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Proposing a dinner date: analysis by rank-dependent expected utility

Gilbert W. Bassett Jr.*

Department of Finance, University of Illinois at Chicago, 601 South Morgan (MC 168), Chicago, IL 60607-7121, USA

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Abstract

The rank-dependent expected utility model is used to analyze a game involving a dinner date proposal. Alternative sharing rules are investigated: Dutch treat (both parties pay for their own dinner), and Oriental treat (the one making the invitation pays for both dinners). The solution depends on the sharing rule as well as optimism or pessimism regarding the chances of an invitation from the other party. Solutions that increase the chances of dinner indicate conditions under which optimism or pessimism is advantageous and might survive. Solutions that favor Dutch or Oriental treat suggest mechanisms by which alternative sharing rules might evolve.

JEL classification: D81

Keywords: Rank-dependent expected utility; Fee sharing rule; Dutch treat; Oriental treat

1. Introduction

In a recent paper, Dutch treat versus Oriental treat (Kim et al., 2002) consider goods whose values are generated only through joint consumption by two or more people. Their focus is on comparing two fee-sharing rules. One is Dutch treat, whereby all participants

* Tel.: +1 312 996 5777; fax: +1 312 413 7948.
E-mail address: gib@uic.edu.

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pay for their own expenses. The other is called Oriental treat in which the initial proposer pays all the expenses.

Their illustrative example involves a simple two-person game between a Man (1) and a Woman (2) who are thinking of going to dinner together. Consumer *i* values the date with consumer *j* as v_i, which is the private information of consumer *i*. It is assumed that v_i is the realization of U_i, a uniform random variable over [0, 1], and U_1 and U_2 are independent. The per-person price for dinner is p. The Man and Woman go to dinner if either proposes and the other accepts.[1] If neither party proposes or if a proposed date is rejected, there is no dinner and the value to each party is 0.

For Dutch treat the analysis is simple and does not involve probability beliefs. The Man proposes if his $v_1 > p$, and the Woman accepts if her $v_2 > p$.

With the Oriental rule the initial proposer pays for both dinners, $2p$, and the other party always accepts (because accepting means not having to pay and the value of dinner is positive). The problem is whether to propose dinner. The advantage of proposing dinner and getting $v_i - 2p$ (in case the other party does not propose) has to be weighed against not proposing and either (i) receiving a free dinner, because the other party proposes or (ii) staying home and receiving nothing. The decision is more complicated than with Dutch treat because it involves probability beliefs.

The game was analyzed in Kim et al. assuming (i) each party maximizes expected utility and (ii) there is a Nash-like equilibrium in which the Woman's belief regarding the probability that the Man will propose is equal to the actual probability that the Man proposes dinner, and vice versa.

Intuitively, the Oriental rule leads to dinner when at least one of the v_i is high. Otherwise, when v_i is moderate, there is a reluctance to propose because (i) the proposer has to pay for both dinners, and (ii) there is the possibility of free-riding on a proposal from the other party.

The dinner game will be analyzed below under the assumption that decisions are based on rank-dependent expected utility (RDEU). This is an extension of expected utility that permits probabilities to be distorted in ways that capture ideas of pessimism and optimism; see, for example, Quiggin (1993) and Diecidue and Wakker (2001). Among the virtues of RDEU are its added flexibility in representing risk attitudes (without recourse to the curvature of a utility function) and its intuitively plausible explanations for many of the well-known anomalies of expected utility. Reasons for, and alternatives to, expected utility have been recently discussed in Rabin (1998) and Rabin and Thaler (2001). Recent applications of the RDEU model include Abouda and Chateauneuf (2002), and Patrick (2000) where the bid-ask spread is considered in light of a market maker's attitudes toward risk, and Bassett et al. (2004) where financial portfolios are evaluated with RDEU-based risk measures.

For the present application, RDEU allows analysis of the dinner game under conditions in which one or both of the parties is pessimistic or optimistic about the other proposing a date. Analysis of the game also offers the opportunity to consider how Dutch or Oriental treat customs might evolve in a world of EU or RDEU decision makers.

[1] It will be assumed that if both propose at the same time, they each pay p. This differs slightly from Kim et al. who assumed that one party would pay $2p$ with probability 0.5.

The Section 2 describes the dinner game and its analysis under expected utility. Section 3 presents a brief description of rank-dependent expected utility. Section 4 analyzes the dinner game under alternative scenarios. Concluding comments are in the final section.

2. The dinner game

The situation from the perspective of the Man (who knows the Woman's valuation follows U_2, but does not know the realization, v_2) is depicted as follows:

	Woman 2	
	Propose	Not propose
Man 1		
Propose	$v_1 - p, U_2 - p$	$v_1 - 2p, U_2$
Not propose	$v_1, U_2 - 2p$	0, 0

The situation from the Woman's perspective is analogous.

Let v_1^* denote the threshold valuation such that when $v_1 > v_1^*$, the Man proposes. Similarly let v_2^* denote the Woman's threshold value. The associated regions that lead to a dinner are depicted, as in Kim et al., in Fig. 1.

Let v_{12} denote the Man's belief regarding the Woman's threshold value and, similarly, v_{21} the Woman's belief regarding the Man's threshold. In general, the Man's threshold will depend on his belief about the Woman's threshold, $v_1^* = v_1^*(v_{12})$, and similarly for the Woman.

Stated in terms of a (probability, prize) lottery $[p_1, x_1; p_2, x_2]$, the "Man propose" option is, Man propose: $[1 - v_{12}, v_1 - p; v_{12}, v_1 - 2p]$. The alternative lottery is, Man not propose: $[v_1, 1 - v_{12}; 0, v_{12}]$. The Woman faces analogous lotteries.

An equilibrium will be a threshold pair $(v_1^{\mathrm{E}}, v_2^{\mathrm{E}})$ such that the Man's belief regarding the Woman's threshold is the Woman's threshold value, and vice versa; $v_2^{\mathrm{E}} = v_2^*(v_1^{\mathrm{E}})$ and $v_1^{\mathrm{E}} = v_1^*(v_2^{\mathrm{E}})$.

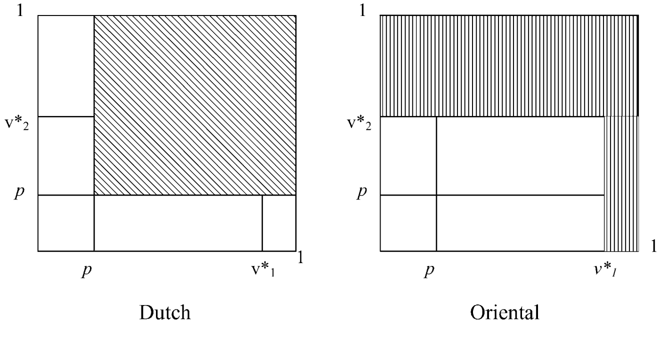

Fig. 1. Dutch and Oriental treat dinner regions.

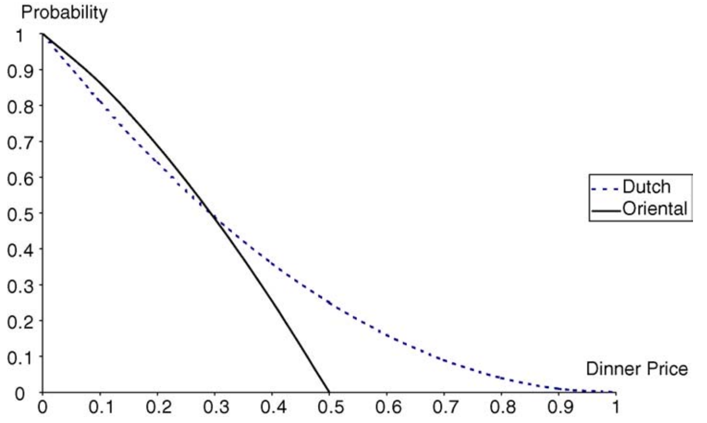

Fig. 2. Dinner probability: Dutch and Oriental treat (expected utility).

2.1. EU: expected utility

To find v_1^* we compute expected payoffs when the Man (i) proposes and (ii) does not propose. Given his private information about the value of the dinner, v_1, and a belief about the Woman's threshold, v_{12}, we have,[2]

$$\text{EU[man propose]}: \quad (v_1 - p)\, Pr(U_2 > v_{12}) + (v_1 - 2p)\, Pr(U_2 < v_{12})$$
$$= (v_1 - p) - pv_{12},$$
$$\text{EU[man not propose]}: \quad v_1\, Pr(U_2 > v_{12}) = v_1(1 - v_{12}).$$

Hence the Man proposes if, $v_1 > p[1 + v_{12}]/v_{12}$, so his threshold function is $v_1^*(v_{12}) = p[1 + v_{12}]/v_{12}$. In a similar fashion for the Woman, $v_2^*(v_{21}) = p[1 + v_{21}]/v_{21}$.

Solving for the equilibrium gives, as in Kim et al., $v_1^{\mathrm{E}} = v_2^{\mathrm{E}} = v^*$, where

$$v^* = \frac{p + \sqrt{p^2 + 4p}}{2}. \tag{1}$$

The probability of dinner under each sharing rule is depicted in Fig. 2 as a function of the dinner price. At low prices there is a higher probability associated with the Oriental rule, while Dutch treat has a higher probability when the dinner price is larger. The cutoff price at which the sharing rules have equal probability of dinner is about $p = 0.30$.

2.2. Discussion

Suppose $p = 0.30$, you are the Man, and your (private) value of dinner is 0.70. In a Dutch treat world you would propose dinner and hope for the $U_2 > 0.3$ event that would make it

[2] In order that the utility of paying for dinner is, $v_1 - p = Ut(\text{dinner}) - p$, assume that utility is locally linear and p is small.

worthwhile for the Woman to accept. However the custom is Oriental treat. What should you do? If you propose dinner you will benefit by 10 utility units (paying 2×0.30, but gaining 0.70). If you do not propose you will get a free dinner if the Woman proposes, but gain nothing otherwise. What should you do?

If you know (i) the Woman is like yourself and (ii) she (and you) use expected utility, then you can determine her threshold v^* and hence the probability that she will make a proposal. You compute $v^* = 0.71$ via Eq. (1). Since the value of dinner is smaller than the threshold, you do not propose. Instead you sit and wait, hoping for a proposal. If she values dinner, $U_2 > 0.71$, she proposes and you get a free dinner, but if $U_2 < 0.71$ you lose a dinner whose net benefit you knew was positive.

It is clear that for $v_1 = 0.70$, no proposal *should* be made when both are using expected utility. But what if decisions are not based on expected utility?

Suppose I suspect that, for whatever reason, the Woman has a threshold of $v_2^* = 0.71$, so the probability of her proposal is just 0.29. Being lucky in cards, I always seem unlucky in these situations. Unwilling to sit and wait and hope for $U_2 > 0.71$, I lower my threshold to, $v_1^*(0.71) = 0.65$, less than 0.70, and propose dinner.

My decision to propose dinner when $v_1 = 0.70$ means that I am not using EU. Is it a mistake? It is not necessarily a mistake if I suspect the Woman does not use EU, and it has the benefit of guaranteeing a dinner whose net benefit is positive. In the following section it is not a mistake because decisions are made on the basis of RDEU.

3. RDEU: rank-dependent expected utility

For a lottery with prizes and probabilities $(p_1, x_1; p_2, x_2; \ldots; p_n, x_n)$ where prizes are *ordered*, $x_1 > x_2 \cdots > x_n$, rank-dependent expected utility (RDEU) is given by the formula,

$$\mathrm{RDEU}(p_1, x_1; p_2, x_2; \ldots; p_n; x_n) = \sum\nolimits_{j=1}^{n} \pi_j Ut(x_j),$$

$Ut(x)$ denotes the utility of the (certain) outcome x, and π_j are "decision weights" that sum to 1. The decision weights are given by

$$\pi_j = w(p_1 + \cdots + p_1) - w(p_1 + \cdots + p_{j-1})$$

with $\pi_1 = w(p_1)$. Standard expected utility corresponds to $w(p_i) = p_i$, so that the decision weights are the probabilities. Otherwise, the decision weights distort probabilities via $w(\cdot)$. There is "rank" dependence because the formula is applied to prizes ranked from highest to lowest. (For presentation and discussion of the RDEU model, see Quiggin (1993) and Diecidue and Wakker (2001).)

Since π-weights sum to 1, RDEU in the case of our two-outcome lottery reduces to

$$\begin{aligned}&\mathrm{RDEU}(p_1, x_1; p_2, x_2)\\ &\quad = \pi_1 Ut(x_1) + (1 - \pi_1) Ut(x_2) = w(p_1) Ut(x_1) + (1 - w(p_1)) Ut(x_2).\end{aligned}$$

Fig. 3 depicts alternative $w(\cdot)$functions. Convex $w(\cdot)$ with $w(p_1) < p_1$ corresponds to a "pessimistic" outlook because the best outcome has decision weight less than p_1 (and the

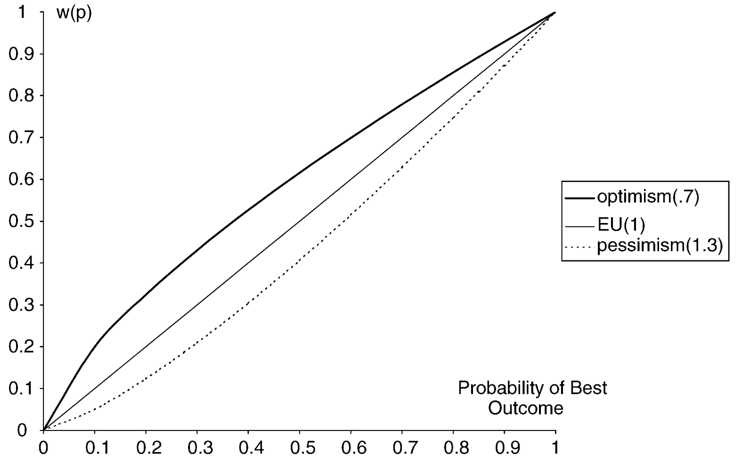

Fig. 3. Distortion functions.

worst outcome has a value larger than $1-p_1$). Conversely, concave $w(\cdot)$ corresponds to an optimistic attitude in which the decision weight on the best outcome is higher than p_1.

In the dinner example, the Man's decision depends on v_{12}, his belief about the Woman's threshold. Optimism means that the decision weight on the favorable outcome, "Woman proposes", is overweighted, $w(1-v_{12})>1-v_{12}$, while pessimism means overweight, $w(v_{12})>v_{12}$, on the state in which the Woman does not propose(and where there might not be dinner).[3]

4. RDEU: dinner

Consider the Man's options and let his distortion function be w_1, so that

$$\begin{aligned}&\text{RDEU(man propose)}\\&\quad=\text{RDEU}(1-v_{12},v_1-p;v_{12},v_1-2p)\\&\quad=(v_1-p)w_1(1-v_{12})+(v_1-2p)(1-w_1(1-v_{12})),\\&\text{RDEU(man not propose)}=\text{RDEU}(1-v_{12},v_1;v_{12},0)=v_1w_1(1-v_{12}).\end{aligned}$$

Hence the Man proposes when $v_1>p[2-w_1(1-v_{12})]/[1-w_1(1-v_{12})]$ and his threshold function is

$$v_1^*(v_{12})=\frac{p[2-w_1(1-v_{12})]}{1-w_1(1-v_{12})}.$$

In a similar fashion for the Woman,

[3] Notice that the dinner lotteries are comonotonic; their rank correlation is one. That is, the best outcome occurs when the other party proposes, and conversely.

Table 1
Equilibrium thresholds: (v_1^E, v_2^E)

Dinner price	(α_1, α_2)								
	(0.7, 0.7)	(1, 1)	(1.3, 1.3)	(0.7, 1)		(0.7, 1.3)		(1, 1.3)	
0	0	0	0	0	0	0	0	0	0
0.10	0.42	0.37	0.34	0.63	0.26	0.71	0.22	0.45	0.28
0.20	0.61	0.56	0.52	0.77	0.46	0.83	0.42	0.62	0.48
0.30	0.77	0.72	0.69	0.89	0.64	0.92	0.61	0.76	0.66
0.40	0.90	0.86	0.84	0.99	0.81	0.99	0.80	0.88	0.83
0.50	1	1	1	1	1	1	1	1	1

$$v_2^*(v_{21}) = \frac{p[2 - w_2(v_{21})]}{1 - w_2(v_{21})}.$$

In order to make easy comparisons to EU it will be assumed that $w_i(p) = p^{\alpha_i}$. With this specification the optimism/pessimism of each party is determined by their α-value: $\alpha > 1$ is the extent of optimism, $\alpha < 1$ is the extent of pessimism, and $\alpha = 1$, corresponds to expected utility.

Substituting for $w(\cdot)$, the equilibrium value for the game is a solution to

$$v_1^E = \frac{p(2 - (1 - v_2^E)^{\alpha_1}}{1 - (1 - v_2^E)^{\alpha_1}}, \qquad v_2^E = \frac{p(2 - (1 - v_1^E)^{\alpha_2}}{1 - (1 - v_1^E)^{\alpha_2}}.$$

Illustrative solutions are presented for alternative α values: 0.7 (optimism), 1.0 (regular expected utility), and 1.3 (pessimism). They are presented when both parties have the same distortion function as well as when the parties differ in their optimism/pessimism. Equilibrium values and related statistics for the alternative specifications are presented in Tables 1–3, and in Fig. 4.

Table 1 shows equilibrium thresholds, (v_1^E, v_2^E). For ease of presentation Table 2 shows the associated probabilities of a proposal, which is just $1 - v_1^E$, $1 - v_2^E$. Table 3 shows the probability that the Man and Woman end up going to dinner. The first three columns in Tables 1 and 2 correspond to cases in which both parties have identical distortion functions and their common $v_1^E = v_2^E$ is shown. In the other columns the parties have different distortion functions, and the proposal probability is presented for each party.

Table 2
Proposal probability (Man, Woman)

Dinner price	(α_1, α_2)								
	(0.7, 0.7)	(1, 1)	(1.3, 1.3)	(0.7, 1)		(0.7, 1.3)		(1, 1.3)	
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.10	0.58	0.63	0.66	0.37	0.74	0.29	0.78	0.55	0.72
0.20	0.39	0.44	0.48	0.23	0.54	0.17	0.58	0.38	0.52
0.30	0.23	0.28	0.31	0.11	0.36	0.08	0.39	0.24	0.34
0.40	0.10	0.14	0.16	0.01	0.19	0.01	0.20	0.12	0.17
0.50	0	0	0	0	0	0	0	0	0

Table 3
Probability of dinner

Dinner price	Oriental treat (α_1, α_2)						Dutch treat
	(0.7, 0.7)	(1, 1)	(1.3, 1.3)	(0.7, 1)	(0.7, 1.3)	(1, 1.3)	
0	1	1	1	1	1	1	1
0.10	0.83	0.86	0.88	0.84	0.84	0.87	0.81
0.20	0.62	0.69	0.73	0.65	0.65	0.70	0.64
0.30	0.41	0.48	0.53	0.43	0.44	0.50	0.49
0.40	0.19	0.25	0.29	0.21	0.21	0.27	0.36
0.50	0	0	0	0	0	0	0.25
0.60							0.16
0.70							0.09
0.80							0.04
0.90							0.01
1.00							0

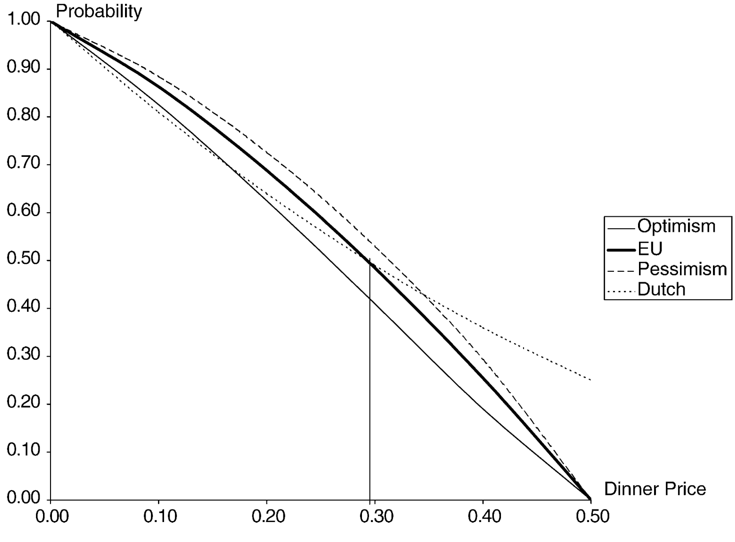

Fig. 4. Probability of dinner: Dutch and Oriental treat (EU and RDEU).

Tables 1 and 2 show that the probability of a proposal depends on optimism and pessimism. We focus on the dinner price of 0.30. When both use EU, the equilibrium threshold is 0.72 (Table 1), and the probability that the Man or Woman makes an invitation is $1 - 0.72 = 0.28$ (Table 2). When both parties are optimistic ($\alpha = 0.7$), the proposal probability drops to 0.39. Optimism reduces the probability as each awaits a proposal from the other party. When both are pessimists, the proposal probability rises to 0.48.

The probabilities for dinner are shown in Table 3.[4] At $p = 0.30$ Oriental and Dutch treat probabilities are about equally likely under EU decision making, but if both are pessimists,

[4] The probability of dinner is closely related to expected consumer surplus; see Appendix A.

an Oriental treat dinner becomes more likely. Under these conditions pessimism is a good thing because it increases the probability of dinner; pessimistic RDEU dominates EU. Further, pessimistic RDEU (but not EU) beats Dutch treat.

Dinner probabilities when there are identical distortion functions are depicted in Fig. 4. It shows the dinner probability as a function of price for different α values as well as for Dutch treat. The EU and Dutch treat cross at the probability of about 0.3 with Dutch treat having higher dinner probabilities at higher dinner prices, and Oriental treat having higher probabilities when dinner prices are lower. Probabilities when both parties are optimistic and pessimistic are also shown. The figure shows that the Oriental sharing rule offers the best chance for dinner when (i) dinner prices are low, or (ii) there is some degree of pessimism.

The remaining columns in the tables show what happens when distortion functions are different for each party. Table 2 shows the proposal probability is higher for the party who is pessimistic. At dinner price 0.30, the proposal probability for the pair (optimistic, EU) (that is, 0.7, 1) is (0.11, 0.36). This compares to (28, 0.28) when both follow EU. Confidence in a proposal from the other party makes the equilibrium probability for the optimist go down to 0.11, but it also affects the EU decision-maker (playing against the known optimist) as the new equilibrium is at the higher 0.36 value. The net effect on dinner probability (shown in Table 3) is a fall from 0.48 to 0.43. The optimist decreases the chances of dinner.

The column headed by (1, 1.3) shows proposal probabilities when one party uses EU and the other pessimistic RDEU. The pessimist makes a proposal (at dinner price 0.30) with a probability that is now higher, 0.34. The other party using EU sees their equilibrium probability of a proposal drop from 0.28 to 0.24; they are less aggressive due to the increased likelihood of a proposal from the pessimist. The net effect is seen to increase the probability of dinner to 0.50 (from (EU, EU) of 0.48), which is also now greater than for Dutch treat. Dutch dominates Oriental when both parties use expected utility, but Oriental dominates if one of the parties is a pessimist.

5. Summary

We have shown that the solution to the dinner proposal game differs under EU and RDEU. The probability of dinner also depends on whether the sharing convention is Dutch or Oriental treat. While the analysis is admittedly very stylized, it at least suggests conditions under which actual sharing rules could evolve. The likelihood of dinner decreases with optimistic RDEU, but increases with pessimistic RDEU. Optimism tends to favor Dutch treat, while pessimism increases the chances that Oriental treat will lead to dinner.

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Table A.1
Consumer surplus

Dinner price	Oriental treat (α_1, α_2)						Dutch treat
	(0.7, 0.7)	(1, 1)	(1.3, 1.3)	(0.7, 1)	(0.7, 1.3)	(1, 1.3)	
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.10	0.762	0.777	0.784	0.760	0.757	0.778	0.729
0.20	0.520	0.551	0.566	0.524	0.522	0.556	0.512
0.30	0.301	0.339	0.360	0.307	0.307	0.347	0.343
0.40	0.119	0.153	0.171	0.124	0.124	0.160	0.216
0.50	0.000	0.000	0.000	0.000	0.000	0.000	0.125

Appendix A

With Dutch treat, consumer surplus is the product of $(1-p)$ and the probability of dinner. For Oriental treat and EU decision making the expected consumer surplus is also the product of $(1-p)$ and the probability of dinner (see Kim et al., 2002, p. 420).

For RDEU decision makers, expected consumer surplus with Oriental treat at threshold, $(v_1^{\mathrm{E}}, v_2^{\mathrm{E}})$, is

$$\int_0^1 \int_{v_1^{\mathrm{E}}}^1 (v_1 + v_2 - 2p)\,\mathrm{d}v_1\,\mathrm{d}v_2 + \int_{v_2^{\mathrm{E}}}^1 \int_0^1 (v_1 + v_2 - 2p)\,\mathrm{d}v_1\,\mathrm{d}v_2$$
$$- \int_{v_2^{\mathrm{E}}}^1 \int_{v_1^{\mathrm{E}}}^1 (v_1 + v_2 - 2p)\,\mathrm{d}v_1\,\mathrm{d}v_2$$
$$= 1 - \frac{(v_1^{\mathrm{E}})^2 v_2^{\mathrm{E}}}{2} - \frac{(v_2^{\mathrm{E}})^2 v_1^{\mathrm{E}}}{2} - 2p(1 - v_1^{\mathrm{E}} v_2^{\mathrm{E}}).$$

Consumer surplus values are given in Table A.1. They correspond, approximately, to the dinner probabilities in Table 3, in that the rule with the higher dinner probability also has greater consumer surplus.

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