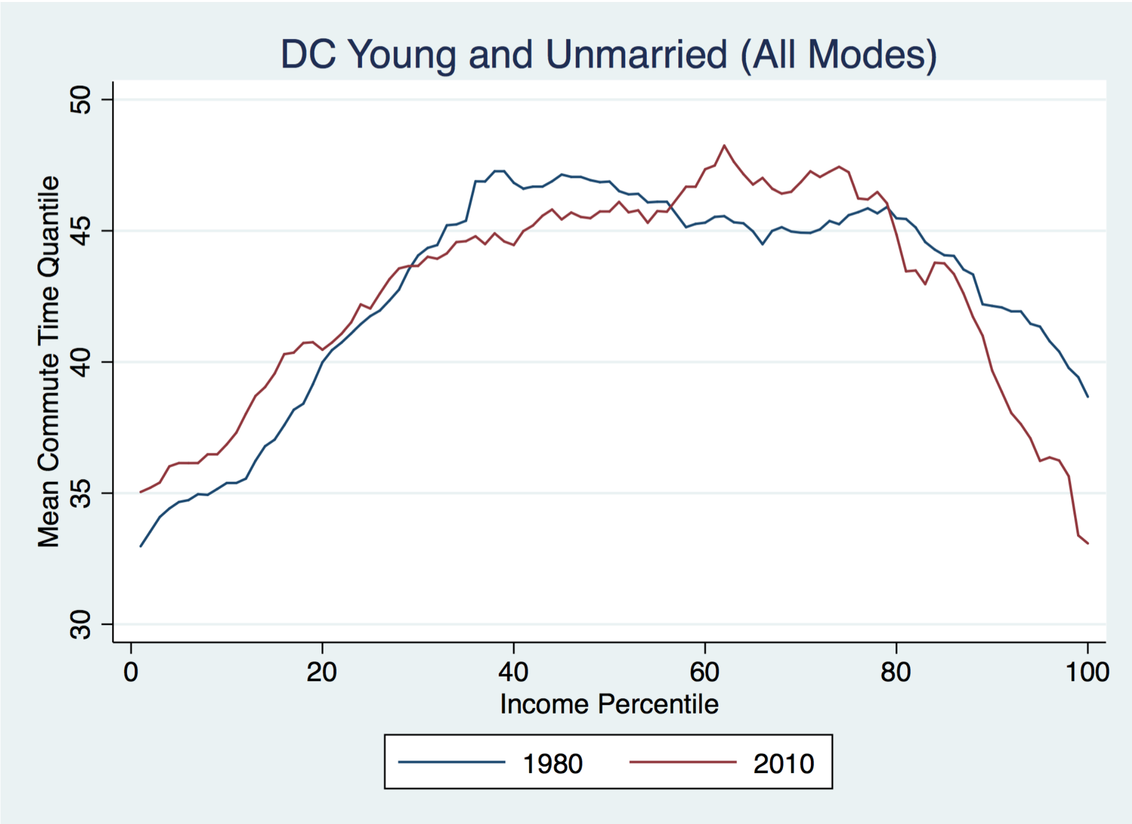

Figure 25: All-mode commute time and income for the unmarried under 35 (smoothed).

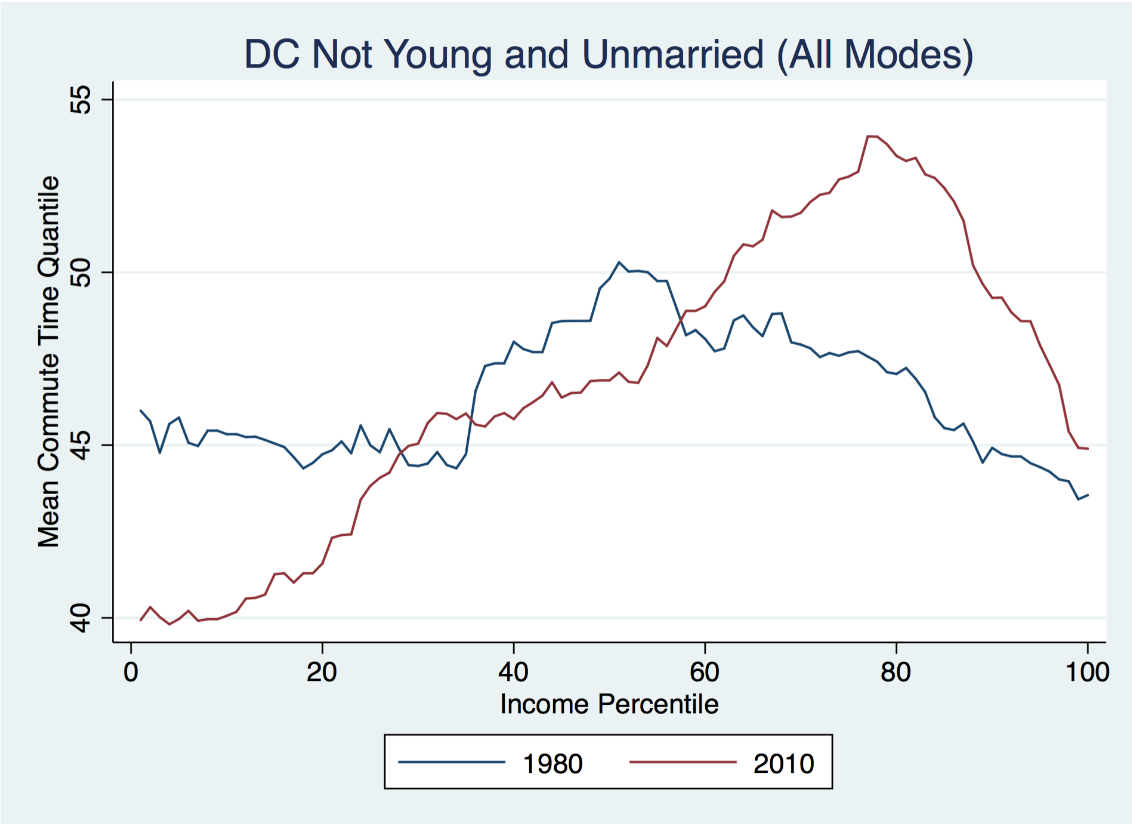

Figure 26: All-mode commute time and income for the unmarried over 35 (smoothed).