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The Rent Gradient: Effects from Proximity to a Major Business District

Salome Gudishvili
Pace University

Honors Thesis

The Rent Gradient Effects from Proximity to a Major Business District

Salome Gudishvili
Business Economics
Advisors: Prof. Mark Weinstock, Dr. Joseph Morreale
Economics Department
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Abstract

This report was created to show that the rent gradient is affected by the proximity of the housing location to the major business district. The previous studies introduce the readers to the characteristics of the business districts and reasons for their attractiveness to residents and investors who want to develop them further. In addition, they discuss the factors that influence the demand and supply of housing rental properties. This report relates to the urban economic model which considers the locational equilibrium for rent prices. The variables in the original model include the distance between the neighborhood and the business district, household income, employment, education, size of the population, age, and ethnicity. Due to the multicollinearity problem in the first regression results, the reduced model includes only distance, employment, and age variables, but it suffers from heteroscedasticity. The concluding results were achieved by the robust model. In addition, a separate model was created to isolate the individual effects of household income on the rent gradient. At the 95 % confidence level, the model shows that there is a significant relationship between the rent gradient and proximity of the residential neighborhood to the major business district.

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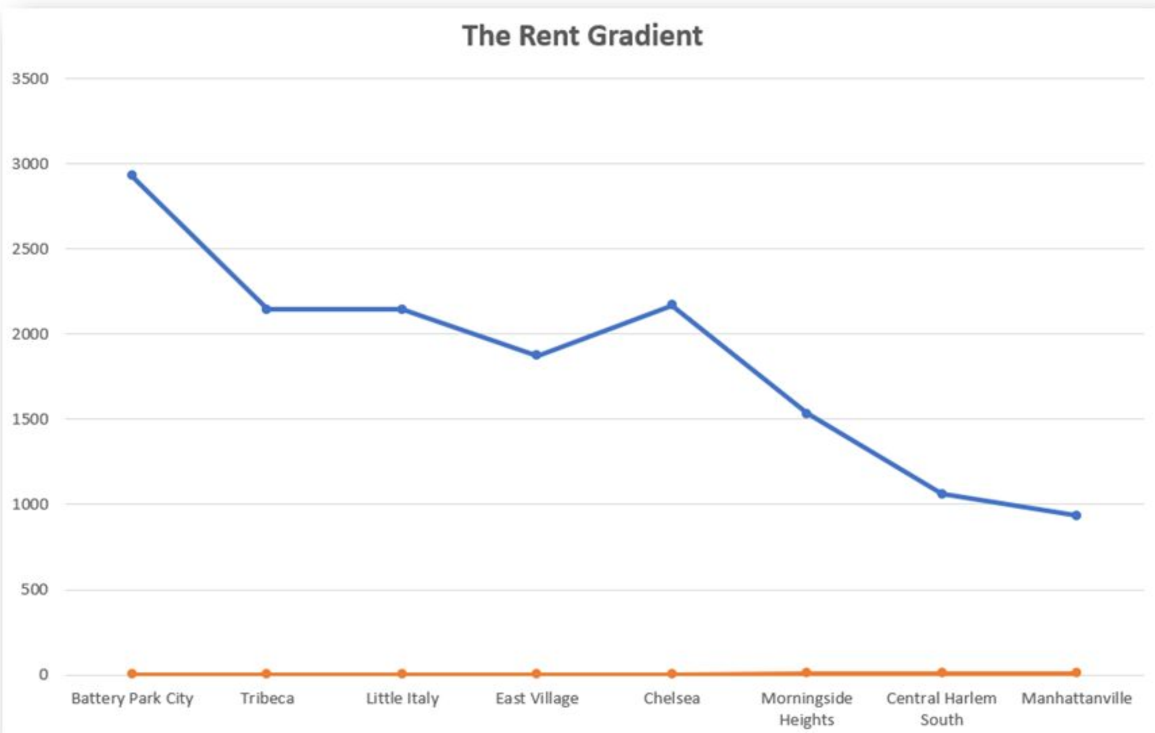
Introduction

Rent prices on properties in different neighborhoods of Manhattan are determined by demand and supply for them. While they can be affected by various factors, this report studies the relationship between rent prices and distance from the residential neighborhood to a major business district. It attempts to find the rent gradient effects from proximity to the major business district in Manhattan. Along with that, it also considers what are the reasons that contribute to the hypothesized inverse relationship between rent prices and distance. First, there are a lot of jobs in the business district of the city. Therefore, assuming that people usually like to live close to their workplace and reduce their commutes, the demand for rental properties is high in the major job center. Second, business districts often become tourist sightseeing as well. For example, Wall Street which represents one of the major business districts in New York City is also a popular tourist destination. Prices for housing rental properties tend to be expensive near Wall Street. Since this paper studies the Financial District of Manhattan, it should be noted that the World Trade Center and a lot of smaller shopping stores are surrounding it. They make the area more attractive for living, which leads to higher demand for rent. In addition, infrastructure is generally better in the business district than in other parts of the city and that somewhat affects its attractiveness to investors. While the subways are usually more crowded in the busy areas, the quality of transportation is higher in terms of availability of various lines that go to the district and proximity of the stations to popular stops. The business districts usually have well-known places where workers go to eat since they would not want to commute far during their lunch or dinner times. Traffic is another reason why New Yorkers want to stay in the same area for most of the day. As far as demand remains high, there will always be entrepreneurs who will try to match the needs and wants. However, since the size of Manhattan is not large compared to other boroughs of New York City and the area of the business district is mostly occupied by offices and stores, the supply of housing rental properties is limited.

Graph 1. The Rent Gradient



Graph 1 is a visual representation of the rent gradient on Manhattan. It includes fewer neighborhoods compared to the data in this study but attempts to show the overall trend in the rent prices across the area. The horizontal orange line represents the Manhattan neighborhoods sorted by proximity to Wall Street. Battery Park City is the closest neighborhood to this business district, and Manhattanville is the farthest one on this graph. The blue line shows the median household rent price for each of these neighborhoods. While there are some ups and downs along the line, it is downward sloping on the larger scale. This research observes the relationship between the rent price and proximity to the business district which is shown on this graph. It finds the significance of this relationship in quantitative measures.

Literature Review

There is a substantial amount of work done on studying the idea of a central business district, its attractiveness, and characteristics, and factors that contribute to high demand for rent in the surrounding areas.

The study about land use and rent gradients (Lai, Merriman, & Tsai, 2014) provides some information about the effects of job centers on the rent prices and attractiveness of the business district in general. The research shows that shopping and cultural attractions greatly influence the rent gradients. Therefore, it is important to observe what kind of amenities are available in the business districts that attract households to live there. The area becomes interesting for a lot of vendors who would like to invest in the business districts and further develop them by building shopping malls, restaurants, libraries, or museums around them. For example, a monopoly vendor chooses the location according to the business district. The traditional urban economic model, based on research by Alonso (1964), Mills (1967), and Muth (1969), derives rent gradient as a function of distance to the single exogenously determined business district. However, big cities like New York have more than one business district. In contrast to Alonso-Mills-Muth model, this study expands the function to two business districts and concludes that the vendor will choose to locate its business at an inner boundary, at one of the outer boundaries, and at the middle point between two business districts. This conclusion emphasizes the importance of the business district for choosing both business and housing locations. The business district is also called the employment center which relates to consumer preferences and willingness to accept certain lengths of commute.

Takaaki Takahashi (2017) also talks about the importance of individual consumer preferences in his paper "*Determination of neighborhood housing amenities: Asymmetric effects of consumers' choices and multiple equilibria*." He discusses that consumers' choices about amenities may be asymmetric meaning that some of the amenities may be valued higher than others. This emphasizes the significance of individual preferences that eventually affect demand. According to this paper, rent price can be derived as a function of choices of consumers who make decisions based on the level of satisfaction received from housing amenities in their neighborhoods. The housing location will be in equilibrium when the rent price matches the value of the neighborhood determined by the consumers. However, this study suggests that there may be multiple equilibria in choosing the housing location based on consumers' choices. Takahashi states that "the rents at two equilibria are determined so that the positive effect of a higher level of amenities at the sparsely populated equilibrium exactly offsets the negative effect of a higher rent at that equilibrium" (2017, p.556). According to his statement, the locational equilibrium may be affected by how compact the neighborhoods are. My thesis includes the variable for the size of the population in each neighborhood to observe its effects on the rent gradient. The author also contradicts the traditional urban economic model and states that "diversity is observed not only for the spaces at different distances but also for those at quite similar distances" (p.555), which is a counter argument for my analysis. He illustrates the example of the Nagoya metropolitan area in Japan, which is the third largest metropolitan area in the country and exhibits different characteristics of land use patterns in the areas at the same distance from the business center. He obtained data on the rent prices of privately-owned rental apartments and detached houses from *Housing and Land Survey* by Statistical Bureau of Japan (2003) and the standard deviations indicated that rent prices may vary a lot at the same distance from the city center. The author attributes this variation to the diverse income levels and preferences of the residents. At the same time, the data shows that, while the rent may vary in the same neighborhood, the overall trend is downward-sloping and the prices go down when moving farther from the center. This relates to the rent gradient shown in Graph 1 and underlines the effects of the business district on the rent prices.

Based on individual preferences, some people are willing to accept longer commutes because of the existing environmental issues, such as the air pollution, discussed in the scientific report "*Assessing the ecosystem services provided by urban green spaces along urban center-edge gradients" by Chang et al. (2017)*. It uses two variables, green space (ecosystem) and land rent (real payment) to test the relationship between ecology and the rent gradient. It concludes that the same area of green spaces near the business district provides much higher cultural services than that near the urban edge (Chang et al., 2017), which means that households obtain bigger non-material benefits from green spaces in the business district. As a result, it is expected to increase demand for housing properties and support higher rent prices in the business district.

While it is important to study the preferences, it is also crucial to find out what determines them. The article “*Flexible form methods for measuring rent gradients”* by Diamond and Gerety (1995) underlines the social and economic characteristics such as income, education, and employment that have impacts on establishing the preferences. For example, the members of households with low income may be forced to accept long commutes and less convenient transportation methods due to financial difficulties. In contrast, others may be able to afford higher rent prices which will allow them to live in the areas with the job center and various amenities around. Employment and educational achievement also affect the preferences along with income. Therefore, it is important to include the information on education and employment levels for each neighborhood. The difference in preference functions controls for bias that could be created by their identity and could skew the results. If these variables were held constant across all neighborhoods, their effects on consumer preferences in choosing housing locations would be ignored. Exclusion of important variables in the research can significantly change its findings.

Since income affects demand and preferences, it is necessary to create a new model that will include rent price and household income along with consumer values and preferences. Important observations are shown in the book *Housing and Commuting: The Theory of Urban Residential Structure* by John Yinger (2005). The author discusses the price-distance function in which a single household selects a housing location which is determined by the market. Then it finds the equilibrium price-distance function based on data from households with identical income and preferences. The report claims that each household will keep moving farther from the major business district until the net benefit of doing so equals zero. Moving farther can be described as a trade-off between the lower price and a longer commute. The household tries to choose the housing location in which the rent price will be set equal to the benefits obtained. It emphasizes the importance of preferences and satisfaction by stating that each household will maximize its utility by simultaneously choosing a combination of commodities and a residential location. Therefore, locational equilibrium will be considered in finding the relationship between the rent prices and the distance from a residential neighborhood to the business district. The rent of a housing unit is defined as the price per unit of housing service[1] multiplied by the number of units of housing services[2] the unit contains. The study brings location to the problem by expressing it as a function of distance from the business district. If H stands for housing services, P(u) is the price per unit of H at a location u miles from the business district, and R(u) is a rent at location u, the following function shows the relationship between rent and location which is the key to understanding the spatial dimension of housing markets:

$$R(u) = P(u) \times H$$

It shows that the rent at u miles from the business district is equal to the price of the housing service at a location u miles from the business district multiplied by the units of housing service. I find this study the most relevant resource for my research because it relates to the idea that the rent price is affected by the location and distance from the housing unit to the business district. While all other previous studies mainly talk about the business district itself and why it is attractive, this source discusses the significance of distance between the housing location and the business district on the rent gradient. My model will be based on the principal analytical tool for housing market analysis, which is called a bid function (Yinger, 2005). I will bring this discussion into practice by studying the Wall Street business district and multiple neighborhoods of Manhattan based on their locations and rent prices.

Theoretical Analysis and Data

The main data source for this research is the American Community Survey which provides information on rent prices, population, age, ethnicity, education, employment, and income levels for the 33 different neighborhoods of Manhattan. This study uses cross-sectional data and all variables, except the distance, are measured in 2016. The distance variable is calculated in miles using Google Maps. This study examines the rent prices in various neighborhoods of Manhattan-based on their proximity to the business district. The Federal Hall is used as a proxy for the location of the business district to measure the distance in miles. In addition, there are other variables considered in this report to study why the demand can be higher and what are the benefits of living closer to the major business district. The cost of transportation will be held constant assuming that subway cost is the same for everyone and Manhattan residents can use it to get to the business district from any of the given neighborhoods. The rent price is a dependent variable and the regression analysis measures how it reacts to changes in independent variables: the distance between the business district and the neighborhood, income, employment, size of the population, age, ethnicity, and education. This is an expected equation:

$$\textbf{Rent} = \beta_0 - \beta_1\,\textbf{Distance} + \beta_2\,\textbf{Income} + \beta_3\,\textbf{Employment} - \beta_4\,\textbf{Population} - \beta_5\,\textbf{Age} + \beta_6\,\textbf{Ethnicity} + \beta_7\,\textbf{Education} + \text{€}_1$$

According to the equation, the rent price and distance are expected to be negatively correlated meaning that closer the neighborhood is to the Federal Hall, higher the median household gross rent is in that neighborhood. Education, employment, and income are additional major variables that may affect the rent prices. Their increases are expected to have positive effects on rent. Size of the population is also considered to give more information on the neighborhood itself. Large size of the population may lead to the tight and less expensive neighborhood; therefore, its expected sign is negative. Age and ethnicity are included to see if the demographics of the neighborhood have any significant effects on the rent prices. This report finds the significance of these variables in estimating the median household gross rent. It is expected that the rent prices are comparatively high in the neighborhoods which are close to the Federal Hall, have a high income, education, and employment levels. Appendix A summarizes the variables, their expected signs, and the sources used in this research.

These variables create the following model:
Dependent Variable:
Ø Rent – Median Household Gross Rent (in 2016 dollars)

Independent Variables:
Ø Distance – Miles from the neighborhood to the Federal Hall

Ø Income – Median Household Income (in 2016 dollars)

Ø Employment – The number of people with jobs as a percentage of total civilian population

Ø Population – The size of population in the neighborhood

Ø Age – Median age of people in the neighborhood

Ø Ethnicity– The number of Hispanics and Latinos as a percentage of population

Ø Education – The number of people with bachelor's degree as a percentage of population

This study measures the effects of changes in independent variables on the dependent variable. The null hypothesis states that there is not a significant relationship between the dependent and independent variables, while the alternative hypothesis claims the opposite. The regression analysis will be used to determine whether the null hypothesis can be rejected or not. Appendix B provides the descriptive statistics of the variables used in this report.

- Ho: Proximity to the business district does not affect the rent gradient.
- Ha: Proximity to the business district affects the rent gradient.

The correlation matrix in Appendix C shows that there is a strong negative correlation between the rent and distance variables which supports the expected equation. However, it should also be noted that income, employment, ethnicity, and education are even more strongly correlated with the dependent variable. In addition, there is a strong positive relationship between the independent variables, such as income and employment, or income and education. A strong relationship between these variables may potentially make it impossible to isolate their individual effects on the dependent variable.

Empirical Results

The regression analysis has been performed using the variables discussed above. This study includes data analyzed by statistical tools in order to test the null hypothesis. The goal is to find out the effects of independent variables on the dependent variable. This report includes four different models and their results have been summarized in Appendix D. The original model 1 includes all variables expressed in the expected equation. An actual equation derived from the first regression results looks as following:

Rent = 20.01 Distance + .12 Income + 8.31 Employment – .001 Population – 21.06 Age + 2.11 Ethnicity + 27.71 Education + 294.18

According to the regression results, my main variable which is the distance from the neighborhood to the business district did not prove to be significant and showed a positive sign which contradicts the expected relationship between the rent prices and proximity of the locations to the major business district. The variables for employment, population, and ethnicity were not significant either. At 95 % confidence level, income, age, and education have significant effects on the rent gradient. In this model, changes in the independent variables explain 95.50 % variation in the median household rent price. An adjusted R-squared equals to 94.24 % which is still very high and emphasizes that most of the significant variables that have effects on the rent prices are included in this model. However, before reaching any conclusions, the model was tested for possible problems in the regression analysis. According to the results, there is no heteroscedasticity[3] (Appendix F) but the Variance Inflation Factor[4] (VIF) test showed that the original model is suffering from multicollinearity[5] (Appendix E) which was somewhat expected from the correlation matrix. As a result, the independent variables are intercorrelated and do not allow the regression analysis to isolate their individual effects on the dependent variable which is the median household rent price.

The second model is reduced and includes fewer variables. The data on the size of the population and ethnicity were excluded from the model due to the insignificance of the variables. Education was also removed because of the VIF results and its strong correlation with other independent variables, such as income and employment. One of the major factors considered in this model is income. It is the most significant variable in the first model and it is highly correlated with rent, distance, employment, ethnicity, and education. In addition, the VIF equals to 6.31 for this variable. In the reduced model 2, income is excluded to isolate its effect on the independent variables. However, since income is a major economic variable which highly determines the demand for rent, the third model includes income with employment and age but excludes the variable for distance. These two reduced models make it possible to observe the individual effects of income and proximity to the business district on the rent gradient without the problem of multicollinearity.

Reduced Model

The reduced model which includes distance, explains 80.82 % variation of dependent variable Y. It means that changes in independent variables determine 80.82% variation in the dependent variable, which is the rent price. The R squared has declined after removing some variables from the model. It was probably caused by the exclusion of the income variable which was highly significant but had significant effects on other independent variables. The difference between R-squared and adjusted R-squared has slightly increased from 1.26 % to 1.98 %. As a result, distance and employment variables proved to be significant at 95 % confidence level. At the same time, the age variable has become insignificant. According to the reduced model, one-mile increase in the distance between the neighborhood and the Federal Hall leads to $34.92 decrease in the rent price. Therefore, the original equation has changed as well.

Rent = – 34.92 Distance + 4.74 Age + 53.15 Employment – 1,644.46

The third model includes the same variables except that distance has been replaced by income. The F statistic, which measures the significance of the model, has increased from 75.76 in the original model to 153.44 in the third model which excludes distance. R squared equals to 94.07% and the income variable is significant at a 99% confidence level. In contrast to the second model, all three variables are highly significant in this case.

Rent = .14 Income + 21.65 Employment – 21.72 Age + 174.25

The reduced models were tested for potential problems in the regression analysis again. As a result, the reduced models do not suffer from multicollinearity as shown in table 5 of VIF test results; but the Breusch-Pagan / Cook-Weisberg test was performed again as shown in Appendix G and it indicated the problem of heteroskedasticity in the second model which includes the distance variable. The results can be seen in the following table. Therefore, I decided to use the robust model to adjust for heteroskedasticity in the regression analysis.

After using the robust model, the coefficients stayed the same as in the second model, but the standard deviations, significance levels, and R-squared changed. In addition, F statistic has slightly declined from 40.74 to 39.14, but it is still much higher than the F critical which equals to 2.28 and gives enough confidence to reject the null hypothesis. Also, the distance variable became more significant and the employment variable – less significant after using the robust model. The final equation looks the same as the second one since coefficients have not changed.

Rent = – 34.92 Distance + 4.74 Age + 53.15 Employment – 1,644.46

Discussion of the Coefficients

Each independent variable affects the rent gradient in their own way. According to the final results from the robust model, at 95 % confidence level, moving of the housing location each mile further from the business district results in $34.92 decrease in the median household gross rent. The relationship between neighborhoods and rent prices is seen in other variables too. The most significant variable turned out to be the employment measure in this model. At the 99% confidence level, when employment goes up by 1 percentage point in the neighborhood, rent price goes up by $53.15. In this case, the dependent and independent variables move in the same direction. In addition, the third model which incorporates income shows that it is the significant variable and $1 increase in the median household income leads to $.14 increase in the median household gross rent.

I acknowledge that this report is not perfect because of the problems that came up in the regression analysis with both multicollinearity and heteroscedasticity at different stages of research; however, it shows that there is a significant relationship between the rent price and proximity of the neighborhood to the major business district. T statistic for Distance variable equals -2.49 and the p-value shows that if the null hypothesis was true, there would be only a 1.9% chance of having the coefficient as high as -34.92. At the 95% confidence level, the null hypothesis which stated that there is not any significant relationship between the rent gradient and proximity of the housing location to the major business district can be rejected. However, there is still a possibility for further research with the model that would ideally include more significant variables in it and would offer more information on the households' background and economic characteristics. 19.18 % of the variation in the dependent variable is still left out of the model which is further convincing that there are other important factors that also have effects on the rent gradient.

Conclusion

The results from this regression model relate to the previous studies that have been conducted in this field. The literature review showed that there are a lot of reasons why the business district itself is attractive to residents and investors. It concluded that income, education, and individual preferences are the key determinants of the location that households choose for living, and the rent price in that location. All these factors contribute to why the rent would be high in or close to the business district. However, my research finds the rent gradient effects from proximity to the major business district. It is almost self-explanatory why the rent prices are high in the business district, but the magnitude that it has on the whole Manhattan borough is measured in my report.

As a result, the rent gradient is significantly affected by the proximity of the residential neighborhood to the business district. In addition, higher employment rate moves the median household gross rent upwards in the neighborhood. The income is the most significant variable in the original model and is highly correlated with other independent variables. It affected my results in the first regression model which suffered from multicollinearity. However, the final model proved to be highly significant and led to the rejection of the null hypothesis. There is a strong negative relationship between the median household gross rent and proximity of the housing location to the business district. As the distance between the housing location and the business district decreases, the rent price goes up. To conclude, the rent gradient is significantly affected by the proximity of the neighborhood to the business district in Manhattan.

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[1] The price per unit of housing service is the associated price concept per unit time, say per month.
[2] Housing services provide a market-determined index of the size and quality of a housing unit.
[3] Heteroscedasticity – If the OLS assumption that the variance of the error term is constant for all observations does not hold, the problem of heteroscedasticity is faced.
[4] In statistics, the variance inflation factor (VIF) is the ratio of variance in a model with multiple terms, divided by the variance of a model with one term alone. It provides an index that measures how much the variance (the square of the estimate's standard deviation) of an estimated regression coefficient is increased because of collinearity.
[5] Multicollinearity – two or more variables in the regression model are highly correlated, making it difficult or impossible to isolate their individual effects on the dependent variable.

Appendix A. Measurement of the variables

VARIABLE	**NAME**	**MEASURE**	**EXPECTED SIGN**	**SOURCE**
Y	Rent *Dependent*	Median Household Gross Rent	+	American Community Survey
X_1	Distance *Independent*	Miles from Federal Hall to neighborhood of Manhattan	-	Google Maps
X_2	Income *Independent*	Median Household Income	+	American Community Survey
X_3	Employment *Independent*	Percentage of employed people	+	American Community Survey
X_4	Population *Independent*	Median Household Income	+	American Community Survey

X_5	Age *Independent*	Median age	-	American Community Survey
X_6	Ethnicity *Independent*	Percentage of Hispanics	+	American Community Survey
X_7	Education *Independent*	Percentage of people with bachelor’s degree	+	American Community Survey

Appendix B. Descriptive statistics

Variable	N	Mean	Std. Dev.	Min	Max
Rent	33	1,818.73	591.02	734	2,931
Distance	33	4.72	3.51	.50	13.40
Income	33	7,334.29	3,114.83	2,281.42	12,982.17
Population	33	57,620.3	22,133.04	21,462	134,019
Age	33	36.68	3.76	29.60	47.90
Ethnicity	33	21.65	20.99	6.04	73.44
Employment	33	64.99	8.46	47.65	77.63
Education	33	29.60	9.76	12.94	40.05

Appendix C. Correlation among the Variables

Variable	**Rent**	**Distance**	**Inc**	**Emp**	**Pop**	**Age**	**Ethnicity**	**Educ**
Rent	1.0000							
Distance	**-0.6330**	1.0000						
Income	**0.9374**	**-0.6565**	1.0000					
Emp	**0.8809**	**-0.5508**	**0.8017**	1.0000				
Pop	0.1329	0.1961	-0.0492	-0.0576	1.0000			
Age	0.2100	-0.2047	0.3932	0.1805	0.3168	1.0000		
Ethnicity	**-0.7426**	**0.8168**	**-0.7876**	**-0.6345**	0.1091	-0.2732	1.0000	
Educ	**0.9244**	**-0.7869**	**0.8967**	**0.8745**	-0.0921	0.2999	**-0.8376**	1.0000

Appendix D. Regression analysis

Variable	**Original, Model 1**	**Reduced, Model 2** Excluding Income	**Reduced, Model 3** Excluding Distance	**Robust, Model 4** Adjusted Model 2
Distance	20.01	**-34.92****	-	**-34.92****
	(14.68)	(17.22)	-	(14.03)
Income	**.12*****	-	**.14*****	-
	(.02)	-	(.02)	-
Employment	8.31	**53.15*****	**21.65*****	**53.15*****
	(7.25)	(6.83)	(5.45)	(9.35)
Population	-.001	-	-	-
	(.001)	-	-	-
Age	**-21.06****	4.74	**-21.72****	4.74
	(8.10)	(13.11)	(7.98)	(21.68)
Ethnicity	2.11	-	-	-
	(2.63)	-	-	-

Education	**27.71****	-	-	-
	(10.39)	-	-	-
N	33	33	33	33
R^2	.9550	.8082	0.9407	.8082
Adjusted R^2	.9424	.7884	0.9346	-

Appendix E. VIF Test Results

	Model 1		Model 2		Model 3		Model 4	
Variable	**VIF**	**1/VIF**	**VIF**	**1/VIF**	**VIF**	**1/VIF**	**VIF**	**1/VIF**
Education	**16.34**	0.06	-	-	-	-	-	-
Income	**6.31**	0.16	-	-	3.41	0.29	-	-
Employment	**5.98**	0.17	1.45	0.69	2.98	0.34	1.45	0.69
Ethnicity	4.85	0.21	-	-	-	-	-	-
Distance	4.23	0.24	1.46	0.69	-	-	1.46	0.69
Age	1.47	0.68	1.05	0.95	1.26	0.79	1.05	0.95
Population	1.22	0.82	-	-	-	-	-	-
Mean VIF	**5.77**		1.32		2.55		1.32	

Appendix F. Test for heteroskedasticity

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of Rent

	Model 1	**Model 2**	**Model 3**	**Model 4**
Chi2 (1)	2.08	5.75	0.77	Not applicable to robust model
Prob > chi2	0.1493	**0.0165**	0.3808	

Appendix G. Test for heteroskedasticity

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of Rent

	Model 1	**Model 2**	**Model 3**	**Model 4**
Chi2 (1)	2.08	5.75	0.77	Not applicable
Prob > chi2	0.1493	**0.0165**	0.3808	to robust model