Land Development Decisions and Lottery Dependent Utility

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Land development behavior has been studied for some time,[1] but not until recently have scholars adopted a psychological approach to explaining such behavior. Drawing on prospect theory, Mohamed[2] proposes a structural explanation of why developers seek suboptimal development decisions, that is, satisficing, not from the perspective of bounded rationality, but from one of behavioral economics. In particular, he argues for four major psychological influences on developer decisionmaking: (1) myopic bracketing, (2) mental accounting, (3) liquidity constraining, and (4) temporal spacing. All four influences are derived from the s-shaped value function of prospect theory.[3]

Myopic bracketing implies that developers narrowly bracket their decisions one project at a time due to the fact that the most important reference point on the s-shaped value function is the profit target for each project. Mental accounting distinguishes developer investment into primary and secondary investments and primary investments allow developers to achieve their profit targets. Because of this distinction, developers only reluctantly make secondary investments. Liquidity constraining is a direct consequence of mental accounting because investment money is non-fungible, developers establish self-imposed liquidity constraints and are unwilling to make secondary investments. Temporal spacing occurs because segregating gains from different projects carries a higher cumulative value than if all the gains were to come at the same point in time from a single project.

All these psychological influences explain why developers prefer to move from one project to another and invest in exurban greenfield sites. In particular, when the approvals process is more predictable this tendency becomes more salient. Mohamed continues to question "do local governments unwittingly promote sprawl when they introduce policies to make the development process more predictable? The answer appears to be tentatively yes."

In this article, we explore another psychological trait in making risky choices, namely lottery dependent utility, and attempts to deposit how it might affect developers' behavior in making land development decisions. In particular, we will report an experiment that attempts to test the hypothesis that utility is fame dependent. We provide a theoretical background on lottery dependent utility to motivate the experimental design and procedure that is discussed. We report the results of the experiment and depict some implications of the findings for land development behavior using the setting of urban growth boundaries (UGBs) as a context. Some relevant issues, including a brief experimental design on investigating how lottery dependent utility would change also are discussed.

LOTTERY DEPENDENT UTILITY

Modern behavioral decision theory started in the 1940s when von Neumann and Morgenstern[4] introduced utility theory and later when Savage[5] constructed subjective expected utility theory. The notion of utility is at best a mathematical construct rather than a psychological trait. In applying utility theory to decisionmaking, it usually is assumed that the decisionmaker's utility function is invariant to be elicited. While this assumption simplifies to a great extent the modeling of choice behavior, we argue that in reality the utility function varies depending on how the decision situations are framed. For example, when a person commits suicide, he or she is choosing a best action that maximizes the utility function from the perspective of his or her decision situation, or *frame*, whereas in hindsight, if the person survived, he or she would consider this act irrational, again perceived from a different *frame*. If this argument of changing utility due to frames holds, as will be illustrated shortly in the experiment reported, the explanation and formulation of choice behavior by prospect theory[6] begs a close reexamination as to why preference reversals occur for the decisionmaker to make choices among logically equivalent questions but framed differently.

More specifically, Kahneman and Tversky were able to show that the decisionmaker was prone to select certain outcomes rather than making risky choices, or certainty effect, and violated expected utility theory. Consider the following problems with payoffs in US dollars.

Problem 1: Choose between

A:	2,500 with probability	.33
	2,400 with probability	.66,
	0 with probability	.01.
B:	2,400 with certainty.	

Problem 2: Choose between

C:	2,500 with probability	.33
	0 with probability	.67
D:	2,400 with probability	.34
	0 with probability	.66.

Most subjects in the experiment preferred B to A and C to D. The first selection pattern between A and B implies that

$$u(2{,}400) > .33u(2{,}500) + .66u(2{,}400) \text{ or } .34u(2{,}400) > .33u(2{,}500)$$

while the second selection pattern implies the reversed inequality.

Note that the utility function, u, is invariant between the two choice problems.

Given the observation of preference reversal, Kahneman and Tversky[7] proposed an alternative model to account for this discrepancy from expected utility theory by replacing probabilities with a weighting function and the utility function with a value function, also invariant, that is, if $(x, p; y, q)$ is a regular prospect, where x and y are the outcomes and p and q are the associated probabilities, then

$$V(x, p; y, q) = \pi(p)v(x) + \pi(q)v(y),$$

where π and v are defined on probabilities and outcomes and V is defined on prospects.

We argue however that the decisionmaker's utility functions in Problem 1 and Problem 2 might not be invariant; rather, they might be contingent on the contexts or frames of the decision situations. More specifically, let u' and u'' be the two contingent utility functions for Problem 1 and Problem 2 respectively. The first selection pattern between A and B implies that

$$0.34u'(2{,}400) > .33u'(2{,}500) \text{ or } u'(2{,}500)/u'(2{,}400) < 1.03,$$

whereas the second selection pattern between C and D implies that

$$.33u''(2{,}500) > .34u''(2{,}400) \text{ or } u''(2{,}500)/u''(2{,}400) > 1.03.$$

Both inequalities satisfy the monotonically increasing pattern of utility functions and thus do not violate the utility maximization principle.

The notion of frame dependent utility is not new. For example, Becker and Sarin[8] developed a lottery dependent utility model to explain preference reversal of a simple, hypothetical example. However, little has been said since then about the validity of lottery dependent utility.[9] Exceptions include Daniels and Keller[10] and Modesti.[11] Though both experiments saw the merits of Becker and Sarin's model, none provided a conclusive claim that the decisionmaker's preferences are indeed frame dependent. Even Becker and Sarin's original work derived from a hypothetical, rather than an experimental, choice situation.

If we consider frames the same as lotteries (as will be depicted shortly), what Becker and Sarin developed is so powerful that it could dispel the confusion between normative vs. descriptive aspects of decisionmaking. For example, the debate on normative vs. descriptive decision models actually could boil down to the question of selecting decision frames, rather than the decision model of utility maximization *per se*. Therefore, instead of examining the validity of Becker and Sarin's model, we address here the issue of frame dependent utility empirically by conducting an experiment to examine whether decisionmakers' utility varies across frames. Frame and lottery are thus used interchangeably here.

EXPERIMENTAL DESIGN AND PROCEDURE

The experiment reported here directly investigates the validity of frame dependent utility by comparing utilities within subjects derived from different frames or lotteries. If the utilities for the same monetary value, but elicited in different frames, were significantly different, we could conclude that the utility for that monetary value varies across frames. In the experiment, utilities are measured based on the probability equivalent (PE) method[12] and the elicitation questions were designed based partly on the original ones in prospect theory.[13] There were six such elicitation questions as shown below:

Q1—A: (NT$ 2,500, 0.33; NT$ 2,400, 0.66; NT$ 0, 0.01)	B: (NT$ 2,400, 1.00)
Q2—A: (NT$ 2,500, 0.33; NT$ 0, 0.67)	B: (NT$ 2,400, 0.34; NT$ 0, 0.66)
Q3—A: (NT$ 6,000, 0.45; NT$ 0, 0.55)	B: (NT$ 3,000, 0.90; NT$ 0, 0.10)
Q4—A: (NT$ 6,000, 0.001; NT$ 0, 0.999)	B: (NT$ 3,000, 0.002; NT$ 0, 0.998)
Q5—A: (NT$ –3,000, 0.90; NT$ 0, 0.10)	B: (NT$ –6,000, 0.45; NT$ 0, 0.55)
Q6—A: (NT$ –3,000, 0.002; NT$ 0, 0.998)	B: (NT$ –6,000, 0.001; NT$ 0, 0.999)

Note that each elicitation question contained a pair of lotteries, and the subjects were asked to compare lottery A and B and select one that he or she thought was preferred. The lotteries were represented in a short form as (x, p; y, q) with a probability of p to obtain x and a probability of q to receive y. The unit of 'NT$' stands for New Taiwan Dollar. Each pair of elicitation questions, *i. e.*, Questions 1 and 2, 3 and 4, and 5 and 6, were designed so that the preference reversal phenomena were presented by Kahneman and Tversky[14] and that the utilities derived from the same monetary value, but in different frames, could be compared statistically. For example, the utilities for NT$ 2,500 derived from Questions 1 and 2 were compared statistically.

Following the PE method, after making a choice between a pair of lotteries, the subject was asked to specify a sequence of converging probabilities so that he or she was indifferent between a certain amount of monetary value, say NT$ -6,000, and a probability p that he or she would receive an amount of NT$ 10,000 (presumably with a utility of one) and a probability of 1-p that he or she would receive nothing (presumably with a utility of zero). The converged probability p was then the utility corresponding to that certain amount of monetary value.

The sequence of the six elicitation questions was first randomized and the subjects in the experiment were then assigned randomly to respond to the questions in each of the randomized sequences. Before answering the questions, the subjects were instructed as to how to proceed in the experiment, including a time limit of responding to the elicitation questions. The 38 subjects were freshman students of the Department of Real Estate and Built Environment at National Taipei University, Taiwan and were paid NT$ 100 afterwards for participating in the experiment. A pretest was conducted before the experiment and the same experiment also was conducted at the Department of Land Management of Zhejiang University in Hangzhou, China.

RESULTS

A t test was conducted to compare the subjects' responses to each pair of the elicitation questions to investigate whether the utilities for the same monetary value, but derived from different lotteries, were significantly different. The means of difference in utility and t values for the absolute differences of utility in the pair of elicitation questions corresponding to the monetary values are listed in Exhibit 1. The results show that all the utilities corresponding to the six monetary values were significantly different in each pair of lotteries at the level of $p = 0.05$. We can conclude that the subjects' utilities corresponding to the monetary values changed in different lotteries.

Note that the same conclusion can be derived from the pretest (25 subjects) in Exhibit 2 and the experiment conducted at Zhejiang University (26 subjects) in Exhibit 3 in

Exhibit 1—The *t* Test of the Comparison of Utilities of Monetary Values Across Frames for the NTPU Experiment ($N = 38$)

Monetary Value	Mean	*t* value	*p*
NT$ 2,500	–0.128931	–6.006	0.000*
NT$ 2,400	–0.109131	–6.115	0.000*
NT$ 6,000	–0.085657	–6.531	0.000*
NT$ 3,000	–0.126973	–5.556	0.000*
NT$ -3,000	–0.158201	–7.188	0.000*
NT$ -6,000	–0.117831	–5.289	0.000*

* Significant at $p = 0.05$

Exhibit 2—The *t* Test of the Comparison of Utilities of Monetary Values Across Frames for the Pretest ($N = 25$)

Monetary Value	Mean	*t* value	*p*
NT$ 2,500	–0.130000	–5.670	0.000*
NT$ 2,400	–0.151680	–5.057	0.000*
NT$ 6,000	–0.196516	–4.072	0.000*
NT$ 3,000	–0.232532	–5.050	0.000*
NT$ –3,000	–0.214088	–4.786	0.000*
NT$ –6,000	–0.234872	–5.483	0.000*

* Significant at $p = 0.05$

Exhibit 3—The *t* Test of the Comparison of Utilities of Monetary Values Across Frames for the Zhejiang Experiment ($N = 26$)

Monetary Value	Mean	*t* value	*p*
CNY 250	–0.050577	–4.752	0.000*
CNY 240	–0.053885	–4.203	0.000*
CNY 600	–0.083462	–4.318	0.000*
CNY 300	–0.057115	–5.694	0.000*
CNY –300	–0.111919	–4.776	0.000*
CNY –600	–0.112692	–4.323	0.000*

* Significant at $p = 0.05$

that all t values were statistically significant at the level of $p = 0.05$. The currency used in the Zhejiang experiment was CNY or Reminbi with a factor less in payoff than the one conducted in Taipei.

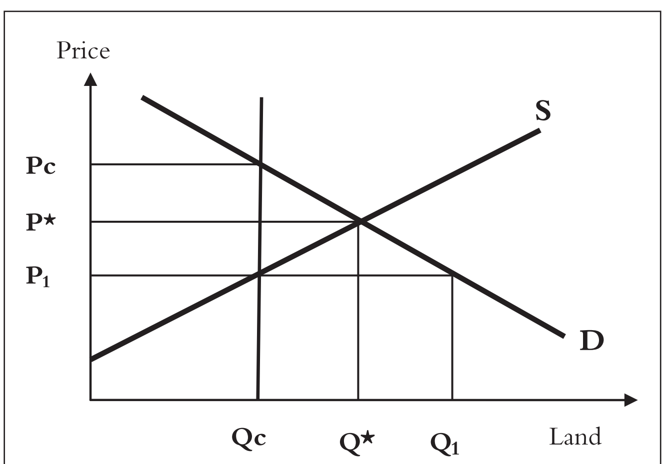
We further tested whether the subjects made choices of lotteries in each of the six elicitation questions according to the principle of maximizing the expected utilities thus elicited. A non-parametric McNemar test shows that in four out of the six elicitation questions (Q3, $p = 0.000$; Q4, p = 0.000; Q5, p = 0.000; and Q6, $p = 0.001$) the subjects did not choose according to the utility maximization principle, at the significance level of 0.05. Note that this observation is compared with the results in the experiment conducted at Zhejiang University in that three out of the six elicitation questions (Q2, $p = 0.002$; Q4, $p = 0.000$; and Q6, $p = 0.000$) were statistically significant, meaning that these subjects did not choose according to the utility maximization principle. A closer examination also shows that the choices predicted by prospect theory[15] did not conform significantly to the choices directly made by the subjects either. More specifically, a non-parametric McNemar test shows that in five out of the six elicitation questions (Q1, $p = 0.000$; Q3, $p = 0.003$; Q4, $p = 0.003$; Q5, $p = 0.001$; and Q6, p = 0.012) did the subjects choose not according to the utility maximization principle, at the significance level of 0.05. Note that this observation is compared with the results in the experiment conducted at Zhejiang University in that three out of the six elicitation questions (Q2, $p = 0.039$; Q3, $p = 0.000$; and Q5, $p = 0.000$) were statistically significant, meaning that these subjects did not choose according to the utility maximization principle. In summary, contrary to our expectation, prospect theory did not outperform expected utility theory in predicting the subjects' choices of lotteries.

IMPLICATIONS FOR LAND DEVELOPMENT DECISIONS

The findings in the experiment can be used to depict land development decisions in relation to the setting of UGBs. The UGB policies in Taiwan and China are different from those in the United States. UGBs in Taiwan or China are the set of zones that provide the land for urban development, such as residential, commercial, and industrial lands, while other zones, such as natural parks, agricultural land, and water bodies, are considered lands outside the UGBs. Therefore, it is possible that after the UGBs are established that delineate urban and non-urban land uses, developers can make the decision whether to purchase land inside or outside the UGBs for development. It has been concluded empirically that the UGB policies in Beijing has failed,[16] while those in Taipei seem successful.[17] However, whether UGBs would contain urban sprawl in Taiwan and China remains an open question. The notion of lottery dependent utility could provide an explanation of why developers, upon being restricted by UGBs in land development, would be inclined to purchase land outside the UGBs.

Elsewhere, we have depicted how developers react to the setting of UGBs in terms of the capturing of property rights.[18] In effect, the imposition of UGBs on a city would increase the price of land inside the UGBs, encourage developers to seek the cheaper land outside the UGBs for development, and thus cause urban sprawl. Referring to Exhibit 4, the initial demand and supply curves for land are shown as D and S. Viewing land as an intermediate, not the final product of the land development process, the developer is on the demand side and the landowner is on the supply side. The market clearing price for land is P* with the associated amount of land exchanged as Q*. Assume a new land control policy of UGBs is imposed inelastic with respect to price that limits all land developed within Qc below the equilibrium amount Q*, indirectly imposing a price limit of land set at Pc. The unit price of land demanded shifts from P* up to Pc, while the unit price of land supplied shifts from P* down to P_1, and the market clearing price would be at Pc. However, the landowner is willing to sell at P_1 with the developer to secure the land at Pc, and there would be a price discrepancy of Pc – P_1 in the marketplace. The difference in the amount between Pc × Qc, the amount developer actually pays for the total amount of transacted land, and Pc × Q_1, the amount the landowner is willing to sell the transacted land, plus the triangular area between P_1 and S, is dissipated in the public domain without identified recipients, but captured by the landowner through the market mechanism. The implication

Exhibit 4—Effects of UGBs as Developable Land Control



is that the developer would be willing to risk violation of the UGBs to pay that amount in order to acquire additional land outside the UGBs at a lower cost.

In the context of lottery dependent utility, after the setting of the UGBs a developer inside the delineation lines would face a choice of whether to remain within the UGBs to seek land for development or purchase a cheaper land outside. Assume that original land price at the equilibrium is P*= NT$ 500,000/ping. One ping is equal to 3.3 m^2. After the setting of UGBs, land price is bid up to Pc = NT$ 1,000,000/ping; however, the marginal cost of land is set at P1 = NT$ 250,000/ping. Assume that the land price outside the UGBs is NT$ 500,000/ping, that the net revenue, thus gain, from a development project inside the UGBs (NT$ 100,000/ping) is higher than that outside (NT$ 50,000/ping), and that the probability of success in land development is higher for the land inside the UGBs (95 percent) than outside (0.85). The developer would face a choice between two lotteries as follows in the unit land of ping:

Problem 3: Choose between

E: NT$ 100,000 with probability .95,

–NT$ 1,000,000 with probability .05.

F: NT$ 50,000 with probability .85,

–NT$ 500,000 with probability .15.

The expected monetary value for Lottery E for land development inside the UGBs is NT$ 45,000, while the expected monetary value for Lottery F outside is –NT$ 32,500. If the utilities for the monetary values between the two lotteries are different and assume that gain effect in Lottery F looms large, implying that the utility for NT$ 50,000 in F would be close to that for NT$ 100,000 in E, in addition to risk seeking, loss aversion, and property rights capturing, the developer would purchase the land outside the UGBs for development. Indeed, using a similar scenario in a recent experiment, one half of the subjects decided to seek the land outside the UGBs for development, which will be reported in the future.

DISCUSSION

The notion of frame dependent utility has a direct impact on the concept of mental accounting based on which Mohamed[19] draws his tentative conclusion that local governments unwittingly promote sprawl when they introduce land control policies to make the development process more predictable. Based on the s-shaped value function proposed by prospect theory and citing Thaler,[20] Mohamed argues that "people prefer to segregate gains so that each gain is associated with its own value because

$$v(x_1) + v(x_2) + \ldots + v(x_n) > v(x) \,, \quad (1)$$

where v is value of the total gain x and $x_1 \ldots x_n$ are discrete gains."

In other words, segregation results in higher total value. "On the other hand, people prefer to integrate losses because

$$v(x) < v(-x_1) + v(-x_2) + \ldots + v(-x_n) \,, \quad (2)$$

where $-x_1 \ldots -x_n$ are discrete loses."

In other words, integration minimizes the disutility associated with losses.

However, if the value function is frame dependent, as shown in the reported experiment, meaning that each gain or loss is associated with a different value function, Equations (1) and (2) may not hold so Mohamed's argument that development decisions are fragmented spatially and myopic temporally might need to be refined.

On the other hand, it is difficult to define concretely what a frame is in a real decision situation because frames can take many forms, including storytelling, scenarios, norms, tradition, and even hunches, but for theory construction purposes we can at least consider a frame as equivalent to the notion of small world introduced by Savage.[21] Consider selecting between two prospects (x, p) and (y, q) where x and y are payoffs and p and q are the associated probabilities. This is equivalent to the two small world matrices shown in Exhibit 5 and Exhibit 6

Exhibit 5—Small World Matrix of Prospect (x, p)

	P	1-p
a	x	0

and

Exhibit 6—Small World Matrix of Prospect (y, q)

	Q	1-q
B	y	0

where *a* and *b* are actions and mutually exclusive. Selecting *a* means selecting the first prospect, and *b* the second one.

Alternatively, following Krantz and Kunreuther,[22] the pair of prospects can be formulated as the following goals/plans matrix of frame shown in Exhibit 7

Exhibit 7—Goals/Plans Matrix of Frame

	x	y
c	p	0
d	0	q

where x and y are payoffs (outcomes) or goals; c and d are actions or plans; and p and q are probabilities or decision weights. The goals/plans representation of frame seems more succinct and a theory of frame dependent utility could be formulated based on this conception of frame, depicting the relationship between payoff and probability.

Finally, we have not dealt with the pattern in which lottery dependent utility changes. One way of investigating how that utility changes could be done by looking into the relationship between the utility of a monetary value, the probability that yields that monetary value, and the other payoff in a lottery. For example, we could conduct an experiment in which subjects specify the utilities of payoffs in a set of lotteries and run a regression of the resulting utilities as an independent variable on the probabilities and the other payoffs as two other dependent variables. If the correlation coefficient R^2 is high enough, we can conclude that the lottery dependent utility is a linear function of the probability associated with the payoff yielding that utility and the payoff associated with the other branch of the lottery.

CONCLUSIONS

We provide evidence through experimentation that utility is labile and contingent on frames in which it is manifested, rather than being stable and fixed. Prospect theory does not outperform subjective expected utility theory in predicting choice behavior when utility is explicitly changing. The immediate implication is that such findings provide a useful, behavioral basis for explaining land development behavior. A more general implication is that a decision model based on lottery dependent utility, such as Becker and Sarin's,[23] would be difficult but desirable. This could be done by conducting further experiments specifically on how utility varies in relation to frames of payoff and probability.

NOTES

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