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Transportation Demands in the Columbia-Snake River Basin

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IWR Report 06-NETS-R-03

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TRANSPORTATION DEMANDS IN THE COLUMBIA-SNAKE RIVER BASIN

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1. Executive Summary and Introduction

Transportation demands are central to Army Corps of Engineer planning models. ACE planning models require demand structures over a wide range of rates. Over the last three years, the Institute for Water Resources (IWR) and others have used a variety of approaches to estimate the demand for transportation by waterways. These studies include a revealed- and stated-preference choice model of agricultural shippers in the Upper Mississippi River Valley (Train and Wilson (2004)), a stated-preference model of annual volumes shipped by Ohio River Valley shippers of a wide range of commodities (Sitchinava, Wilson, and Burton (2005)), a panel data model of southbound monthly Upper Mississippi corn movements (Boyer and Wilson (2004), and a variety of time series models by Dager et al (2005) and Fuller et al. (2005).

While panel data and time series approaches can provide meaningful estimates of revealed demand elasticities, they are limited in the sense that the estimates are likely only relevant for the observed range in rates, transit times and reliability levels. This limited range of key variables hinders estimation of demand parameters and forecasting under new circumstances. The studies that use stated-preference data provide estimates over a wide range of rates, transit times, and reliability, which has the potential to improve the estimation of demand parameters and to allow forecasting for policies and waterway improvements under which rates and travel times may change considerably. However, this advantage of stated-preference data is mitigated by the possibility that responses by shippers to stated-preference questions may not represent the way that shippers would respond in real-world settings. This trade-off presented by stated-preference data – of greater variability in relevant variables, but the possibility of less realism in shippers' stated response – provides the backdrop and motivation for the current study.

The current study continues this stream of research dedicated towards the estimation of transportation demands. This study addresses directly the trade-off described above, namely, that stated-preference data provide greater variance in rates and times, which is useful for estimation and forecasting, and yet shippers' responses to stated-preference questions might not represent their responses in real world settings. The current study makes several methodological improvements in the elicitation and analysis of stated-preferences. In particular, stated-preference questions are utilized that can be expected to be more realistic for shippers, and hence, more likely to provide reliable information, relative to standard stated-preference methods. This new type of stated-preference question necessitates the use of a new econometric method, which is developed and applied in this study. The econometric method combines each shippers' choices in real-world settings with their responses to the new stated-preference questions. Differences in shippers' responses to stated-preference questions from their responses in real world situations are explicitly represented.

The data for the study were collected through a survey of shippers in the Columbia-Snake River Valley, implemented by the Social and Economic Sciences Research Center at Washington State University. Eastern Washington is one of the primary wheat producing regions in the country and produces primary soft white winter wheat. Over 90 percent of this wheat travels to ocean terminals located in Portland (Jessup and Casavant). The sample covers shipments from 181 of 391 eligible warehouses, which represents a 50 percent sampling rate.

Shippers were asked to identify the options that were available to them for shipping their grain to Portland, with the possible options being, e.g., truck to Pasco and barge to Portland, truck to a rail terminal and rail to Portland, and so on. The shippers were asked which of the available options they chose for a recent shipment, which constituted the revealed-preference choices of the shippers. Stated-preference questions were asked to determine whether the shipper would choose the same or a different option under specified changes in rates, transit times, or reliability. The shippers' choice model were estimated on the revealed-preference data alone and on the combined revealed- and stated-preference data, utilizing the new method, discussed above, that appropriately accounts for the stated-preference questions. Explanatory variables included the rates, transit times, and reliability of the available options, as well as alternative-specific constants that capture the average impact of other factors. Models with fixed coefficients were estimated, as well as more general models that allow the coefficients to vary over shippers, reflecting the fact that different shippers place different values on transit time and reliability.

The primary findings of the analysis are that:

1. Rates, transit times and reliability each have statistically important effects on transportation demands;
2. Elasticity estimates are provided for each option for a wide of rate, time and reliability changes. The arc elasticities for rate increases range from 1.82 to 0.38, depending on the alternative (e.g., barge to Portland versus truck to Pasco and then barge to Portland) and on the amount of the rate

increase. Arc elasticities are smaller for transit time increases, ranging from 0.89 to 0.19 depending on the alternative and amount of increase. Arc elasticities for decreases in reliability are smaller in magnitude than those for rate increases but larger than those for transit time increase, ranging from 1.51 to 0.51 depending on the alternative and the amount by which reliability decreases.

3. The analysis indicates that some shippers seem to be "captive" to their current mode. About 25 percent of the shippers stated that they had no options other than the one they currently used. Of those with options, our analysis indicates that about one-third of them would not change alternatives if the rates for their current alternative were doubled.

4. The estimated models allow the value of time and reliability to be calculated. We find that, on average, shippers value an extra day of transit time about the same as an extra $1.34 per ton in higher rates, and this value varies considerably over shippers. The value of a one percent increase in reliability (i.e., the chance of the shipment arriving on time) is estimated to be $0.16 per ton, on average, with considerable variance over shippers.

5. The estimated models also allow calculation of the own-price elasticity for barge shipments as well as the cross-price elasticity with respect to rail rates. Our analysis implies that an own-price arc elasticity of -0.34 and a cross-price arc elasticity with respect to rail rates of 0.52 (with both calculated for a ten percent change in rates.)

The report is organized as follows:

- Section 2 describes the sample of shippers
- Section 3 describes the estimation procedure
- Section 4 gives the estimation results
- Section 5 provides elasticities from the estimated models.

2. Sample and Data Description

The study examines agricultural shipments in the Pacific Northwest. As discussed by Jessup and Casavant (2004), Eastern Washington is one of the primary wheat producing regions in the U.S. and has the largest wheat-producing county (Whitman Country) in the United States. Within Eastern Washington, there are17 grain producing counties of which five account for over 75 percent of the state's production (Jessup and Casavant (2004)).

The region has an interconnected transportation system that consists of a series of rail lines and the Columbia-Snake river basin. Most of the wheat (over 90 percent) produced travels to ocean terminals located in or near Portland by rail or barge (Jessup and Casavant (2004)). While wheat can flow to other locations, this is not a prominent tendency. This makes the statistical methods employed much simpler in that it allows a focus on mode choice rather than both modes and location choices.

The data employed in the analysis were collected through a survey conducted by the Social and Economic Sciences Research Center at Washington State University. The survey instrument and methodology along with detailed sample summary statistics are provided and fully described by Jessup and Casavant (2005). The survey was pre-tested and reviewed both by academics and target survey recipients. It was conducted in October of 2004. There was a first mailing, a follow-up postcard, and a second mailing. Non-responders were also contacted after the second mailing. The survey was sent to both grain and non-grain shippers. Grain shippers represent the bulk of the population (over 80 percent) and the bulk of the respondents (over 85 percent). There were only two refusals of the 78 firms contacted, and a total of 29 firms that completed the questionnaires, representing a total of 181 of an approximate 391 eligible warehouses. This gives nearly a 50 percent response rate.

Shippers were asked a set of questions that relate to revealed and stated preference demand modeling. In addition, a set of questions provided characteristics of the shipper. There are six generic options for shipping grain to Portland:

1. Truck to Pasco and Barge to Portland;
2. Truck to another barge port and barge to Portland;
3. Rail to Portland;
4. Truck to a rail terminal and rail to Portland;
5. Barge to Portland; and
6. Other.

Shippers were asked to consider their last shipment. First, shippers were asked which of these six options were available to them for this shipment and which option did they choose. For each available option, they were asked to provide rates, transit times and reliability measures. Transit times were to include the scheduling, waiting time for equipment, and travel time. Reliability was measured by asking the shippers to estimate the percentage of time that shipments like this arrive "on-time" at the final destination.

Table 1 provides summary statistics for shippers' responses by option. As expected, the rate per ton-mile by barge (option 5, without truck access to barge) is the lowest of all options. It is somewhat unexpected that the transit-times are also lowest for this option also. However, transit times include scheduling and waiting for equipment, and multi-modal shipments require added scheduling, waiting for equipment, etc. Finally, movements that involve barge-only or a truck-barge combination yield the most reliable service, while railroad-alone and truck-rail involve the lowest reliability measures.

Each shipper was asked what they would have done if the option they choose were unavailable for six months. Table 2 provides a summary of these data. While there are some seeming analomies among the responses, e.g., switching to the same alternative chosen, most of these are explained by different truck options, different ports to the river, etc. Note that 51 of 200 respondents (over 25%) report they have no alternatives. A similarly large share of supposedly "captive" shippers (i.e., with no alternatives fromn their chosen mode) was obtained in a survey of Upper Mississippi river shippers (Train and Wilson, 2004). Of those shippers who report no alternatives, most involve some form of barge shipments (34 of 51) or shipments to other locations (17 of 51).

Table 1.—Revealed Choice Data Summary

Option	N	Available (% yes)	Choice (%)	Rate (per tonmile)	Time (days)	Reliability (%)
1. Truck to Pasco-Barge to Portland	120	61.3	7.3	5.05	11.2	77.3
2. Truck to Port-Barge to Portland	107	54.7	32.7	4.2	4.1	90.5
3. Rail to Portland	65	33.4	16.1	3.7	10.4	63.2
4. Truck to Rail-Rail to Portand	95	50.9	13.7	4.2	11.3	73
5. Barge to Portland	22	12.3	8.3	2.6	1.09	88.1
6. Other	12	11.8	21.9	13.1	4.4	90.1

Table 2.—Revealed Choices and Next Best Alternative

Alternative	Original Choice						
	1	2	3	4	5	6	Total
1	1	4	13	13	1	0	32
2	0	14	10	5	1	3	33
3	0	5	0	1	2	3	11
4	7	9	4	0	1	4	25
6	4	11	6	9	2	16	48
7	3	21	0	0	10	17	51
Total	15	64	33	28	17	43	200

Option	Description
1	Truck to Pasco-Barge to Portland
2	Truck to Port-Barge to Portland
3	Rail to Portland
4	Truck to Rail-Rail to Portland
5	Barge to Portland
6	Other
7	No Alternatives available

As described in section 1, the standard form of stated-preference questions were not used and an alternative, more realistic form was used instead. The usual procedure for stated-preference question is to present each shipper with a set of hypothetical options from which they choose one. The rate, transit time, and reliability of each hypothetical option is described, and the respondent's choice among the hypothetical options is used to infer the relative value placed on rates, time and reliability. In the current study, we implemented a procedure that we call "sp-off-rp," because the stated-preference (sp) questions are based on the revealed-preference setting and choice of the shipper. Recall that each shipper was asked which of the six options was available and which one they chose for their last shipment. For the sp-off-rp questions, the shipper was asked whether they would have chosen that option if its rate were x% higher. For example, if the shipper had used barge (option 4) for their last shipment, then the shipper was asked "Suppose that the rates for barge were 10% higher than currently. Would you still choose barge, or would you choose a different option?" If the shipper said they would choose a different option, they were asked which option they would choose instead. The percent increase in rates was varied over shippers, chosen randomly from 10, 20, 30, 40, 50 and 60 percent changes. Similar questions were also asked for an increase in transit time and decrease in reliability.

Note that these "sp-off-rp" questions relate to the shippers real-world choice situation, unlike standard sp questions that present the shipper with a set of hypothetical options. In answering the sp-off-rp question, the shipper is facing the same options, with all the same factors affecting their decision, as they actually faced when making their last shipment. The only change from the actual situation is in one of the attributes of their chosen option (rate, time or reliability); all other factors remain the same. This similarity to the real-world setting that the shipper faces gives them a greater realism, relative to standard sp choices, which can be expected to translate into more accurate and generalizable estimates of shipper response to changes in rates, transit times, and reliability.

Table 3 summarizes shippers' responses to the "sp-off-rp" questions. A considerable degree of switching is evidenced overall, and the rate changes tend to accrue slightly more switching than the time and reliability changes. Specifically, 107 of 140 would switch in response to a rate increase, 98 of 146 would switch in response to a transit time increase, and 93 of 146 would change in response to a reliability decrease. Finally, as is standard, the rates of switching increase with the level of the change. For example, for those that have rate increases of 50 or 60 percent, 68 percent would switch, while those with rate increases of 10 or 20 percent, 51 percent would switch.

Table 3.—Switching Behavior

% Change	N	Rate	Time	Reliability
10	23	10	11	11
20	22	13	11	9
30	35	28	28	24
40	24	17	17	15
50	38	25	29	23
60	19	14	11	11
Total Switches/ Total Responses	161	107/140	98/146	93/146

In addition to the revealed and stated preference information, the survey also asked the shippers to provide information about their business. This information included: the length of time in business, whether they had access to rail and barge loading facilities along with distances to each if they did not have access, number of rail cars that can be loaded, etc. Generally, these organizations have been in business a long time. The average number of years in business was 46 years with about 90 percent in business 10 years or more. In terms of loading facilities, 205 of 206 reported they could load trucks, 91 had direct access to rail, and 25 had direct to barge. It is notable that 11 of 211 had access to all modes, and 106 of 211 had access only to truck.

Access to modes is, of course, necessary for some options, and this causes the choice set to vary across the shippers. For example, a shipper with access only to trucking must truck to a river terminal, to rail, or, in one case, to the Portland area terminals. Of the 91 carriers with direct access to rail, the average number of rail cars that can be loaded at a given time is slightly more than eight. More importantly, about 40 percent had rail car capacities of 25 cars or more. This is important in that there are serious decreases in rail rates with increases in shipment sizes e.g., unit car rates are substantially lower than single car rates.

3. Choice Model and Estimation

In this section, we describe the econometric method that is used to estimate choice models on the revealed-preference (rp) data and the shippers' responses to the "sp-off-rp" questions. The presentation is largely descriptive. For interested readers, we provide a technical report with complete details (Train and Wilson (2005)). As stated above, the sp-off-rp questions provide greater realism than standard sp questions, since the sp-off-rp questions relate specifically to the situation that the shipper faced for their last shipment. However, this realism has implications for the econometric techniques that are used to analyze the data. The sp-off-rp questions ask the shipper which option they would choose in the rp setting if the rate, time, or reliability of the option they actually chose were changed. These questions have two features that need to be addressed in the estimation. First, when answering the sp-off-rp questions, the shipper is choosing among options in the rp setting. This implies that the attributes of the options in the rp setting, including, importantly, the attributes that are not observed by the researcher, affect the shipper's answer to the sp-off-rp questions. Stated in econometric terms: The unobserved factors associated with each option in the rp setting can be expected to enter the shipper's evaluation of these options when answering the sp-off-rp questions. Second, the sp-off-rp questions ask the respondent about a change in the rate, time or reliability of the option that was chosen in the rp setting. In econometric terms: The sp-off-rp questions are conditional on the outcome of the rp choice. This conditionality implies that the distribution of unobserved attributes that enter the shipper's responses to the sp-off-rp responses is not the unconditional distribution, as in standard choice models, but rather the distribution conditional on the shippers' rp choice.

The econometric method that we develop and apply incorporates both of these implications (Train and Wilson (2005)). In particular, the unobserved factors in the rp setting enters the model of the shipper's response to the sp-off-rp questions, and the probability of each possible response is derived based on the conditional distribution of these unobserved factors, conditional on the shipper's choice in the rp setting. We provide below the specification of the model. We first describe a version with fixed coefficients for rate, time and reliability. We then generalize the model to allow for random coefficients, reflecting the fact that the relative value of rates, time, and reliability differs over shippers. The next subsections present the alternative estimation strategies in more detail and outlines the "choice framework." Essentially, shippers choose from the array of options in a manner that maximizes their payoffs which are taken as a function of rates, times of transit and reliability. The specific form of the payoffs varies according to the treatment of the unknown parameters that are estimated. For readers interested primarily in the results may choose to skip to section 4.

3.1 Fixed coefficients

With fixed coefficients, the shipper's choice in the rp setting is a standard logit model. The shipper faces J alternatives for its last shipment. The utility of each alternative depends on observed variables, namely, rate, transit time, and reliability, as well as unobserved factors.[1] The observed variables are denoted x_j for alternative j (with the subscript for the shipper omitted for simplicity), and the unobserved random factors are denoted collectively ε_j as for alternative j. Utility of alternative j is denoted $U_j=\beta x_j+\varepsilon_j$. Under the assumption that each ε_j is distributed iid extreme value, the probability that the shipper chooses alternative i is the logit formula:

$$P_i = \frac{e^{\beta x_i}}{\sum_j e^{\beta x_j}}$$

The researcher presents the shipper with a series of sp-off-rp questions that are constructed on the basis of the shipper's rp choice. We provide more general notation than is necessary for our particular sp-off-rp questions, to facilitate the use of the method in other settings that might use different types of sp-off-rp questions. (For example, our questions ask the shipper about a change that makes the option they chose worse; an

[1] The model is framed in a utility context although the term profit maximization can be employed so long as there are no agency issues i.e., the shipper makes decisions consistent with the firm's objective of maximizing profit.

alternative would be to ask the shipper about a change that improves an option that they did not choose.) The researcher asks *T* sp-off-rp questions, with attributes $\tilde{x}^i_{jt}$ for alternative *j* in question *t* based on alternative *i* having been chosen in the rp setting. For our questions, $\tilde{x}^i_{it} \neq x_i$ for the alternative that was chosen in the rp setting, while $\tilde{x}^i_{jt} = x_j \, \forall j \neq i$ for the non-chosen alternative; however, more general specifications of $\tilde{x}^i_{jt}$ possible. The shipper is asked to choose among the alternatives in response to each sp-off-rp question. The shipper's choice can be affected by unobserved factors that did not arise in the rp setting, reflecting, e.g., inattention by the agent to the task, pure randomness in the agent's responses, or other quixotic aspects of the sp choices. These factors are labeled as η_j for alternative *j*. The relative importance of these factors will be estimated, as described below. The shipper obtains utility $W_{jt} = \beta \tilde{x}^i_{jt} + \varepsilon_j + \eta_{jt}$ from alternative *j* in sp-off-rp question *t*. That is, the shipper evaluates each alternative using the same utility coefficients and with the the same unobserved attributes as in the rp setting, with the addition of new errors that reflect quixotic aspects of the shippers' responses to the sp-off-rp questions. In response to each sp-off-rp question, the shipper chooses the alternative with the greatest utility. To complete the model, we assume that each η_{jt} is iid extreme value with scale $1/\alpha$, which is proportional to the standard deviation of these errors. A large value of parameter α indicates that there are few quixotic aspects to the sp-off-rp responses and that the shippers choose essentially the same as they would in a rp situation under the new attributes. Utility can be equivalently expressed as $W_{jt} = \alpha\beta \tilde{x}^i_{jt} + \alpha\varepsilon_j + \eta_{jt}$ where now η_{jt} is iid extreme value with unit scale. The sp-off-rp responses are, therefore, standard logits with ε_j as an extra explanatory variable. Since the ε_j 's are not observed, these logits must be integrated over their conditional distribution, as follows. The chosen alternative in response to question t is denoted k_t and vector $k = \langle k_1, \ldots, k_T \rangle$ collects the sequence of responses to the sp-off-rp questions.

The probability of alternative k_t in response to sp-off-rp question t, conditional on i being chosen in the rp choice is:

$$P_{k_t|i} = \Pr ob\left[\alpha\beta\tilde{x}^{i}_{k_t t} + \alpha\varepsilon_{k_k} + \eta_{k_k t} > \alpha\beta\tilde{x}^{i}_{jt} + \alpha\varepsilon_j + \eta_{jt}\, \forall j \neq k_t \mid \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j\, \forall j \neq i\right]$$
$$= \int \frac{e^{\alpha\beta\tilde{x}_{k_t t} + \alpha\varepsilon_{k_t}}}{\sum e^{\alpha\beta\tilde{x}^{i}_{jt} + \alpha\varepsilon_j}} f(\varepsilon \mid \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j\, \forall j \neq i) d\varepsilon.$$

This probability is a mixed logit (Train, 2003), mixed over the conditional distribution of $\varepsilon = \langle \varepsilon_1, \ldots, \varepsilon_J \rangle$. It can be simulated by taking draws from the distribution of ε, calculating the logit formula for each draw, and averaging the results.

Draws of ε from its conditional density are easy to obtain, given the convenient form of the conditional density of extreme value deviates (Train and Wilson, 2005.) In particular, the density of ε_i conditional on alternative i being chosen in the rp setting is extreme value with mean shifted up by $-ln(P_i)$. A draw is obtained as $-ln(P_i)-ln(-ln(\mu))$ where μ is a draw from a uniform between zero and one. Conditional on ε_i and on i being chosen, the density of each $\varepsilon_j\, \forall j \neq i$, is extreme value truncated above at $\beta x_i - \beta x_j + \varepsilon_i$. A draw is obtained as $-ln(-ln(m(\varepsilon_i)\mu))$, where μ is a draw from a uniform between zero and one, and $m(\varepsilon_i) = \exp(-\exp(-(\beta x_i - \beta x_j + \varepsilon_i))$. Since draws of ε are constructed analytically from draws from a uniform (as opposed to by accept-reject methods), variance reduction procedures can readily be applied, such as Halton draws (Bhat, 2001, Train, 2003), (t,m,s)-nets (Sandor and Train, 2003), and modified Latin hypercube sampling (Hess et al, 2004.)

Combining these results, and using the independence of η_{jt} over t, the probability of the agent's rp choice and the sequence of responses to the sp-off-rp questions is:

$$P_{ki} = \int \left[L_{1|i}(\varepsilon) \ldots L_{T|i}(\varepsilon) \right] f(\varepsilon \mid \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j \, \forall j \neq i) d\varepsilon \frac{e^{\beta x_i}}{\sum e^{\beta x_j}}$$

where

$$L_{t|i}(\varepsilon) = \frac{e^{\alpha\beta\tilde{x}^i_{k_t t} + \alpha\varepsilon_{k_t}}}{\sum e^{\alpha\beta\tilde{x}^i_{jt} + \alpha\varepsilon_j}}.$$

This probability is simulated by taking draws of ε from its conditional distribution as described above, calculating the product of logits within brackets for each draw, averaging the results, and then multiplying by the logit probability of the rp choice.

Note that as $\alpha \to \infty$ the simulator for the responses to the sp-off-rp questions approaches an accept-reject simulator based on the shipper's utility function in the rp setting with no additional errors (Mcfadden, 1989; Train, 2003, sections 5.6.2 and 6.5). Seen in this light, for large α, the logit formula for the responses to the sp-off-rp questions can be seen as a smoothed accept-reject simulator based on the true utility $\beta\tilde{x}^i_{jt} + \varepsilon_j$, whose purpose is to improve numerical optimization rather than having a behavioral interpretation.

3.2 Random coefficients

Utility is as above except that β is now random with density $h(\beta)$ that depends on parameters (not given in the notation) that represent, e.g., the mean and variance of β

over shippers. The probability for the rp choice is the logit formula integrated over the density of β:

$$P_i = \int L_i(\beta)h(\beta)d\beta$$

where

$$L_i(\beta) = \frac{e^{\beta x_i}}{\sum_j e^{\beta x_j}}$$

This is a standard mixed logit. By Bayes' rule, the density of β conditional on i being chosen is $L_i(\beta)h(\beta)/P_i$.

For the responses to the sp-off-rp questions, let $L_{t|i}(\varepsilon,\beta)$ be the same as $L_{t|i}(\varepsilon)$ defined above but with β treated as an argument. The probability of the sequence of responses to the sp-off-rp questions is

$$P_{k|i} = \iint L_{1|i}(\varepsilon,\beta)\ldots L_{T|i}(\varepsilon,\beta)f(\varepsilon \mid \beta, \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j)h(\beta \mid \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j)d\beta d\varepsilon$$

$$= \iint L_{1|i}(\varepsilon,\beta)\ldots L_{T|i}(\varepsilon,\beta)f(\varepsilon \mid \beta, \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j)L_i(\beta)h(\beta)d\beta d\varepsilon / P_i .$$

The probability of the rp choice and the sequence of responses to the sp-off-rp questions is P_i times the above formula, which is:

$$P_{ki} = \iint L_{1|i}(\varepsilon,\beta)\ldots L_{T|i}(\varepsilon,\beta)f(\varepsilon \mid \beta, \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j)L_i(\beta)h(\beta)d\beta d\varepsilon .$$

This probability is simulated by:

1. Draw a value of β from its unconditional density.
2. Calculate the logit probabiliuty for the rp choice using this β.
3. Draw numerous values of ε from its conditional density given β using the method described above. Caluclate the product of logit formulas for the responses to the sp-off-rp questions for each draw of and average the results.

4. Multiply the result from step 3 by the result from step 2.
5. Repeat steps 1-4 numerous times and average the results.

In theory, only one draw in step 3 is required for each draw in step 1; however, taking more than one draw in step 3 improves accuracy for each draw of β and is relatively inexpensive from a computational perspective.

4. Estimation Results

Table 4 gives the estimated parameters of a standard logit model that was estimated on the rp data alone. The estimated coefficients of rate, time, and reliability all take the expected signs, and the rate and reliability coefficients are significant at the 95 percent confidence level. The ratios of coefficients imply that a day of extra transit time is considered equivalent to about 27 cents per ton in higher rates and that decreasing reliability by 1 percentage point is considered equivalent to 26 cents per ton in higher rates. These two estimated values being nearly the same seems unreasonable. First, note that, absent risk aversion, the expected value of a one percent increase in the chance of a one-day delay is 1/100 the expected value of one day of extra transit time. While unexpected delays can be more burdensome than an anticipated increase in transit time, and the delay may be for more than a day, it seems doubtful that these factors are sufficient to counteract the 100-fold difference in these expected values. Second, previous studies on shippers' values (Shinghal and Fowkes, 2002, and Bergantino and Bolis, 2005) have found that that a day of time savings is worth more than a one percent reduction in the chance of delay.

Table 4: Fixed Coefficients Model on Revealed-Preference Data

Explanatory Variable	Estimated parameter	Standard error	T-statistic
Rate, in dollars per ton	-0.1252	0.0633	1.977
Time, in days	-0.0342	0.0320	1.070
Reliability	0.0322	0.0114	2.839
Constant for alt. 1	-1.7421	0.5579	3.123
Constant for alt 3	1.0753	0.5103	2.107
Constant for alt 4	-0.6748	0.3963	1.703
Constant for alt 5	-0.4564	0.7818	0.584
Constant for alt 6	-0.5962	1.0561	0.565
Mean log-likelihood	-0.83828		

Table 5 gives the estimated parameters of a fixed-coefficients logit estimated on the rp data along with the responses to the sp-off-rp questions. Simulation was performed with 1000 pseudo-random draws of the conditional extreme value terms, with different draws for each observation. As expected, the level of significance for the coefficients of rate, time, and reliability rise considerably. The scale parameter α is estimated to be about 5.6, which implies that the standard deviation of the additional unobserved portion of utility that affects the responses to the sp-off-rp questions is less than a fifth as large as the standard deviation of unobserved utility in the rp choices. As discussed above, if there were no quixotic aspects to the responses to the sp-off-rp questions, such that shippers answered the same as in the rp setting with the changed attributes, then the standard deviation would be zero (α unbounded high.) The relatively small estimated standard deviation implies that respondents were apparently paying careful attention to the sp-off-rp questions and answering similarly to how they would behave in the rp setting.

Table 5: Fixed Coefficients Model on RP and SP-off-RP Data

Explanatory Variable	Estimated parameter	Standard error	T-statistic
Rate, in dollars per ton	-0.2086	0.0371	5.625
Time, in days	-0.1483	0.0233	6.356
Reliability	0.0282	0.0046	6.127
Constant for alt. 1	-0.1037	0.3378	0.307
Constant for alt 3	0.9921	0.3965	2.502
Constant for alt 4	-0.1021	0.3073	0.332
Constant for alt 5	-0.9890	0.0775	1.276
Constant for alt 6	-0.9287	1.0711	0.867
Scale of sp error (α)	5.5874	1.6223	3.444
Mean log-likelihood	-2.34026		

The relative values of time and reliability seem more reasonable when the responses to the sp-off-rp questions are utilized. In particular, the value of time rises from 27 to 71 cents per ton, and the value of reliability drops from 26 to 14 cents per ton. The magnitudes of these changes, though large from a policy perspective, are not unreasonable given the standard errors in Table 4. In fact, the changes confirm the purpose of utilizing the sp-off-rp questions, which is to augment rp data when the rp data contain insufficient variation to estimate parameters precisely.

We next examine a random coefficients specification. The time and reliability coefficients are specified to be distributed normally with censoring at zero.[2] That is, the coefficient of time is specified as the minimum of 0 and β_2, where β_2 is normally distributed with mean and standard deviation that are estimated; and the coefficient of reliability is the maximum of 0 and β_3 with normal β_3. This specification assures that the time and reliability coefficients have the expected sign throughout their support. Also, by having a mass at zero, the specification allows for the possibility that some shippers do

[2] See Train and Sonnier (2005) for a discussion and application of censored normals and other distributions with bounded support within mixed logit models.

not care about time or reliability (at least within the ranges that are relevant.) The rate coefficient is held fixed, following Goett et al. (2000) and Hensher et al., (2005a,b), which implies that the distribution of the value of time and reliability is simply the distribution of these variables' coefficients scaled by the fixed price coefficient.[3]

When we attempted to estimate the random coefficients model with all parameters free, the value of α rose without bound in the iterative maximization process. This result, taken at face value, implies that no additional errors enter the sp choices, beyond the unobserved portion of utility in the rp choices. Since a bounded α was obtained with the fixed coefficients model, the unbounded value in the random coefficients model implies that differences in coefficients account for the sp responses that seem quixotic in a fixed coefficients model. That is, sp responses that appear quixotic when all shippers are assumed to have the same coefficients for rate, time and reliability are found not actually to be quixotic when shippers are allowed to have different coefficients.

Table 6 gives the estimated parameters for a random coefficients model with α set at 10. Simulation was performed with 1000 draws of the random coefficients and 10 draws of the extreme value terms for each draw of the random coefficients (for 10,000 draws of the extreme value terms in total for each observation.) As described above, the large value of α can be interpreted as providing a logit-smoothed accept-reject simulator of the probability of the responses to the sp-off-rp questions, which aids numerical maximization without reflecting the existence of any additional errors. The estimated

[3] Ruud (1996) points out that a random coefficients model with all random coefficients is nearly unidentified empirically, especially with only one or a few observed choices per agent, since only ratios of coefficients are behaviorally meaningful. Holding the price coefficient fixed assists with empirical identification. Train and Weeks (2005) discuss reasons for and against holding the price coefficient fixed and compare estimation methods when the price coefficient is random.

mean value of time is $1.34 per ton with a standard deviation of 0.89, and the estimated mean value of reliability is 16 cents with a standard deviation of 7.2 cents. The mean value of time is higher than that obtained with fixed coefficients ($1.34 versus $0.71), while the mean value of reliability is about the same (16 cents versus 14 cents.) Fewer than 9 percent of shippers are estimated not to care about transit time (i.e., the mass at zero is less than 0.09), and fewer than 2 percent are estimated not to care about reliability.

Table 6: Random Coefficients Model on RP and SP-off-RP Data

Explanatory Variable	Estimated parameter	Standard error	T-statistic
Rate, in dollars per ton	-0.2325	0.0306	7.610
Time: mean	-0.3031	0.0603	5.027
Time: standard deviation	0.2235	0.0648	3.448
Reliability: mean	0.0367	0.0054	6.756
Reliability: standard deviation	0.0170	0.0045	3.777
Constant for alt. 1	-0.2206	0.3734	0.537
Constant for alt 3	1.1227	0.4326	2.595
Constant for alt 4	-0.3469	0.3759	0.923
Constant for alt 5	-1.2563	0.7883	1.594
Constant for alt 6	-0.9684	1.1192	3.448
Mean log-likelihood	-2.22959		

5. Switching Rates and Elasticities for Each Alternative

The estimated model in Table 6 is used to forecast the impact of changes in rates, times, and reliability for each of the six alternatives. We consider first the forecasted impact of rate increases. To forecast this impact, the rate for each of the six alternatives was increased by a given percentage, and the estimated model was used to calculate the change in the share of shippers choosing that alternative. Table 7 gives the percent of shippers that are predicted to change alternatives when the rate for their chosen alternative is raised. Consider, for example, the value of 18.2 that is given for a 10 percent rate increase for truck to Pasco, barge to Portland. This number is interpreted as follows: if the rate for shipments by truck to Pasco and then barge to Portland rose by 10 percent, and the rates for other alternatives remained the same, then the model predicts that 18.2 percent of the shippers who currently use truck to Pasco and barge to Portland would switch to another alternative.

Table 7: Percent of shippers who are predicted to switch in response to Rate increases

Percent increase	Truck to Pasco, barge to Portland	Truck to Port, barge to Portland	Rail to Portland	Truck to rail, Rail to Portland	Barge to Portland	Other
10	18.2	5.5	10.4	13.9	4.0	10.0
20	33.8	10.7	20.7	26.7	8.0	18.0
30	46.8	15.7	30.8	38.2	12.0	24.6
40	57.4	20.6	40.3	48.3	16.0	30.0
50	65.8	25.4	49.2	56.7	19.8	34.6
60	72.4	30.2	57.2	63.5	23.6	38.6
70	77.5	35.0	64.2	69.1	27.3	42.1
80	81.4	39.8	70.3	73.4	30.8	45.1
90	84.4	44.5	75.5	76.8	34.2	47.8
100	86.8	49.1	79.8	79.5	37.5	50.2

As expected, larger increases in rates induces greater switching. For truck to Pasco and barge to Portland, a 10 percent increase in rates induces 18.2 percent of shippers to switch to another alternative, while a 50 percent increase in rates induces 65.8 percent of the shippers to switch. Note, however, that some shippers do not switch even when rates are raised quite considerably. For example, 13.2 percent of shippers who truck to Pasco and barge to Portland would continue to do so even if the rates for that alternative were doubled.

The smallest switch rates are obtained for shippers who barge to Portland without using truck access (i.e., shippers who are at a river port.) For these shippers, a 10 percent increase in rates induces only 4 percent to switch to another alternative. When rates are doubled, nearly two-thirds of these shippers are predicted to continue using barge to Portland.

As just stated, the switch rates for barge to Portland are lower than for the other options. However, comparisons of switch rates across options need to be considered carefully. The switch rate for any alternative represents the share of shippers who would switch from that alternative in response to a change in the rate for that alternative, including the truck access to barge or rail if the alternative includes such access. For example, the switch rate induced by a 10 percent rate increase is lower for barge to Portland than for truck to Pasco/barge to Portland. However, the rate for truck to Pasco/barge to Portland includes the rates for both the truck and barge portions of the shipment. If the barge rate rose by 10 percent and the truck rate remained the same, then the total rate for truck to Pasco/barge to Portland would rise by less than 10 percent. Suppose that truck access accounts for half of the total rate of the truck to Pasco/barge to Portland. Then a 10 percent increase in barge rates would represent in a 5 percent increase in the total rate for truck to Pasco/barge to Portland. The switch rate for a 10% increase in barge rates, holding truck rates constant, would therefore be about half that given in the table: 9.1 instead of 18.2. This switch rate with respect to only barge rates is closer to that for barge to Portland, which does not have truck access.

Table 8 gives the arc elasticities that are implied by the switching rates given in Table 7. For example, consider the elasticity of 1.82 for a 10 percent increase in the rate for Truck to port, barge to Portland. As shown in Table 7, the model predicts that 18.2 precent of the shippers who currently truck to Pasco and barge to Portland will switch to a different alternative if the rates for that option rose by 10 percent. Since there is a 18.2 percent reduction in response to a 10 percent increase in rates, the arc elasticity is 1.82 (18.2/10).

The elasiticies decrease somewhat as rates increase. For example, the arc elasticity for a 20 percent increase in rates is lower than that for a 10 percent increase in rates. This relation does not imply, of course, that larger rate increases induce less switching than smaller rate increases. Rather, it implies that the number of shippers who switch in response to the rate increases rises less than proportionally with the size of the rate increase. For example, consider a 20 percent rate increase for the option of Truck to Pasco, barge to Portland. The arc elasticity is 1.69, which is smaller than the elasticity of 1.82 from a 10 percent rate increase. The elasticity of 1.69 means that, as given in Table 7, that 33.8 percent of the shippers who chose this option would switch if the rate for this option rose by 20 percent (since 33.8/20=1.69.) A 10 percent rate increase induces 18.2 percent to switch and a 20 percent rate increase induces 33.8 percent to switch: the share who switch is higher with a 20 percent rate increase than a 10 percent rate increase, but is not twice as high. As a result, the arc elasticity is lower with a 20 percent rate increase than a 10 percent rate increase.

Table 8: Arc Elasticities with respect to Rates

Percent increase	Truck to Pasco, barge to Portland	Truck to Port, barge to Portland	Rail to Portland	Truck to rail, Rail to Portland	Barge to Portland	Other
10	1.82	0.55	1.04	1.39	0.40	1.00
20	1.69	0.53	1.04	1.34	0.40	0.90
30	1.56	0.52	1.03	1.27	0.40	0.82
40	1.43	0.51	1.01	1.21	0.40	0.75
50	1.32	0.51	0.98	1.13	0.39	0.69
60	1.21	0.50	0.95	1.06	0.39	0.64
70	1.11	0.50	0.92	0.99	0.39	0.60
80	1.02	0.50	0.88	0.92	0.38	0.56
90	0.94	0.49	0.84	0.85	0.38	0.53
100	0.87	0.49	0.80	0.79	0.38	0.50

Tables 9 and 10 give switch rates and arc elasticities for increases in transit times. These switch rates and elastiticies are lower than those for comparable increases in rates. This finding suggests, as expected, that shippers are more responsive to changes in rates than changes in transit time, though they are response to both.

Table 9: Percent of shippers who are predicted to switch in response to Transit Time increases

Percent increase	Truck to Pasco, barge to Portland	Truck to Port, barge to Portland	Rail to Portland	Truck to rail, Rail to Portland	Barge to Portland	Other
10	8.9	2.3	6.8	6.4	2.3	9.2
20	16.8	4.4	13.5	12.5	4.4	17.4
30	23.8	6.3	19.7	18.1	6.5	24.6
40	29.8	8.1	25.7	23.3	8.5	30.9
50	35.0	9.9	31.2	28.0	10.5	36.4
60	39.4	11.5	36.2	32.2	12.3	41.2
70	43.2	13.2	40.8	36.1	14.0	45.5
80	46.5	14.9	44.9	39.6	15.7	49.2
90	49.3	16.6	48.6	42.9	17.3	52.5
100	51.7	18.4	51.9	45.9	18.9	55.4

Table 10: Arc Elasticities with respect to Transit Times

Percent increase	Truck to Pasco, barge to Portland	Truck to Port, barge to Portland	Rail to Portland	Truck to rail, Rail to Portland	Barge to Portland	Other
10	0.89	0.23	0.68	0.64	0.23	0.92
20	0.84	0.22	0.67	0.62	0.22	0.87
30	0.79	0.21	0.66	0.60	0.22	0.82
40	0.75	0.20	0.64	0.58	0.21	0.77
50	0.70	0.20	0.62	0.56	0.21	0.73
60	0.66	0.19	0.60	0.54	0.20	0.69
70	0.62	0.19	0.58	0.52	0.20	0.65
80	0.58	0.19	0.56	0.50	0.20	0.62
90	0.55	0.18	0.54	0.48	0.19	0.58
100	0.52	0.18	0.52	0.46	0.19	0.55

Tables 11 and 12 give switching rates and arc elasticities for decreases in the reliability of shipments, where reliability is represented as the chance that the shippment will arrive on time. The switch rates and elasticities are lower than those for rates but higher than those for transit time. This finding that reliability elasticities are larger than transit time elasticities suggests that shippers are more concerned that the shipment arrives when scheduled than in the amount of scheduled shipment time.

Note that for some alternatives the arc elasticities are nearly the same for all levels of changes in reliability. For example, the arc elasticity for truck to port, barge to Portland is 0.52 or 0.51 for all percent changes in reliability. This relation implies that the percent of shippers who switch in response to a reduction in reliability is essentially proportional to the percent by which reliability is reduced. For truck to port\barge to Portland, 5.2 percent of shippers are predicted to switch in response to a 10 percent reduction in reliability, and 10.4 percent – twice as many – are predicted to switch in response to a 20 percent reduction in reliability. Since the percent switching doubles when the percent change in reliability doubles, the arc elasticity is the same.

Table 11: Percent of shippers who are predicted to switch in response to Reliability decreases

Percent increase	Truck to Pasco, barge to Portland	Truck to Port, barge to Portland	Rail to Portland	Truck to rail, Rail to Portland	Barge to Portland	Other
10	15.1	5.2	8.6	11.4	7.7	14.3
20	28.6	10.4	17.0	22.1	15.3	26.2
30	40.2	15.7	25.1	31.8	22.4	35.7
40	49.8	20.9	32.7	40.2	29.0	43.4
50	57.5	26.1	40.0	47.3	35.0	49.6
60	63.7	31.3	45.9	53.1	40.5	54.7
70	68.6	36.4	51.5	57.9	45.4	59.0
80	72.4	41.4	56.5	61.9	49.8	62.7
90	75.5	46.2	60.8	65.1	53.9	65.9
100	78.0	50.7	64.6	67.8	57.5	68.8

Table 12: Arc Elasticities with respect to Reliability

Percent increase	Truck to Pasco, barge to Portland	Truck to Port, barge to Portland	Rail to Portland	Truck to rail, Rail to Portland	Barge to Portland	Other
10	1.51	0.52	0.86	1.14	0.77	1.43
20	1.43	0.52	0.85	1.10	0.76	1.31
30	1.34	0.52	0.84	1.06	0.75	1.19
40	1.24	0.52	0.82	1.00	0.72	1.08
50	1.15	0.52	0.79	0.95	0.70	0.99
60	1.06	0.52	0.77	0.89	0.67	0.91
70	0.98	0.52	0.74	0.83	0.65	0.84
80	0.91	0.52	0.71	0.77	0.62	0.78
90	0.84	0.51	0.68	0.72	0.60	0.73
100	0.78	0.51	0.65	0.68	0.57	0.69

6. Barge and Rail Elasticities

The elasticities presented in the previous section pertain to the six alternatives for shipping in the Columbia/Snake river basin. However, many of the planning models rest on "barge" elastisticities and "rail" elastiticies. There are three different options that involve using barge to Portland, namely: Truck to Pasco-Barge to Portland, Truck to port-Barge to Portland, and Barge to Portland. The elasticity for barge to Portland is calculated by increasing the barge rate component of the total rate for these three options and using the model to predict the change in shares for these three options combined. Similarly, two options involve rail to Portland, namely: Rail to Portland, and Truck to rail-Rail to Portland. The elasticity for rail to Portland is calculated by increasing the rail rate component of the total rate for these two options and using the model to predict the change in shares for the two options combined.

In the data, we observe the truck and the barge portion of the total rate for each option. For the Truck to Pasco-Barge to Portland, the average proportion of barge costs to total costs is .45, while for the Truck to port-Barge to Portand, the average proportion of barge costs to total costs is .62. Of course, the proportion of rate that is barge for the Barge to Portland option is 1.00 (i.e., the entire rate is for barge.) Similarly, for rail, the average proportion of rail costs to total costs is .73 for Truck to rail-Rail to Portland and 1.0 for Rail to Portland.

Table 13 presents the forecasted impact of a 10 percent increase in barge rates (that is, for the portion of total costs that are for barge) and, in the lower part of the table, the impact of a 10 percent increase in rail rates (that is, for the portion of total costs that are for rail.) If rates for barge to Portland rose by 10 percent, the share of shippers using barge would fall from 0.575 to 0.555, for a decline of 0.02. This implies that only 3.45 percent (=(0.02/0.575)*100) of the shippers who currently use barge to Portland would switch away from barge. Most of the shippers who switch are forecasted to switch to an option that uses rail to Portland. The share of shippers who use rail to Portland is forecast to increase from 0.410 to 0.429, for a rise of 0.019, which constitutes nearly all of the barge decline of 0.020. Only a very small share of shippers are forecasted to switch to an alternative other than barge or rail to Portland: the share for the other option rises by only 0.001.

The arc elasticities are calculated as the percent change in shares divided by 10 since the forecasts are for a 10 percent rise in barge rates. The own-rate elasticity for barge is very low: only -0.34. The cross-rate elasticity of rail with respect to barge rates is also low: 0.47. (Note that the signs of the elasticites are retained in the current section, since own- and cross-elasticities are being reported, while in the previous section which reports only own-elasticities, the signs are not retained for convenience.)

Table 13: Forecasted Impacts of a 10 Percent Increase in Barge or Rail Rates

	Barge	Rail	Other
Change in barge rates:	0.575	0.410	0.015
Shares before change	0.555	0.429	0.016
Forecasted shares after change	-0.020	0.019	0.001
Percent change in shares	-3.45	4.71	3.41
Arc elasticities	-0.34	0.47	0.34
Change in rail rates:	0.575	0.410	0.015
Shares before change	0.605	0.378	0.017
Forecasted shares after change	0.030	-0.032	0.002
Percent change in shares	5.19	-7.67	10.2
Arc elasticities	0.52	-0.77	1.02

If rates for rail to Portland rose by 10 percent, the share of shippers using rail would fall from 0.410 to 0.378, for a decline of 0.032. This implies that 7.67 percent (=(0.032/0.410)*100) of the shippers who currently use rail to Portland would switch away from rail. Most of the shippers who switch are forecast to switch to an option that uses barge to Portland. The share of shippers who use barge to Portland is forecast to increase from 0.575 to 0.605, for a rise of 0.030, which constitutes nearly all of the rail decline of 0.032. The remaining 0.002 share represents shippers who switch from rail to an option other than barge or rail to Portland. The own-rate elasticity is higher for rail than barge, but is still low: the elasticity of rail share with respect to the rail rate is -0.77, which is about twice as large in magnitude as the own-rate elasticity for barge.

6. Summary and Conclusions

The demand for transportation by mode is an essential part of planning infrastructure. For planning infrastructure, there is a need not only for demand functions by mode, but also for a wide variety different shipment attributes such as rates and transit times. Often, revealed data do not provide significant variation in the attributes. This means that the demand functions are more difficult to estimate precisely and the range of attributes (rates) over which the estimation occurs does not coincide with the rate of attributes (rates) needed for planning. While stated preference methods overcome both difficulties, they are often criticized for presenting the decision-maker with hypothetical, and perhaps, irrelevant alternatives. In this paper, we use a methodology that employs both types of data. Specifically, we "ground" the stated preference information in the revealed choice made by the shipper. The stated preference information is directly tied to the revealed choices made by the shipper, circumventing the irrelevance issue and, yet, providing sufficient variation in the attributes which allow for precise estimation of demand parameters and provides estimates over a wide range of attribute values necessary for planning.

In this report, the methods are applied to the shipment of agricultural commodities from eastern Washington. Almost all of the shipments travel to Portland, making the choice of location largely irrelevant. On discussion with industry analysts, six different options account for the shipments. These options include both barge and rail only alternatives as well as options that involve truck to access either barge or rail modes. We framed the choice of which alternative to use in terms of rates, transit times and reliability of each option and calculated elasticities with respect to each attribute. We found that elasticities vary with the attribute and the level of the rate change. For rates, elasticities range from .38 to 1.82; for transit times, elastiticies range from .18 to .89; and for reliability, elasticities range from .51 to 1.51.

The elasticity estimates provided are defined for each option. In the final section, we derive estimates for the elasticity of barge and rail transportation. In particular, there were three options that involved barge and two involving rail. Barge rates were raised for each of these options, and elasticities calculated; and similarly for rail rates. The results imply that both barge and rail are inelastic, with barge being more inelastic than rail. In particular, the arc elasticity of the number of shippers using barge to Portland with respect to a ten percent rise in the rate for barge to Portland is 0.34 (in magnitude). The comparable elasticity for rail use with respect to rail rate is 0.77.

Finally, the quantity shipped by barge depends on the rates of alternative modes e.g., rail. Our analysis estimates that a ten percent increase in rail rates will increase barge demand by about 5 percent, for an arc cross-elasticity of 0.5.

These findings are of direct relevance to the Army Planning Models. First, it provides a direct connection between choice modeling and the elasticity of barge transportation. The results imply low elastiticities with respect to barge rate. The elasticities are nevertheless higher than those used in the Army Corps Modeling, which assume a perfectly inelastic demand up to a threshold. Second, we provide direct information on the cross-price elasticity of demand between rail and barge. Generally, in the Army Corps planning models, barge demands are constant to a threshold, above which all shifts to rail. The results suggest that barge and rail are substitutes, with changes in rail rates affecting barge demand and vice versa.

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