The Alonso-Muth model predicts how a worker's income affects his residential location within an urban area. Workers choose a residential location, balancing the lower rent at locations distant from the city center against the higher commuting cost that such locations entail. If the income elasticity of housing demand is greater than that of marginal commuting cost, the bid-rent function of a high-wage worker is flatter than that of a low-wage worker, and thus the high-wage worker lives farther from the city center. This theory, which was first articulated in the 1960s, was consistent with empirical evidence from that period.

The model did not fare so well in the 1970s and 1980s, however. On one hand were new studies of housing demand. Polinsky and Ellwood (20) pointed out biases in earlier studies and found income elasticities less than unity when these biases were corrected. These results indicate that the income elasticity of housing demand is less than that of marginal commuting cost, since the latter is typically close to unity, which in turn implies that the bid-rent function of a high-wage worker is steeper than that of a low-wage worker. Wheaton (25) provided more direct evidence on this point. He estimated bid-rent functions of different income groups and found no significant difference between those of higher and lower income households. These studies suggested that the Alonso-Muth model could not explain the residential pattern observed in the 1950s and 1960s.

On the other hand was the change in that pattern. In the 1970s, upper-income households began to return to the cities, the so-called...
"regentrification" movement. In the aggregate, that movement is still small, but is has produced a significant change in several American cities. Of course, if the income elasticity is less than unity, the Alonso–Muth model predicts that higher income households live closer to the city than lower income households, and thus regentrification might be viewed as a return to the long-run equilibrium. The question then is: Why was there a deviation from that equilibrium in the 1950s and 1960s?

LeRoy and Sonstelie (16) suggested one answer, an answer rooted in the life cycle of a commuting mode. Suppose there is just one mode to begin with and that the income elasticity of housing demand is less than unity, as the empirical evidence suggests. Higher wage workers have steeper bid–rent functions, so the Alonso–Muth model predicts that they live closer to the CBD than lower wage workers. Now introduce a new mode that is faster but more expensive than the existing mode. Because higher wage workers have higher values of time, the new mode may be economical for them, but not for lower wage workers. The speed of the new mode lowers the marginal commuting cost of higher wage workers, making their bid–rent functions flatter. If the new mode is fast enough, the bid–rent functions of these workers will be flatter than those of the lower wage workers who do not commute by the new mode. Higher wage workers will then have a comparative advantage in living farther from the city center. Thus, the new mode can lead to a change in residential patterns with some higher wage workers living farther from the center than lower wage workers.

As wages rise relative to the cost of the new mode, the new mode becomes economical for lower wage workers. Eventually almost everyone commutes on a new mode, and the comparative advantage that higher wage workers had in distant location evaporates. Residential locations then return to the pattern that prevailed before the new mode was introduced.

According to this view, the residential patterns observed after World War II result from the introduction of the automobile. The automobile was introduced in the 1910s, but automobile ownership was still concentrated among upper-income households in the 1950s. This accounts for the residential pattern observed in the 1950s and 1960s with high-income suburbs and low-income cities. By the 1970s, however, wages had risen enough relative to the cost of an automobile to make automobile ownership economical for almost everyone. Upper income households lost the advantage they previously had in suburban locations due to their exclusive ownership of automobiles. This led to the regentrification of the 1970s and 1980s.

The automobile was not the first instance in which a new mode of commuting was introduced in American cities. The first was the horse-
drawn streetcar introduced in the 1850s; before that time, most commuters walked to work. If the theory outlined above is correct, the streetcar should have had an effect on residential patterns that was similar to that hypothesized for the automobile nearly a century later. We examine that proposition in this paper.

Using data from Philadelphia in 1880 and a technique developed by Ellickson (91, we estimate bid-rent functions for different wage groups. Our estimates show that higher wage groups had steeper bid-rent functions in those areas of the city where all groups would have walked to work. In the absence of the streetcar, therefore, higher wage groups would have lived closer to the center than lower wage groups. In those areas where a higher wage group would have ridden the streetcar and a lower wage group would have walked, the bid-rent function of the lower group is steeper, indicating that the higher wage group would have lived farther from the center. We conclude that the streetcar did have the hypothesized effect on residential location.

I. PHILADELPHIA: WORK, RESIDENCE, AND THE STREETCAR IN 1880

In 1880, Philadelphia's central business district was concentrated along Market Street, between Broad Street and the Delaware River (see Fig. 1). Table 1 indicates that 45% of all adult male workers were employed at locations within a mile of the center of that area. Nevertheless, some employment enclaves were beginning to develop in other parts of the city, based on particular industries. Shipbuilding took hold on the Delaware River north of the original city in the districts of Kensington and the Northern Liberties. In the northwest, the proximity of Manayunk to the Schuylkill River made that part of the city attractive to the textile industry, which was dependent on water power.

The size of manufacturing establishments was growing during this period. In the first half of the nineteenth century, many establishments were small enough so that workplace and residence could be combined. By 1860, however, about half of manufacturing employees worked in industries that averaged more than 10 workers per establishment.¹ Workplace and residence became more separate as a consequence. Table 1 indicates that population was more disperse than workplaces in 1880, implying that many workers must have commuted from outlying areas to the center.

The main modes of commuting were walking and riding the streetcar (horse-car). The streetcar was a horse-drawn wagon, carrying up to 40

¹Warner (24), p. 77.
TABLE 1
Percent of Adult Males Working or Residing at Locations within \( D \) Miles from Center

<table>
<thead>
<tr>
<th>( D )</th>
<th>Working</th>
<th>Residing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>1.0</td>
<td>45</td>
<td>19</td>
</tr>
<tr>
<td>1.5</td>
<td>59</td>
<td>41</td>
</tr>
<tr>
<td>2.0</td>
<td>74</td>
<td>63</td>
</tr>
<tr>
<td>3.0</td>
<td>86</td>
<td>83</td>
</tr>
<tr>
<td>4.0</td>
<td>88</td>
<td>89</td>
</tr>
<tr>
<td>5.0</td>
<td>92</td>
<td>91</td>
</tr>
<tr>
<td>6.0</td>
<td>97</td>
<td>96</td>
</tr>
</tbody>
</table>

TABLE 2
Streetcar Ridership, 1862–1880

<table>
<thead>
<tr>
<th>Year</th>
<th>Passengers</th>
<th>Year</th>
<th>Passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1862</td>
<td>22,303,022</td>
<td>1872</td>
<td>66,781,414</td>
</tr>
<tr>
<td>1863</td>
<td>26,663,510</td>
<td>1873</td>
<td>69,771,195</td>
</tr>
<tr>
<td>1864</td>
<td>29,813,710</td>
<td>1874</td>
<td>78,008,201</td>
</tr>
<tr>
<td>1865</td>
<td>25,043,398</td>
<td>1875</td>
<td>87,387,331</td>
</tr>
<tr>
<td>1866</td>
<td>30,919,120</td>
<td>1876</td>
<td>117,795,833</td>
</tr>
<tr>
<td>1867</td>
<td>25,762,453</td>
<td>1877</td>
<td>89,588,128</td>
</tr>
<tr>
<td>1868</td>
<td>41,775,925</td>
<td>1878</td>
<td>85,343,035</td>
</tr>
<tr>
<td>1869</td>
<td>49,594,497</td>
<td>1879</td>
<td>90,824,855</td>
</tr>
<tr>
<td>1870</td>
<td>55,400,926</td>
<td>1880</td>
<td>99,045,515</td>
</tr>
<tr>
<td>1871</td>
<td>57,081,978</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


passengers, running on trials imbedded in city streets. The first streetcar company in Philadelphia was the Philadelphia and Delaware River Railroad, which went into operation on January 20, 1858. The streetcar was faster than walking, attaining speeds of four to six miles per hour. The initial fare was five cents per ride. It increased to six cents in 1862 and seven cents in 1865, an increase which may be partly due to the Civil War inflation. Fares remained constant until 1877, when they dropped to six cents per ride. In comparison, a laborer earned about $1.00 a day during that period.

A number of companies provided streetcar service. Each originally occupied a small niche, and little effort was made to develop an integrated route system. Most of the major companies operated lines travelling north-south, matching the general pattern of expansion of the city itself. Growth to the north was unimpeded by topographical features, while growth to the west and south was restricted by the Schuylkill River. It was not until the 1870s, after a number of bridges had been built across the Schuylkill, that the city began expanding to the west (Beers (3)). The routes for each company are described in Cox (7).

2Taylor (23) describes general characteristics of the streetcar, Stirling (22) gives specifics of its history in Philadelphia, and Steen (21) examines its effect on Philadelphia’s population density.

3Development to the west was further stimulated by the Pennsylvania Railroad’s “Main Line,” a commuter railroad. However, it was not until 1882, when the opening of the Broad Street Station allowed passengers to travel to the heart of the city, that the Main Line became a significant commuting mode. Prior to that, commuters had to disembark at the railroad’s West Philadelphia terminal (Burt and Davies (5)).
Table 2 gives total ridership on all streetcar lines from 1862 to 1880. Ridership was relatively stable until 1867, never exceeding 31 million, then climbed steadily to a peak of over 110 million rides in 1876. However, ridership for that year was abnormally high because of the Centennial Exposition, suggesting that the 99 million in 1880 is more indicative of the long-run trend. Ridership grew faster than the population during the period, with 39 rides per capita in 1862, 83 in 1870, and 116 in 1880.

How significant was the streetcar in the commuting process? By comparing the daily ridership for companies serving different parts of the city under a variety of circumstances, Hershberg et al. (13) estimated that in 1880 37% of streetcar passengers were commuters. Assuming each regular commuter made 624 trips per year (2 trips per day, 6 days per week, 52 weeks per year), that estimate implies that 16.82% of the city's workforce commuted by streetcar.

II. A THEORY OF THE STREETCAR AND RESIDENTIAL PATTERNS BY INCOME

In the theory of urban residential location developed by Alonso (1) and Muth (18), people work in a central business district, reside in the surrounding area, and commute between residence and workplace. Because commuting is costly, workers are willing to pay more for housing closer to the center. This tradeoff between housing rent and distance from the center is captured by a worker's bid-rent function, \( b(d, u) \), which gives rent per unit of housing as a function of distance to the center, \( d \), and utility level, \( u \). At each distance, \( d \), a worker's bid-rent is the most he could pay per unit of housing while achieving the utility level, \( u \). If a worker's bid-rent functions are relatively steep, he will have a comparative advantage in residential locations close to the center.

The gradient of a worker's bid-rent functions depends on his marginal commuting cost and his housing demand. Let \( h(d, u) \) denote the quantity of housing he would demand at utility level \( u \) and rent \( b(d, u) \), and let \( c(d) \) denote his commuting cost. Following the standard analysis,

\[
\frac{\partial b(d, u)}{\partial d} = -\frac{c'(d)}{h(d, u)}.
\]

The slope of his bid-rent function is thus determined by the ratio of his marginal commuting cost to his compensated housing demand.

A worker's marginal commuting cost would have depended on his mode of commuting: walking or riding the streetcar. A worker would have commuted by streetcar if the value of time saved exceeded its fare. To express the condition analytically, let \( w \) denote the value of time in dollars per hour, and let \( s \) denote the difference between walking and the...
streetcar in the hours required to travel one mile. The value of time saved by riding the streetcar for distance \( d \) is \( wds \). Since it increases with \( d \), define a break-even distance, \( d^* \), at which the value of time saved by the streetcar equals its fare, denoted by \( f \). The break-even distance is

\[
d^* = \frac{f}{ws}
\]  

(2)

A commuter would have walked to work if he had lived closer to the center than \( d^* \), and he would have ridden the streetcar if he lived farther than \( d^* \).

Since the streetcar was faster than walking, it lowered the marginal commuting cost, making the bid-rent function flatter. The bid-rent function would therefore be kinked at the break-even distance \( d^* \).\(^4\) For distances less than \( d^* \), the commuter would have walked, and the bid-rent function would have been the same as it was without the streetcar. For distances beyond \( d^* \), the commuter would have ridden the streetcar, and the bid-rent function would be flatter than it was without the streetcar.

Figure 2 depicts two representative bid-rent functions for a worker. The steeper one assumes he walks to work. The flatter one assumes he rides the streetcar to work. Both functions constrain him to the same utility level. His unconditional bid-rent function assumes he commutes by

\(^4\)A flat fare, as assumed here, implies one kink. Fares that vary discretely with distance introduce more than one kink. Fares were essentially flat in Philadelphia during the period studied here.
the cheapest mode; it is the upper envelope of the two conditional functions. The two conditional functions intersect at the break-even distance $d^*$. The availability of the streetcar makes the worker's bid-rent for distances beyond $d^*$ greater than before, implying that he can compete more effectively for residential locations at these distances.

A worker's breakeven distance depends on the value of his time. Workers with high wages and thus high values of time would have break-even distances relatively close to the center. On the other hand, except for very long rides, commuting by streetcar would not be economical for workers with low wages. The streetcar would have increased the amount high-wage workers were willing to pay for distant locations without affecting the willingness to pay of low-wage workers. As a consequence, the streetcar should have increased the frequency of high-wage workers in distant locations.

Its effect on locations close to the center is less clear. In areas so close that neither high- nor low-income workers would find commuting by streetcar economical, bid-rent functions would be the same as they were before the streetcar. If high income workers tended to live closer to the center before the streetcar, there may have also been a concentration of those workers near the center after the streetcar. This issue is pursued in more detail in LeRoy and Sonstelie (16).

### III. ESTIMATES OF BID-RENT FUNCTIONS WITH THE STREETCAR

How significant was the residential decentralization of high-wage workers? To address this question, we employ a method developed by Ellickson (9). Workers are classified into $n$ wage groups. The bid-rent function of a member of a specific group is represented as the sum of a nonstochastic function common to all members of the group (the bid-rent function of the representative member) and a random disturbance term, which reflects differences in tastes among the members. We assume the nonstochastic function takes the following functional form for group $i$ bidding on location $t$:

$$\log(b_{it}) = \alpha_i + \beta_i d_t + \gamma_i (d_t - d_{it}^*) x_{it},$$

where $b_{it}$ is the bid of the representative member of group $i$ for a unit of housing at location $t$, $d_t$ is the distance from $t$ to the center, $d_{it}^*$ is the break-even distance of a group $i$ from location $t$, $x_{it}$ is a dummy variable taking the value of unity if $d_t$ exceeds $d_{it}^*$ and zero otherwise, and $\alpha_i$, $\beta_i$, and $\gamma_i$ are unknown parameters. Since the function is log-linear, its gradient is the percentage change in the bid-rent per unit change in distance. The gradient takes two values depending on whether the dis-
tance from $t$ to the center is less than the break-even distance for group $i$. If it is less, $x_{it}$ is zero, and the gradient is $\beta_i$, which is the percentage change in bid-rent, assuming the representative member walks to work. If $x_{it}$ is unity, the gradient is $\beta_i + \gamma_i$, which is the percentage change in bid-rent, assuming the representative member rides the streetcar to work. The theory of urban residential location outlined in Section II implies that $\beta_i$ should be negative and $\gamma_i$ should be positive.

Following Ellickson, we assume that the random disturbance terms are independently and identically distributed Weibull and that the worker with the highest bid for a location occupies that location. These assumptions permit a simple expression for the log of the odds that a member of group $i$ will occupy location $t$ rather than a member of some other reference group. Let $p_{it}$ denote the probability that a member of group $i$ occupies location $t$. The log odds expression is

$$\log\left(\frac{p_{it}}{p_{1t}}\right) = (\alpha_i - \alpha_1) + (\beta_i - \beta_1) d_t + \gamma_i (d_t - d_{it}^*) x_{it}. \quad (4)$$

Group 1 is the reference group in the expression. In our empirical work, the lowest income group plays that role. The advantage of this selection is that because of its low wage it never chooses the streetcar over walking. Thus the dummy variable $x_{it}$ is always zero, and the terms multiplying that variable vanish in the log odds expression. We take advantage of that fact by leaving those terms out of Eq. (4).

Equation (4) is our basic estimating equation. Note that the $\gamma$'s can be estimated directly in that equation, but only differences between the $\beta$'s can be estimated. There is no loss in that, however, since it is the difference in the gradients of bid-rent functions that is crucial in determining residential location. Suppose group $i$ has a higher wage than group $j$. Its break-even distance will be closer to the center. For distances less than or equal to this break-even distance, both groups are walking. If $\beta_i - \beta_j < 0$, group $i$'s bid-rent function is steeper than group $j$'s in this region, and the frequency of group $i$ relative to group $j$ declines with distance. For locations between the break-even distances of the two groups, $i$ rides the streetcar and $j$ walks, so the frequency of group $i$ relative to group $j$ declines if and only if $\beta_i + \gamma_i - \beta_j < 0$. Finally, for distances beyond the break-even distance of the lower wage group, the frequency of group $i$ declines relative to group $j$ if and only if $\beta_i + \gamma_i - \beta_j - \gamma_j < 0$. The streetcar can cause a fundamental change in residential patterns because of the second zone. Even if the frequency of the high-wage group declines in the first zone because $\beta_i - \beta_j < 0$, it may increase with distance in the second zone if $\gamma_i$ is sufficiently large.

The form of the bid-rent function we have chosen implies that the compensated demand for housing has a price elasticity of unity. To see
this, assume that $x_{it}$ is zero and differentiate Eq. (3) with respect to
distance, yielding $\frac{\partial b_{it}}{\partial d_i} = \beta_i b_{it}$. From Eq. (2), the derivative of the
bid-rent function with respect to distance is equal to the ratio of the
marginal commuting cost to the compensated demand for housing. Let $c'_{it}$
be the marginal commuting cost, and let $h_{it}$ be the compensated demand
for housing. Equating these two expressions for the gradient of the
bid-rent function yields $b_{it} h_{it} = c'_{it} / \beta_i$. Assuming that marginal commut-
ing cost is constant, this expression implies that total housing expendi-
tures, $b_{it} h_{it}$, does not vary as housing rent, $b_{it}$, varies, which in turn
implies that the compensated demand for housing must have a price
elasticity of unity. Estimates of the price elasticity are lower than unity
(see Polinsky and Ellwood (2011), but we retain the form because of its
simplicity. In particular, it allows us to represent the gradient of a
bid-rent function with one parameter.

Our data set is a sample of adult males from the U.S. Census of
Philadelphia in 1880. The set was created by the Philadelphia Social
History Project. Blacks, Irish, and Germans were intentionally oversam-
plesd in creating the data set; we reduced their representation to yield a
7.5% sample of all adult males in Philadelphia. The record for each
person sampled includes his residential location and his occupation. Using
estimates from Goldin (12) of the average wage in 1880 for each occupa-
tion reported in the data set, wages were assigned to each person, and
each person was then assigned to one of five wage groups. The intervals in
weekly wages for each group are given in Table 3. Those without occupa-
tions or wages were excluded from the sample. Table 3 also gives the
distribution of the sample among the five wage groups.

The data were grouped into geographical grids about one-sixth of a
square mile in area. Each grid was treated as an observation for our

---

**TABLE 3**

Distribution of Sample among Wage Groups

<table>
<thead>
<tr>
<th>Weekly Wage</th>
<th>Percent of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>$0-$8</td>
</tr>
<tr>
<td>Group 2</td>
<td>8–12</td>
</tr>
<tr>
<td>Group 3</td>
<td>12–16</td>
</tr>
<tr>
<td>Group 4</td>
<td>16–20</td>
</tr>
<tr>
<td>Group 5</td>
<td>20 &amp; above</td>
</tr>
</tbody>
</table>

---

1Wages were taken from an unpublished appendix to Goldin (12), entitled “Wage Data for Various Occupations in the South, 1870 and 1880,” by Linda Johnson.
estimation of Eq. (4), and the frequencies of each group within a grid were
the observations of the $p_{ij}$'s in that equation. In essence, we estimate Eq.
(4) by regressing the log of the relative frequencies of the groups in each
grid on the two distance variables in that equation. The first of these two
distance variables is the distance from the grid to the center. Euclidean
distance was used for this variable.

The second of these variables involves the break-even distance, $d^*$. Maps of the streetcar lines compiled by the Philadelphia Social History
Project were used to determine which grids had streetcars running through
them. For grids with streetcar lines, $d^*$ was calculated as in Eq. (2). The
value of time for a group was assumed to be half its average wage, and
streetcar fares and speeds were taken from the Auditor General's Report
(2). For grids with streetcar lines, break-even distances were 4.48 miles for
group 2, 3.30 miles for group 3, 2.70 miles for group 4, and 1.44 miles for
group 5.

For grids without streetcar lines, we attempted to take account of the
fact that riding the streetcar would have implied a more circuitous com-
mute than walking. The distance to the nearest line was calculated, and
the value of time required to walk that distance was treated as a fixed cost,
like the fare, in calculating $d^*$. Because many residential areas were not
served directly by streetcar lines, break-even distances varied considerably
in our sample, giving us observations on how the availability of the
streetcar affected bid-rent, holding distance from the center constant.

Four equations must be estimated, one for each income group other
than the reference group. The method developed by Parks (19) was used
to estimate these equations. The results are displayed in Table 4. Estimates of the $\beta_i - \beta_1$ coefficient are negative and significant for Groups 3,
4, and 5, and estimates of the $\gamma_i$ coefficient are positive for all three and
significantly so for Groups 4 and 5. It is also positive for Group 2, though
not significant. The insignificance of the coefficients for Groups 2 and 3 is
not surprising. The break-even distances for these Groups are 4.48 and
3.30 miles, respectively, and there are only a few grids located that far
from the city center. As a consequence there are few observations in our
sample in which Groups 2 and 3 are assumed to ride the streetcar. The
fact that the streetcar has a significant effect only for the upper two wage
groups also agrees with estimates by Hershberg et al. (13) that only about
17% of the workforce commuted by streetcar in 1880. The theory suggests
that these commuters should be concentrated in the upper wage groups

---

6 We took the value of time in commuting to be half the wage based on studies summarized in Bruzelius (4).

7 We have also estimated bid-rent functions for 1850, 1860, and 1870. These results are reported in an earlier version of the paper, which is available on request.
TABLE 4
Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_{2} - \beta_{1}$</td>
<td>0.022</td>
<td>0.022</td>
</tr>
<tr>
<td>$\gamma_{2}$</td>
<td>0.056</td>
<td>0.075</td>
</tr>
<tr>
<td>$\beta_{3} - \beta_{1}$</td>
<td>$-0.076^*$</td>
<td>0.025</td>
</tr>
<tr>
<td>$\gamma_{3}$</td>
<td>0.058</td>
<td>0.065</td>
</tr>
<tr>
<td>$\beta_{4} - \beta_{1}$</td>
<td>$-0.141^*$</td>
<td>0.026</td>
</tr>
<tr>
<td>$\gamma_{4}$</td>
<td>0.198$^*$</td>
<td>0.055</td>
</tr>
<tr>
<td>$\beta_{5} - \beta_{1}$</td>
<td>$-0.127^*$</td>
<td>0.033</td>
</tr>
<tr>
<td>$\gamma_{5}$</td>
<td>0.171$^*$</td>
<td>0.052</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>$N$</td>
<td>455</td>
<td></td>
</tr>
</tbody>
</table>

*aSignificant at 5% level.

and hence that the effect of the streetcar on bid-rent functions would only be significant for those groups.

These results are explored in more detail in Table 5. The top half of that table reports differences in bid-rent gradients among all five groups when each is walking. For each of the 10 possible pairings, the table reports the differences between the gradient of the higher wage group and that of the lower wage group. The entries are $\beta_{i} - \beta_{j}$, for $i > j$. If an entry is negative, the higher wage group has the steeper bid-rent function when both groups are walking. Note that 8 of the 10 differences are negative, and 7 of those are significantly negative. The only two that are positive are for Group 2 versus Group 1 and Group 5 versus Group 4, but neither is significantly different from zero. The lack of significant difference in these two cases is not surprising since each involves comparisons between adjacent groups, groups that are not very different in wages. If differences in wages cause separation among groups, we would expect that separation to be most significant for groups with the largest differences in wages. That seems to be the case in the top half of Table 5, so we conclude that the higher wage group tends to have the steeper bid-rent function when both groups are walking. This conclusion is the reverse of the standard assumption made in the 1960s about the bid-rent functions of different income groups. However, it is consistent with the predictions of the Alonso-Muth model if the income elasticity of housing demand is less than unity, as Polinsky and Ellwood (20) have found. It is also consistent with the basic
TABLE 5

Differences in Bid–Rent Gradients
(Row Gradient Less Column Gradient)$^a$

<table>
<thead>
<tr>
<th>Walking</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>0.022</td>
<td>(0.022)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 2</td>
<td>0.076$^b$</td>
<td>(0.025)</td>
<td>-0.097$^b$</td>
<td>(0.024)</td>
</tr>
<tr>
<td>Group 3</td>
<td>0.141$^b$</td>
<td>(0.026)</td>
<td>-0.162$^b$</td>
<td>(0.024)</td>
</tr>
<tr>
<td>Group 4</td>
<td>0.127$^b$</td>
<td>(0.033)</td>
<td>-0.148$^b$</td>
<td>(0.032)</td>
</tr>
<tr>
<td>Group 5</td>
<td>0.078</td>
<td>(0.068)</td>
<td>0.039</td>
<td>(0.054)</td>
</tr>
<tr>
<td>Streetcar</td>
<td>0.018</td>
<td>(0.058)</td>
<td>0.036</td>
<td>(0.043)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.058</td>
<td>(0.040)</td>
<td>0.133$^b$</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Group 3</td>
<td>0.046</td>
<td>(0.031)</td>
<td>0.120$^b$</td>
<td>(0.038)</td>
</tr>
<tr>
<td>Group 4</td>
<td>0.023</td>
<td>(0.034)</td>
<td>0.185$^b$</td>
<td>(0.039)</td>
</tr>
<tr>
<td>Group 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$Standard errors in parentheses.
$^b$Significant at 5% level.

premise of LeRoy and Sonstelie (16): When everyone commutes by the same mode, the rich tend to live closer to the center than the poor; deviations from that pattern can occur when a new mode is introduced.

The bottom half of Table 5 reports these same differences in bid–rent gradients when the higher wage group is riding the streetcar and the lower is walking. The entries are $\beta_i + \gamma_i - \beta_j$, for $i > j$. A positive coefficient implies that the higher wage group has the flatter bid–rent function when it is riding the streetcar and the lower wage group is walking. Eight of the ten are positive, and three are significantly positive. Now the significant coefficients are for adjacent or nearly adjacent groups (5 versus 4, 5 versus 3, and 4 versus 3), which is consistent with the results in the top half of the table. Without the streetcar, the higher wage groups tend to have the steeper bid–rent, and that difference is larger as the larger is the difference in wages between the groups. The streetcar flattens bid–rents. In cases where the groups had very similar bid–rent without the streetcar (adjacent groups), the streetcar will give the higher wage group a decided advantage in more distant locations. In cases where the lower group had a
decided advantage in distant locations without the streetcar (nonadjacent groups), the streetcar will neutralize that advantage. The net effect is to give the highest wage groups, 4 and 5, a significant advantage over Group 3 in suburban locations and to neutralize the distinct advantage that Groups 1 and 2 would have had in suburban locations without the streetcar.

In our view these results support the conclusion that the streetcar caused a decentralization of high-wage workers. When high-wage and low-wage workers are both walking to work, high-wage workers tend to have steeper bid-rent functions. When high-wage workers are riding the streetcar and the low-wage workers are walking, the opposite occurs. From riding the streetcar, high-wage workers gained a comparative advantage in distant locations that they would not have had without it.

IV. CONCLUSION

The streetcar became faster and more efficient as electrification was introduced in the 1980s. Elevated lines and subways were built in the first decade of the 1900s, further improving service. Fares fell to five cents per ride and remained there until 1920.

We do not have data on residential location during this period, but it is tempting to speculate on the consequences of these developments based on our exploration of the preceding period. Our results indicate that high-wage workers had a comparative advantage in distant locations when they rode the streetcar and low-wage workers walked. In the early phase of the streetcar's development, low-wage workers would have rarely found it economical to commute by streetcar, giving high-wage workers an advantage in distant locations. But this advantage could not have lasted long. From 1880 to 1920, the nominal wage of laborers in Pennsylvania more than tripled. Since the nominal cost of the streetcar remained constant and its speed increased, the streetcar must have soon become an economical mode of commuting for low-wage workers as well, eroding the comparative advantage that high-wage workers had in distant locations. As a consequence, the movement of high-wage workers away from the city in the second half of the nineteenth century should have been reversed in the first few decades of the twentieth century.

We do not know whether this reversal occurred, but there is reason to believe that it did not because of another innovation in commuting: the automobile. The automobile was introduced in the 1910s, and its effect must have been similar to that of the streetcar in an earlier era. The

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8Lebergott (17) reports in Table A5 that a common laborer in Pennsylvania had average daily earnings of $1.25 in 1880 and average hourly earnings of $0.49 in 1919. Assuming a 10-hour day, the 1880 wage is $0.125 per hour, less than a third of $0.49.
automobile was faster and more convenient than its chief competitor, the trolley, but it entailed a large fixed cost. As a consequence, it would only have been economical for someone with a high value of time. Just as the streetcar in an earlier time, it gave its riders a comparative advantage in distant locations. The movement of high-wage workers away from the city center initiated by the streetcar would have only been intensified by the automobile.

This speculation squares with a common public concern in the 1950s and 1960s: the flight of the middle class to the suburbs. Our explanation is that the middle class had cars in the 50s and 60s, the lower class did not, and car ownership is a source of comparative advantage in suburban locations. These conditions are changing in the 70s and 80s, however, as car ownership becomes more widespread. In 1977, 75% of households in the bottom two quintiles of the income distribution owned cars; only 35% owned cars in 1952. The advantage that the middle class had in suburban locations has eroded as a consequence, which may explain the movement of the middle class back to the city centers in the 1970s and 1980s. The extent of this so-called “reentification” of the cities is still to be determined. Even in its current limited form, however, it represents some reversal of the suburbanization of the 1950s and 1960s. The modern era may be playing out a scenario that was previously forestalled by the introduction of the automobile, a hypothesis developed in more detail in LeRoy and Sonstelie [16].

We would not like to leave the impression that our theory relating residential location to the life cycle of commuting modes is the only explanation for suburbanization and reentification. There are other explanations rooted in demographics and the changing nature of cities (see Dynarski (8) and Kern (15)). Our purpose here is only to connect events more than a century ago with our more recent urban history and to suggest that some of the same forces may still be at work.

REFERENCES

Katona et al. (14) and Federal Reserve Board (10).