CHAPTER 4

EMPIRICAL RESULTS

This chapter is divided into five parts. The first part describes estimated results. The second part reports the odd ratios of multinomial logit estimation and illustrates the plots of odd ratios. Marginal effect is discussed in the third part. The next part interprets the estimated results and other notifications are analyzed in the last part.

4.1 Diagnostic Tests and Goodness of Fit of the Model

To explore the influence of transport innovation on residential location patterns in Bangkok, the basic model as equation (3.17) is estimated. Later diagnostic tests and goodness of fit of the model are employed as post-estimation analyses to assess the reliability of the model.

4.1.1 Diagnostic Tests

There are three types of post-estimation analyses that we consider for efficiency and reliability of the model. Independent variables as a group differentiating between two outcomes test whether they should be combined is firstly reported. Then testing for individual coefficient with Wald test is provided for interest of a given model. The remaining test is the test of independence of irrelevant alternatives (IIA) assumption which concerns independence of individual dependent choice that is taken into the model.

Testing for Combining Dependent Categories

Testing that none of the independent variables significantly affect the odds of outcome *i* versus outcome *j* (treated *j* as based category), we indicate that *i* and *j* are indistinguishable with respect to the variables in the model (Anderson, 1984). Thus outcome *i* and *j* being indistinguishable corresponds to the hypothesis;

$$Ho: \beta_i = \beta_j = 0 \text{, and } Ho: \gamma_i = \gamma_j = 0$$

where β is estimated coefficient for "*dist*" variable and γ is estimated coefficient for "*(difdist)x*" variable.

Again, it can be tested with either a Wald or an LR test, for which both of them provide very similar results. However, Wald test for combining outcomes is used for this study (shown as table D.2 in Appendix D).[1] All pairs of outcomes pass the test in 1998 and case 1 in 2004. However, sampled households who have a monthly income of less than or equal to 5,000 Baht (the 1st group) and who have monthly income greater than 5,000 to 15,000 Baht (the 2nd group) are indistinguishable for case 2 in 2004, while only the 2nd to the 3rd comparing income group for case 3 in 2004 can pass the test. Keep in mind that which pair of income groups that cannot pass Wald test for combining dependent variables should be collapsed. However, adjusting the model by combining some pair of dependent choice also affects testing results and goodness of fit of the model on the other cases.[2] Therefore considering the most powerful model based on all another diagnostic tests and goodness of fit of the model is needed.

[1] Testing for the model with five different income groups is set as income scenario 2 in Appendix D.

[2] See another model with adjusting income scenario following combining test for dependent category in Appendix D.

Testing the Effects of Independent Variables

Coefficients estimated by maximum likelihood method can be tested with Wald test and likelihood-ratio (LR) test. For both types of tests, the null hypothesis (*Ho*) that implies constraints on the model's parameters;

$$Ho:(\beta_i - \beta_j) = 0 \qquad \text{or} \qquad Ho:\gamma_i = 0$$

The LR test requires estimations of two models 1) The full model including all variables and 2) The restricted model excludes the tested-variable. While the Wald test assesses *Ho* through only an estimation with two information, 1) The distance between the estimated coefficients and the hypothesized values and 2) the curvature of the log-likelihood function. The LR test and Wald test are asymptotically equivalent. However, if the sample is very large, the computational costs of the LR test can be prohibitive. Therefore the alternative Wald test without estimating additional model is considered in this study. In the Table D.1 in appendix D, Wald test statistics and their significance are reported. Both "*dist*" and "*difdistx*" variables are significant in explaining the model in 1998 and case 1 and 2 in 2004, however, in case 3 in 2004 could not pass the test.

Test for Independence of Irrelevant of Alternatives (IIA)

Hausman test was conducted for IIA assumption testing in this study. Statistical tests of IIA of each year and each case of study are reported in Table D.3 in Appendix D. It omits one of all non-based categories, while the first test in row, the poorest group, is computed by re-estimating the model using the largest remaining category as the based category. Results indicate that it fails to meet the IIA assumption only if the model omits choice 3 for case 2 in 2004. All other choices that passed the test performed the suitability in selecting dependent categories used in the model. However, the rejection of the IIA assumption implies that the specific model when residents choose between initial bus transit and the alternative rapid rail transit, which includes only difference in income levels, should not neglect the 3^{rd} income group in explaining residential location pattern in Bangkok. The tested statistics which are negatives are found to be very common. Hausman and McFedden (1984) noted this possibility and concluded that a negative result is evidence that IIA has not been violated.

4.1.2 Goodness of Fit of the Model

A scalar measurement can be useful in comparing competing models and ultimately in selecting a final model. It provides some information that must be assessed within the context of the theory motivating of the estimated parameters of the model being considered. Thus McFadden's Pseudo R2 and Count R2 are considered superior in this study. They are computed by

McFadden's Pesudo R2 (R^2_{McF}) $= 1 - \frac{L_F}{L_I}$

where L_F is log likelihood of the full model with all explanatory variables, and

L_I is log likelihood of the model with just intercept

And Count R2 $= \frac{1}{N}\sum_j n_i$

where the n_i 's are the number of correct prediction for outcome *i* and

N is number of observations

McFadden's Pseudo R2 and Count R2 of the estimated model are shown as Table 3.2.

Table 4.1

McFadden's Pseudo R2 and Count R2

Measurement of Fit	1998	2004		
		Case 1	Case 2	Case 3
McFadden's Pseudo R2	0.985	0.509	0.183	0.036
Count R2	0.991	0.697	0.574	0.517

For McFadden's Pseudo R2, it is standard scalar measurement of fit of multinomial logit model. It explained how much explanatory variable can explain the probability of odd choices by comparing the model with just the intercept to the model with taking all independent variables into account. However it can never exactly equal one. Its value falling among 0.2-0.5 is acceptable (Scott and Freese, 2001). McFadden's Pseudo R2 is high in 1998, in which it equals 0.985. And it is acceptable for case 1 in 2004 in which it equals 0.509, while it is quite low for case 2 and case 3 in 2004. However, Count R2 indicated how much observed and predicted values can be used in the model is supported the fit of the model for case 2 and3 in 2004. By the fit statistic, it shows observed and corrected prediction for case 2 and case 3 in 2004 is greater than 50 percent.

4.2 Estimated Results

The basic equation (3.17) can be regressed by multinomial logit estimation, and the results are shown as follows;

Table 4.2
Coefficients for a Multinomial
Logit Model in 1998

	1998					
Income Group	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
2						
dist	-3.883	1.259	-3.09	0.002	-6.350	-1.417
(difdist)x	20.762	5.291	3.92	0.000	10.391	31.133
Constant	5.043	1.96	2.57	0.010	1.200	8.885
3						
dist	-30.054	8.169	-3.68	0.000	-46.065	-14.043
(difdist)x	47.575	9.839	4.84	0.000	28.291	66.858
Constant	17.431	4.279	4.07	0.000	9.044	25.818
4						
dist	-95.592	17.843	-5.36	0.000	-130.564	-60.619
(difdist)x	113.098	18.663	6.06	0.000	76.518	149.677
Constant	37.839	7.452	5.08	0.000	23.233	52.445
5						
dist	-175.135	25.419	-6.89	0.000	-224.954	-125.315
(difdist)x	192.630	26.003	7.41	0.000	141.666	243.593
Constant	52.570	8.333	6.31	0.000	36.238	68.902
Observation						1445
L(0) Intercept Only						-1657.978
L(1) Full Model						-24.734
Pseudo R2 (McFadden's R2)						0.985
Count R2						0.991

Note: the 1st income group is the reference group

Table 4.2

Coefficients for a Multinomial Logit Model

Case 1 in 2004 (Continued)

	case 1/2004					
Income Group	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
2						
dist	-0.023	0.009	-2.72	0.007	-0.040	-0.006
(difdist)x	-0.697	20.695	-0.03	0.973	-41.259	39.864
Constant	0.916	0.127	7.21	0.000	0.667	1.164
3						
dist	-0.565	0.109	-5.18	0.000	-0.779	-0.351
(difdist)x	27.991	18.330	1.53	0.127	-7.934	63.917
Constant	0.587	0.470	1.25	0.211	-0.333	1.508
4						
dist	-7.621	3.062	-2.49	0.013	-13.622	-1.621
(difdist)x	35.863	18.642	1.92	0.054	-0.674	72.401
Constant	5.619	1.914	2.94	0.003	1.868	9.370
5						
dist	-31.899	7.390	-4.32	0.000	-46.382	-17.416
(difdist)x	60.418	19.838	3.05	0.002	21.537	99.300
Constant	18.274	3.948	4.63	0.000	10.537	26.011
Observation						1512
L(0) Intercept Only						-1781.620
L(1) Full Model						-874.169
Pseudo R2 (McFadden's R2)						0.509
Count R2						0.697

Note: the 1st income group is the reference group

Table 4.2

Coefficients for a Multinomial Logit Model

Case 2 in 2004 (Continued)

	case 2/2004					
Income Group	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
2						
dist	-0.021	0.009	-2.47	0.014	-0.038	-0.004
(difdist)x	31.218	35.667	0.88	0.381	-38.688	101.124
Constant	0.859	0.127	6.75	0.000	0.610	1.109
3						
dist	-0.008	0.013	-0.62	0.533	-0.034	0.017
(difdist)x	31.878	35.667	0.89	0.371	-38.028	101.784
Constant	-0.946	0.194	-4.88	0.000	-1.326	-0.566
4						
dist	-0.178	0.054	-3.31	0.001	-0.283	-0.073
(difdist)x	32.348	35.667	0.91	0.364	-37.558	102.254
Constant	-1.906	0.442	-4.31	0.000	-2.772	-1.040
5						
dist	-0.997	0.161	-6.20	0.000	-1.312	-0.682
(difdist)x	33.296	35.667	0.93	0.351	-36.611	103.203
Constant	0.281	0.502	0.56	0.576	-0.703	1.265
Observation						1512
L(0) Intercept Only						-1781.620
L(1) Full Model						-1454.841
Pseudo R2 (McFadden's R2)						0.183
Count R2						0.574

Note: the 1st income group is the reference group

Table 4.2

Coefficients for a Multinomial Logit Model

Case 3 in 2004 (Continued)

	case 3/2004					
Income Group	Coef.	Std. Err.	z	P>|z|	95% Conf. Interval	
2						
dist	-0.002	0.009	-0.24	0.807	-0.020	0.015
(difdist)x	74.886	382.973	0.20	0.845	-675.727	825.499
Constant	0.486	0.134	3.62	0.000	0.223	0.749
3						
dist	0.012	0.013	0.92	0.358	-0.014	0.037
(difdist)x	74.951	382.973	0.20	0.845	-675.662	825.564
Constant	-1.225	0.200	-6.12	0.000	-1.617	-0.832
4						
dist	0.016	0.023	0.72	0.471	-0.028	0.061
(difdist)x	74.982	382.973	0.20	0.845	-675.631	825.595
Constant	-2.715	0.357	-7.60	0.000	-3.415	-2.015
5						
dist	0.004	0.021	0.19	0.850	-0.037	0.045
(difdist)x	74.946	382.973	0.20	0.845	-675.667	825.559
Constant	-2.281	0.316	-7.22	0.000	-2.899	-1.662
Observation						1512
L(0) Intercept Only						-1781.620
L(1) Full Model						-1717.740
Pseudo R2 (McFadden's R2)						0.036
Count R2						0.517

Note: the 1st income group is the reference group

Although the estimated logit coefficients cannot be directly interpreted, the sign of coefficients should be considered first. Following theoretical concept, the significant variables show corrected signs. The coefficients of Euclidean distance "*dist*" variable considered when all income groups commute by the initial transit produce negative signs, as the richer group has steeper bid-rent function than the poorer group (based group). Although it is insignificant for case 2 in 2004, comparing the 3rd group to the 1st group and for case 3 in 2004, the 2nd group relative to the 1st group, they yielded correct signs. Further incorrect signs without significance are found in case 3 for the 3rd, 4th, and 5th relative to the based group.

The coefficients of the second variable "(*difdist)x*", mostly yield correct signs. It is expected that the second variable concerned when only the higher income group commute by the alternative transit, should be positive. An advantage of the alternative transit is that it reduces bid-rent slope of the richer group. Although the lack of significance of this variable for case 2 and 3 in 2004 and only 87.3 percent level of confidence of the 3^{rd} group relative to the 1^{st} group for case 1 in 2004, it achieves a corrected sign. However, for case 1 in 2004, estimated coefficient of the second variable of the 2^{nd} relative to the referenced group, shows negative sign, but it is insignificant.

For constant term, it is the difference in intercepting the bid-rent function of the higher income group relative to the lowest income group. Although there is no speculative identification that follows the theory, it should be positive if the higher income group has steeper bid-rent function relative to the referenced group when both commuted by the initial transit. Therefore, only for the 3^{rd} and the 4^{th} group relative to based category for case 2 in 2004 and comparing the 3^{rd}, the 4^{th}, and the 5^{th} to the referenced group for case 3 in 2004, constant terms are incorrect negative and significant.

4.3 <u>Odd Ratios</u>

Discrete changes reported as estimated coefficient is in the log odds scale illustrating the effect of independent variable on the probability of both non-based and based categories. To deal with how does it affects the odds of that location *t* is occupied by the higher income group relative to the lowest income group, odds ratios referred as factor change coefficients can be used. The odds ratios and their significance are shown as follows;

Table 4.3

Odd Ratios for a Multinomial Logit Model

1998				
Variable	2	3	4	5
dist	0.0206*	8.86e-14*	3.05e-42*	8.71e-77*
difdistx	1.04e+09*	4.59e+20*	1.31e+49*	4.55e+83*
2004				
		Case 1		
Variable	2	3	4	5
dist	0.9770*	0.5684*	0.0005*	1.40e-14*
difdistx	0.4979	1.43e+12	3.67e+15**	1.74e+26*
		Case 2		
Variable	2	3	4	5
dist	0.9791*	0.9919	0.8372*	0.3690*
difdistx	3.61e+13	6.99e+13	1.12e+14	2.89e+14
		Case 3[3]		
Variable	2	3	4	5
dist	0.9978	1.0120	1.0166	1.0040
difdistx	3.33e+32	3.55e+32	3.67e+32	3.54e+32

For example, the odds ratios for the effect of Euclidean distance "*dist*" on having location *t* is occupied by the 2nd income group versus by the 1st income group is 0.9770 for case 1 in 2004. It means that when two income groups commuted by the initial bus transit, distance affected the odds of having location *t* is occupied by the 2nd group 0.9770 times greater than by the 1st based group. Note that taking exponential log on estimated coefficient[4] is equal to the odd ratio; $\exp(-0.0232) = 0.9770$.

For difference in Euclidean distance and the break-even distance multiplied by dummy *x*, "*(difdist)x*", the odds ratio on having location *t* is occupied by the 2nd income group versus the 1st group is 0.4979 for case 1 in 2004. It implies that, when the second group adopted automobile but the first group still commuted by bus, distance affected the odds of having location *t* is occupied by the 2nd group 0.4979 times greater than by the 1st group.

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[3] Estimation for case 3 in 2004 is set tolerance at 0.1.
[4] Estimated coefficients are reported in table 4.2.

However, examining all of the coefficients for even a single variable with only five dependent categories is complicated. The odds ratios plots make it easy to understand the pattern of the result. Figure 4.1a-4.1d shows the odds ratios plot with its significant level.

Figure 4.1

Odds Ratios in 1998 and 2004

Figure 4.1a

Odds Ratios in 1998

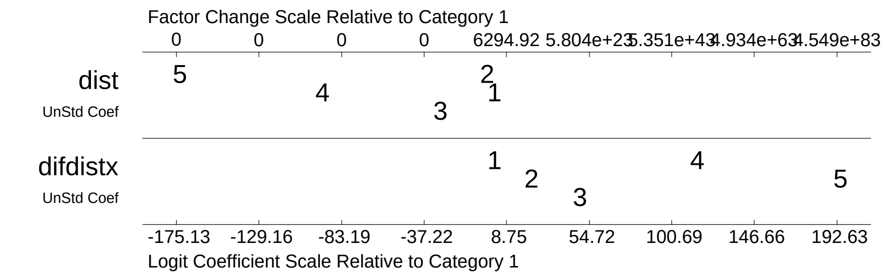


Figure 4.1b

Odds Ratios for Case 1 in 2004

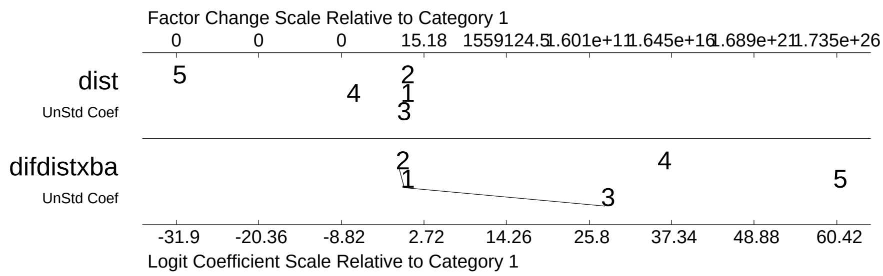


Figure 4.1c

Odds Ratios for Case 2 in 2004

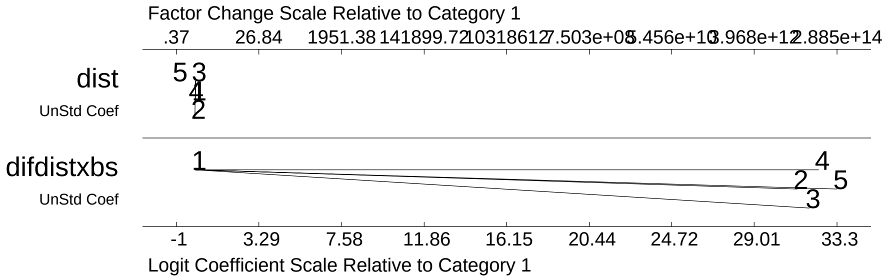
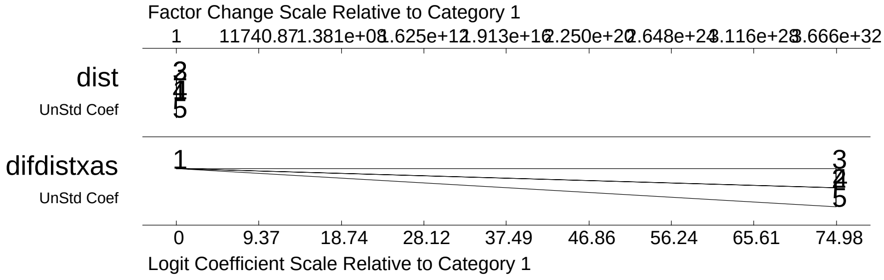


Figure 4.1d

Odds Ratios for Case 3 in 2004



In the odds ratios plots, the independent variables are each represented on a separate row. The horizontal axis indicates the relative magnitude of the coefficients associated with each outcome. The reason that they stacked on top of each other is that the plot uses the 1^{st} group as the based category for graphing the coefficients. If a number of an income group is to the left of the based group (number "1"), it means the coefficient yielded negative sign. On the other hand, if it is to the right it yields positive sign. An increase in distance variable (*dist*) made it more likely that the group on the left-side occupied location *t* than the group on the right-side. In contrast for "*(difdist)x*" variable, the group on the right-side is more likely to occupy location *t* than the group on the left-side. The magnitude of the effects is indicated by the space between a pair of number of a group. The longer the space the higher effect of the independent variable on probability that location *t* is occupied by an income group relative to the based group. For example, the distance between number "5" and "1" is greater than between "2" and "1" for "*dist*" variable for case 1 in 2004. It means that when all groups commuted by bus transit, the 5^{th} group was more likely to occupy location *t* than the 1^{st} group as a unit of distance increase which was really greater than the 2^{nd} group relative to the 1^{st} group. Accordingly, the distance from "1" to "5" is the sum of the distance from "5" to "4", "4" to "3", "3" to "2" and "2" to "1". Finally, the lack of statistical significance is shown by connecting the line suggesting that those two outcomes are tied together.

4.4 Interpretation

The results are explored in more detail as in Table 4.4a. In Table 4.4a, all estimated coefficients are again summarized so that the recalculation of differences in bid-rent gradients as in Table 3.1 can be followed more easily. Then the differences in bid-rent gradients are shown in Table 4.4b.

Table 4.4a

Parameter Estimates

Odd Comparing	Parameter	1998	2004		
			case 1	case 2	case 3
2 – 1	$\beta_2 - \beta_1$	-3.8832*	-0.0232*	-0.0211**	-0.0022
	γ_2	20.7622*	-0.6974	31.2180	74.8857
3 – 1	$\beta_3 - \beta_1$	-30.0543*	-0.5649*	-0.0081	0.0119
	γ_3	47.5746*	27.9915	31.8778	74.9507
4 – 1	$\beta_4 - \beta_1$	-95.5919*	-7.6214**	-0.1777*	0.0165
	γ_4	113.0975*	35.8632***	32.3481	74.9818
5 – 1	$\beta_5 - \beta_1$	-175.1345*	-31.8991*	-0.9969*	0.0040
	γ_5	192.6295*	60.4184*	33.2958	74.9464
3 – 2	$\beta_3 - \beta_2$	-26.1710*	-0.5417*	0.0130	0.0141
	$\gamma_3 - \gamma_2$	26.8124*	28.6888**	0.6598*	0.0650***
4 – 2	$\beta_4 - \beta_2$	-91.7087*	-7.5982**	-0.1566*	0.0187
	$\gamma_4 - \gamma_2$	92.3353*	36.5605*	1.1301*	0.0961
5 – 2	$\beta_5 - \beta_2$	-171.2512*	-31.8759*	-0.9758*	0.0061
	$\gamma_5 - \gamma_2$	171.8673*	61.1157*	2.0778*	0.0607
4 – 3	$\beta_4 - \beta_3$	-65.5376*	-7.0565**	-0.1696*	0.0046
	$\gamma_4 - \gamma_3$	65.5229*	7.8717**	0.4704*	0.0311
5 – 3	$\beta_5 - \beta_3$	-145.0802*	-31.3342*	-0.9888*	-0.0080
	$\gamma_5 - \gamma_3$	145.0548*	32.4269*	1.4180*	-0.0043
5 – 4	$\beta_5 - \beta_4$	-79.5426*	-24.2777*	-0.8192*	-0.0125
	$\gamma_5 - \gamma_4$	79.5319*	24.5552*	0.9477*	-0.0354

Note: The lower income group is the reference group

* is significance at 99% level of confidence

** is significance at 95% level of confidence

Table 4.4b[5]

Differences in Bid-Rent Gradients

in 1998 and 2004

1998				
	Bus			
Bus	1	2	3	4
2	-3.8832*			
3	-30.0543*	-26.1710*		
4	-95.5919*	-91.7087*	-65.5376*	
5	-175.1345*	-171.2512*	-145.0802*	-79.5426*
Automobile	1	2	3	4
2	16.879 (*)			
3	17.5203 (*)	0.6414 (*)		
4	17.5056 (*)	0.6266 (*)	-0.0147 (*)	
5	17.4950 (*)	0.6161 (*)	-0.0254 (*)	-0.0107 (*)

[5] Significance in parenthesis, (*), refers to the significant level of the estimated parameters concerned the second variable "*(difdist)x*", since shifting in the sign of the bottom half results depend on the value and the sign of the second variable coefficients.

Table 4.4b

Differences in Bid-Rent Gradients

in 1998 and 2004 (Continued)

2004				
Case 1				
	Bus			
Bus	1	2	3	4
2	-0.0232*			
3	-0.5650*	-0.5417*		
4	-7.6214**	-7.5982**	-7.0565**	
5	-31.8991*	-31.8759*	-31.3342*	-24.2777*
Automobile				
2	-0.7206			
3	27.4266	28.1471 (**)		
4	28.2418 (***)	28.9623 (*)	0.8152 (**)	
5	28.5193 (*)	29.2398 (*)	1.0927 (*)	0.2775 (*)
Case 2				
	Bus			
Bus	1	2	3	4
2	-0.0211**			
3	-0.0081	0.0130		
4	-0.1777*	-0.1566*	-0.1696*	
5	-0.9969*	-0.9758*	-0.9888*	-0.8192*
Rapid Transit				
2	31.1969			
3	31.8697	0.6728 (*)		
4	32.1704	0.9735 (*)	0.3008 (*)	
5	32.2989	1.1020 (*)	0.4292 (*)	0.1285 (*)
Case 3				
	Automobile			
Automobile	1	2	3	4
2	-0.0022			
3	0.0119	0.0141		
4	0.0165	0.0187	0.0046	
5	0.0040	0.0061	-0.0080	-0.0125
Rapid Transit				
2	74.8835			
3	74.9626	0.0791 (***)		
4	74.9983	0.1148	0.0357	
5	74.9504	0.0668	-0.0123	-0.0479

The top half of Table 4.4b reports differences in bid-rent gradients among each pair of five income groups when each adopt initial transport mode, which are bus transit for 1998, case 1 and case 2 in 2004 and automobile for case 3 in 2004. For each of ten possible pairings, the table reports the differences between the gradient of the higher income group and that of the lower income group. The entries are $\beta_i - \beta_j$, for $i > j$. If an entry is negative, the higher income group has a steeper bid-rent function than the lower income group when both groups adopt initial transport mode. In other words, the frequency of the higher income group relative to lower income group declines with distance. On the other hand, if the entry is positive, it means that the higher income group has a flatter bid-rent function than the lower income group when both groups adopt the same initial transport mode, and frequency of the richer group relative to the poorer group increases with distance.

The bottom half of Table 4.4b reports differences in bid-rent gradients when the higher income group adopts the alternative transport mode, which is automobile for 1998 and case1 in 2004, and rapid rail transit for case 2 and 3 in 2004, while the lower income group still adopts the initial transport mode. The entries are $(\beta_i + \gamma_i) - (\beta_j + \gamma_j)$ for $i > j$. Note that the coefficient of the second variable for the 1^{st} income group is always zero since the lowest income group has never preferred the alternative transit over the initial transit.[6] A positive coefficient implies that the higher income group has a flatter bid-rent function than the lower income group when they adopt the alternative transit and the lower income group adopts the initial transit. It implies that the frequency of the higher income group relative to the lower income group increases with distance. In contrast, a negative coefficient implies that the higher income group has a steeper bid-rent function when the richer group adopts alternative mode and the poorer group adopts the initial mode. The frequency of the richer group relative to the poorer group declines with distance. Ultimately, distinct conflicting of the sign of difference in bid-rent gradient of any income group relative to the based group with and without alternative transit indicates the advantage of availability of alternative transit.

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[6] Recall in chapter 3 section 3.2.

In 1998, when two income groups commuted by initial bus transit, the top half of Table 4.4b for 1998 reports all negative entries with 99% level of confidence. The higher income group was more likely to have steeper bid-rent function than the lower income group if both groups commuted by bus transit. It implies that there is a probability that frequency of the higher income group relative to the lower income group decreases with distance. It is consistent with the prediction of the Alonso-Muth's model if the income elasticity of housing demand is less than that of marginal commuting cost. According to the theory of LeRoy and Sonstelie (1983), when everyone commutes by the same mode, the rich tend to live closer to the center than the poor.

However, deviations from that pattern can occur when a new mode which reduces commuting cost is introduced. In 1998, the new transport mode was the automobile. The bottom half of the Table 4.4b for 1998 reports differences in bid-rent gradients when the higher income group drove an automobile but the lower income group took a bus. Seven of the ten entries are positive and significant at 99% level of confidence. It implies that the automobile flattens bid-rent functions. For the net result, the 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} income groups tend to have a flatter bid-rent function than the 1^{st} income groups. Now, it is more likely to have frequency of the 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} income group relative to the 1^{st} income group increase with distance. The automobile will give the 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} income group a decided advantage in more distant locations. In other words, the automobile caused them to decentralize. However, when considering the position of the 3^{rd}, 4^{th}, and 5^{th} income groups, we found that the 3^{rd} income group tends to locate on itself peripheral side rather than the 4^{th} and the 5^{th} income group, and the 4^{th} group also tends to locate itself on the peripheral side relative to the 5^{th} group. Estimated coefficients yielded negative signs and significant for the 4^{th}-3^{rd}, 5^{th}-3^{rd}, and 5^{th}-4^{th} comparing groups. This pattern can be explained as re-gentrification of the rich.[7] As automobiles were present in Bangkok before 1998, commuting costs of automobiles might have reduced (relative to income level) enough for the 3^{rd} and the 4^{th} income group to adopt it and occupy more distant areas, while the 5^{th} group lost their comparative advantage on peripheral areas.

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[7] Recall in chapter 2 section 2.2.

For case 1 in 2004, when a household faces two choices of transit; bus and automobile, the results are shown in the Table 4.4b for case 1 in 2004. All entries are negative and significant. Similar to 1998, the higher income group is more likely to have a steeper bid-rent function than the lower income group and frequency of the richer group relative to the poorer group tends to decrease with distance. It implies that the richer group tends to locate itself on central side while the poorer group tends to locate itself on peripheral side, if both adopt bus transit.

In contrast, when the higher income group commutes by automobile while the lower income group continues to use the bus, nine out of the ten are positive, and eight are significantly positive, although, the difference in bid-rent gradients of the 3rd relative to the 1st group is positive at 87.3% level of confidence. Again, the higher income group tends to have a flatter bid-rent function than the lower income group, and the frequency of the higher income group relative to the lower income group increases with distance if only the higher income group commutes by automobile. For the net result, as time cost saving advantage of automobile transit, the 3rd, 4th, and 5th income groups are more likely to have an advantage over the 1st and the 2nd group on more distant areas with adopting automobile. However, one entry is negative and insignificant. The lack of significant difference in bid-rent gradient between the 2nd and the 1st income groups is not surprising. It involves a comparison between adjacent groups that are not very different in incomes. Thus responding to "*(difdist)x*" variable which involve income level is not very different among this two adjacent groups. Further, it implies that the difference is larger, as the larger is the difference in income between the groups. For example, *28.2418 < 28.5193* accord to differences in income between the 5th and the 1st groups greater than between the 4th and the 1st groups.

Employing a comparative static approach, residential location pattern when individual household face with two competing choices of transit, bus and automobile, in 1998 and 2004 are similar. If everyone takes a bus, the higher income group tends to have a steeper bid-rent function, while if the higher income group adopts the automobile but the lower income group does not, the higher income group will receive an advantage and tends to locate itself in more distant areas. However considering individual income groups, the 2nd group in 1998 has a significant chance to adopt automobile, gain time saving advantage and locate itself in more distant areas, while the 2nd group for case 1 in 2004 has no chance to switch to automobile transit due to less income levels compared to 1998.[8] The insignificance of the difference in bid-rent gradient of the 3rd group relative to the 1st group when only the 3rd group adopts automobile occurs for case 1 in 2004, although the 3rd group receives an advantage from using the automobile and moving outward as coefficient's sign change but the effect on the residential location change is not significant. There are two reasons for this. First, although fixed cost of automobile commuting decreased in 2004 when compared to in 1998, fixed cost of bus commuting reduced also. Further, while variable cost of bus transit decreased in 2004, variable cost of automobile as gasoline cost also increased. Second, income level of the 3rd group is less compared to 1998 (considering in real term). Therefore commuting cost for automobile transit relative to income level does not appear to reduce over time suggested by theory. Moreover, the negative differences are yielded only in 1998 when the rich adopt automobile. As previously explained, the advantage received from using automobile provided enough time cost saving for the 3rd and the 4th group to adopt it and compete for more distant areas making the 5th group lose their advantage in the outermost areas.

For case 2 in 2004, when a household chooses between the initial bus transit and the new alternative rapid rail transit, results are shown in Table 4.4b case 2 in 2004. If everyone takes the bus, nine entries are negative differences in bid-rent gradients for which only eight of them are significant. However the difference in bid-rent gradient between the 3rd and the 1st group are insignificantly negative. Further difference in bid-rent gradient of the 3rd versus the 2nd groups is positive and insignificant. Insignificance of the 3rd income group corresponds with its failure to meet IIA test.[9] It indicates that the 3rd group does not vary independently from the 1st and the 2nd group as distance increases. Thus the net result implies that the 4th and the 5th income group are more likely to have a steeper bid-rent function than the 1st, 2nd, and 3rd group when all of them commute by bus. Therefore its frequency relative to the poorer group decreases with distance. In other words, the 4th and the 5th group tend to live in the city center relative to the others when all of them adopt bus transit.

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[8] As shown in table 3.1.

[9] See detail for IIA test in section 4.1.

When the higher income group takes rapid rail transit and the lower income group continues to take a bus transit, all entries are positive and six of them are significant. Positive entries mean that, if only the 3rd, 4th, and 5th is adopting rapid rail transit, they tend to have a flatter bid-rent function than the 2nd group. And it is more likely that the frequency of them relative to the 2nd group increases with distance. The net result shows that the 3rd, 4th, and 5th groups are more likely to gain time cost saving advantage of rapid rail transit over the 2nd group and live in more distant areas.

When considering case 1 and case 2 in 2004, buses were the initial transit and automobiles were the alternative transit in case 1 and rapid rail transit was the alternative choice in case 2.Notice that the 2nd group has a chance to gain time cost saving advantage of the alternative transit, only when it is rapid rail transit, it is showed as changing of the difference in gradient's sign. Even though the effect of rapid rail transit is insignificant for the 2nd group to change its residential location, it shows that with less monetary cost and faster speed of rapid rail transit relative to automobile transit, the 2nd income group is more likely to switch to rapid rail transit and change their residential site. However lack of significance in difference in bid-rent gradient between any higher income groups relative to the first income group occurs only when the higher income groups adopt rapid rail transit rather than automobile but the lower income groups adopt bus transit.

For case 3 in 2004, when all households commute by the initial automobile mode, surprisingly, only some entries are negative. The differences in bid-rent gradients between the 2nd – 1st, 5th – 3th, and 5th – 4th groups are negative. It implies that the 2nd group tends to locate itself in the city center relative to the 1st group, and the 5th group is more likely to live on central-side relative to the 3rd and the 4th income groups when all of them commute by automobile. When the rapid rail transit was introduced and only the richer group adopted this new alternative mode while leaving the poorer group to adopt the automobile, Table 4.4b for case 3 in 2004 reports eight positive entries, while the differences in bid-rent gradients of the 5th-3rd and the 5th-4th competing group are still negative. It is interesting that rapid rail transit cannot lead to residential pattern changes for the 4th and the 5th groups. They remain located in central side whether they commute by automobile or rapid rail transit. Notice that only the differences of the 2nd relative to the 1st group that yielded opposite sign with and without rapid rail transit, which is consistent with the theory. It implies that the

2nd group is more likely to gain time cost saving advantage of rapid rail transit over the 1st income group and locates itself in more distant areas. However it is not significant. Insignificance of the differences in gradients occurred with the inappropriate assumption that all income groups adopt automobile as initial transit, since the empirical result in 1998 and case 1 in 2004 supports that only the 3rd, the 4th, and the 5th group have significant advantage in peripheral area when they use automobiles. Furthermore, the only difference in bid-rent gradient between the 3rd and the 2nd is significant at 90% level of confidence. However the 3rd group ignores the advantage of rapid rail transit which affects residential site as it tends to locate itself on the peripheral side even when commuting by automobile.

Nevertheless, insignificance in differences is more likely to occur when rapid rail transit network is the alternative choice since its network is non-ubiquitous, which leads a lot the second variable of sampled households to disappear. Taking into account that commuter are faced with more fixed cost to access the rapid rail station which does not extend throughout the city, the fixed cost for calculating break-even distance is quite high for areas without rapid transit network. Therefore, the influence of rapid rail transit plays a role on residential location patterns in Bangkok representing the effect of the second variable coefficients (γ) are not significant, even though they yielded correct signs. However, notice that only difference in bid-rent gradient of the 2nd relative to the 1st group yielded correct sign. It implies that the distinct advantage of rapid rail transit as time cost saving when competing to automobile transit occurs only for the 2nd group. Finally, comparing case 2 and 3 in 2004, rapid rail transit seems to give significant advantage on a more distant area for the 3rd, 4th, and 5th groups if rapid transit competes with the initial bus transit. However rapid rail transit seems to give distinct advantages only for the 2nd income groups in the peripheral area as they can commute by rapid rail transit rather than automobile which is a more expensive commuting cost. Comparative results can be referred to showing that rapid rail transit is suitable to treat as competing mode for bus transit. The distinct difference in money and time spent on rapid rail transit when compared to bus transit make it more competitive than in comparing to automobile. Therefore, the effect of rapid rail transit is distributed to many high income groups significantly. While just a little time cost saving relative to automobile transit, rapid rail cannot obviously persuade mode switching of the rich car commuter and lead their residential pattern changes within the border of the city.

Ultimately, It is quite interesting that some constant terms for case 2 (the 3rd and the 4th relative to the 1st group) and case 3 (the 3rd, the 4th, and the 5th relative to the 1st group) in 2004 are negative and significant at 99% level of confidence (see details in Table 4.1). It implies that there are other variables that influence differences in bid-rent gradient of the higher income group relative to the based group. Notice only when the alternative transit is rapid rail transit, negative significant constant terms are yielded. This is consistent with less significant and fit of the model for case 2 and 3 in 2004 that rapid rail transit can explain residential location pattern changes among different income groups.

Corresponding to past studies, they have revealed that residential location form cannot be solely explained by influence of transport innovation such as rapid rail transit. It is not similar as the role of automobile that have highly induced moving-outward of residential location pattern. It also depended on characteristics of the individual; age, education level, family size, family composition, and life style. However, less significant of estimated coefficients and goodness of fit of the model also involve the presence of the second independent variable. Obscure results occurred when considering the alternative rapid rail transit for case 2 and 3 in 2004. As previously explained the rapid rail network did not extend to all areas, thus traveling by rapid rail transit yielded much more access cost to the nearest station, especially for commuters who living in the areas without rapid rail lines, then its high monetary cost cannot be offset by the reduction in time cost compare to the other modes of transport. Then disappearance of the second variable occurs as infinity break-even distance take that high access cost into account.