Meta Analysis for Benefits Transfer – Toward Value Estimates for Some Outputs of Multifunctional Agriculture

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Abstract— **As a contribution to valuing the outputs of multifunctional agriculture, we report three new meta analyses estimating value functions for agricultural conservation program impacts on water quality, wetlands, and upland habitat and open space. As is often the case in valuation, where methods have yet to be standardized, the data sets are relatively small and noisy. With a clear objective of benefits transfer, we seek robust parameter estimates for key RHS variables, even at the cost of some loss of goodness of fit. We present our estimated full equations, and benefits transfer values calculated from equations estimated after backward elimination of insignificant variables, and offer a rationale for this approach to benefits transfer.**

Keywords— **Meta analysis, benefits transfer, multifunctional agriculture**

I. SETTING THE CONTEXT

As a contribution to valuing the outputs of multifunctional agriculture, we report three new meta analyses estimating value functions for agricultural conservation program impacts on water quality, wetlands, and upland habitat and open space. Our empirical work was undertaken in the context of conservation programs in US agriculture, which have been a significant component of the agricultural policy landscape since the 1980s. They are extensive and complex, and they represent a substantial public investment, so it comes as no surprise that there is widespread interest in assessing their effects and benefits. USDA has undertaken a major Conservation Effects Assessment Program (CEAP) and, while it stops short of formal benefit assessment, USDA/ERS has begun some serious inquiries into benefits.

Randall [16] outlined a consistent valuation and pricing framework for outputs of multifunctional agriculture, in which programs generate values (not directly, but via effects that modify the quantity and quality of valued services), and these values (reflecting quantity, quality, and location of services produced) are implemented at the farm level as green prices. Flury *et al.* [7] demonstrate the welfare gains from targeting green prices to reflect regional differences in productivity of environmental services. Hoehn and Randall [10] drew attention to the role of scarcity and substitution and complementarity relationships in valuing policies substantial scale and scope, and Schläpfer and Hanley [18] showed that scale and scope are spatial in nature and systematically affect nonmarket values. Valuation of complex policies is a complicated matter and, in this paper, we will not be able to pursue all of the complexities. Instead, we will focus on meta analysis for benefits transfer, address some issues in empirical strategy, and present our results.

A. Meta analysis: generalizing from the valuation literature

There is a large literature reporting valuation studies worldwide, and given the expense of new primary-data studies, policy analysts are tempted to look for generalizable findings from the substantial body of existing valuation research. Meta-analysis has become the standard method of searching for general patterns in a body of existing specific research results [8, 9, 14]. Borisova-Kidder [2] has identified 28 completed meta-analyses of environmental services. Representative studies include Smith and Huang [20] on air pollution, Dalhuisen et al. [4] on residential water demand, Rosenberger and Loomis [17] on outdoor recreation, and Brander et al. [3] on wetlands. A general model of the following type is estimated with regression techniques:

$$WTP_{i,j,k,l} = f(\Delta\ Service_{j,k}\ , Subst/com_{j,k}\ , Demographic_{i,k}\ , Research\ procedure_{j,k,l}),$$

where the four categories of independent variables are expressed as vectors, and i : person or household; j : service type; k : location; and l : valuation project.

WTP per capita (or per household) is hypothesized to be influenced by the change in level(s) of environmental service(s), the availability of substitute services, relevant demographic variables, and the research procedures used in value estimation. For meta-analysis, each study constitutes a single observation (if it reports a single valuation) or a single panel of observations if it reports valuations of, say, several options that vary in scale and scope of environmental improvements. To enjoy a reasonable prospect of success, a meta-analysis project requires a sufficiently large set of independent studies, each with methods and results reported in sufficient detail, and all sharing at least a degree of methodological consistency. Economists, responding to the extensive data requirements of meta-analysis, have assembled environmental valuation data bases for that purpose [5, 6, 11, 13, and 21]. The total number of studies included exceeds 1,800 (although some duplicate entries are likely). However, when we start eliminating studies for various good reasons – some address amenities unrelated to agriculture, some do not report sufficient information about research procedures to enable independent assessment of their validity, some provide no evidence of peer review, etc. – the numbers diminish markedly. Given that the norms of valuation research are better adapted to methods development than assembling an empirical record, meta-analyses of economic valuation studies typically must deal with data sets that are small given the task at hand, and relatively noisy.

B. Benefits transfer

Benefits transfer (BT) seeks to economize on valuation research costs by applying the findings of particular local valuation studies to a broader set of sites [1, 20, and 22]. In its simplest configuration, benefits estimated at one site are applied (with only ad hoc modifications) to illuminate policy options at another site. Unfortunately, empirical tests of simple BT models have not yet vindicated the decision-makers' enthusiasm for the savings in research costs that BT promises [15]. A more sophisticated approach is based on meta-analysis. Assuming the meta-analytic equation is reasonably robust, this approach is preferred because it replaces the ad hoc adjustments of the simple approach with estimated effects generalized from the inventory of empirical studies that pass some tests of quality and relevance.

II. Meta Analyses for Improvements in Wetlands, Terrestrial Habitat, and Surface Water Quality

We approached the meta analysis task with a clear objective, benefits transfer. So, rather than placing highest priority on goodness of fit (which at worst has the analyst chasing data points all over the map by proliferating dummy and interaction variables, even at the risk of estimating study-specific variables), we sought robust estimates of parameters useful in benefit transfer.

We considered three categories of environmental services – wetlands, terrestrial habitat, and surface water quality.

Wetlands. We started with the set of studies assembled by Woodward and Wui [23], conducted our own search for additional studies, and applied our own selection criteria, eventually settling on a set of 72 valuations from 34 US studies, which are listed in [2]. Variables used in our meta analysis are listed in Appendix Table A.

Terrestrial habitat. We assembled a set of 23 valuations from 12 US studies, which are listed in [2]. Variables used in our meta analysis are listed in Appendix Table B.

Surface water quality. We assembled a data set from scratch, and then were able to augment it with the data set of Johnston et al. [12]. After applying our own selection criteria, we eventually settled on a set of 98 valuations (total value, i.e., use and nonuse) from 40 US studies, which are listed in [2]. Variables used in our meta analysis are listed in Appendix Table C.

While the studies chosen include some that provide single value observations and some providing panels of observations, we tested for, and rejected, fixed and random events in each case. Accordingly, we settled on OLS estimation. In each case, the log-linear specification was chosen, as is often the case in meta analysis of environmental service values. Log-linear specifications typically produce estimates that are robust around the mid-range of the data, but are less plausible near and beyond the endpoints of the data series. RHS variables were chosen according to the following criteria: continuous variables were limited to those reported for all studies in the data set; environmental services, regional conditions (which may reflect substitutes and complements), demographics, and research procedures were represented; binary variables representing service types and regions were omitted whenever there were fewer than 3 studies in a given category (0 or 1); and interactions between dummies were not used (the latter two requirements eliminate the chance of estimating study-specific effects).

Initial regression runs for wetlands and terrestrial habitat/open space suggested significant positive Year effects (even after deflation of reported values). On detailed examination of data plots and the correlation matrix, we concluded that the strong Year effect was spurious, and likely an artifact of shifts over time in the salience attributed to particular environmental services, and in valuation methods used. The simple correlation coefficient between Year and lnvalue is tiny (.035) for open space and modest (.215) for wetlands. Plots of lnvalue against Year do not support the potent effects attributed to Year by initial log-linear regression results. Compared with lnvalue, Year is much more highly correlated with other variables having to do with researcher decisions about what to value and how to value it. In the habitat and open space data set, the simple correlation coefficient between Year and Habitat – i.e., the researcher highlighted habitat as a service provided – is high (.793) while that between Year and Viewing was strongly negative (-.858). Researchers shifted almost *en masse* from thinking about open space as a scenic resource in earlier years to thinking about it as habitat in later years. In the wetlands data set, we see negative simple correlations between Year and Saltwater Marsh (-.415) and MPPFNFI (-.455); and positive simple correlations between Year and Habitat (.474) and CVM (.474). Over time, researchers became much less likely to value saltwater marshes using budgeting methods, and more likely to value wetlands as habitat resources using contingent valuation. In light of the above concerns, Year was omitted in subsequent runs of all three meta analyses, even at the cost of a modest loss of goodness of fit.

Estimated full models for wetlands, open space/habitat, and surface water quality are shown in the two right-most columns of Appendix Tables A, B, and C, respectively. In every case, there are a number of significant coefficients, but these are a relatively small proportion of the RHS variables. Some of the insignificant coefficients are quite large, so that BT values calculated from the full models seemed overly sensitive to RHS variables that were quite insignificant. A case in point is Region – some regional effects are large even though all regional coefficients were a long way from significant. To address this problem, our full estimated models served as the starting points for backward elimination of insignificant variables.

In the wetlands model, only income, wetlands type, two service types (water quality improvement and recreational fishing) and one valuation method (energy analysis) survived backward elimination (Table 1).

Table 1. Wetlands, backward elimination

Dependent variable: lnvalue

Item	Model w/ regional variables	Model w/o regional variables
Intercept	0.502 (2.00)	0.836 (1.55)
Income	0.141*** (0.04)	0.134*** (0.03)
Freshwatermarsh*	-1.444 (0.94)	-1.418* (0.87)
Saltwatermarsh	-3.235*** (1.05)	-3.220*** (0.94)
Prairiepothole	-4.045*** (1.14)	-4.025*** (1.04)
Quality	1.663*** (0.60)	1.677*** (0.57)
RecFish	0.841 (0.52)	0.843** (0.49)
EA	6.655*** (1.39)	6.685*** (1.34)
R1	0.053 (1.14)	
R2	-0.036 (1.25)	
R3	0.186 (1.07)	
K (no. independent variables)	10	7
N (number of observations)	72	72
R^2 (Adj- R^2)	0.552 (0.478)	0.551 (0.502)
F	7.50***	11.22***
Durbin-Watson	1.882	1.893

* Freshwater marsh was significant at the .15 level, but the elimination process was stopped there in order to leave a complete set of wetland types in the final model.

The regional variables were then re-introduced; they were very insignificant (pr. = .862 for the most significant region) and were subsequently dropped.

For open space/habitat, only three variables, all of them service descriptors, remained after backward elimination (Table 2). The open space data set was too small to support regional variables, even in the full model.

Table 2. Habitat and open space, backward elimination.

Dependent variable: lnvalue

Variables	Coefficients (standard errors)
Intercept	0.423 (1.55)
Viewing	3.308^{***} (1.26)
Open space	3.560^{***} (1.28)
Habitat	3.725^{***} (1.44)
K (number of indep. variables)	3
N (number of observations)	23
R^2 (Adj- R^2)	0.397 (0.302)
F	4.17^{***}
Durbin-Watson	1.683

For water quality, only Watersize, Wqchange, Freshwater, and 6 variables addressing contingent valuation technique survived backward elimination (Table 3). The regional variables were re-introduced but very insignificant, and so were dropped again.

Table 3. Surface water quality, backward elimination

Dependent variable: lnwtp

	Model w/ regional variables	Model w/o regional variables
Intercept	4.618^{***} (0.25)	4.550^{***} (0.19)
Watersize	2.71E-6*** (6.82E-7)	2.76E-6*** (6.48E-7)
Wqchange	0.168^{***} (0.05)	0.162^{***} (0.05)
Protestbids	0.541^{***} (0.16)	0.565^{***} (0.15)
Outlierbids	-0.512^{***} (0.18)	-0.525^{***} (0.17)
Nonpar	-0.407^{***} (0.16)	-0.398^{***} (0.15)
Voluntcontr	-0.659^{***} (0.22)	-0.683^{***} (0.21)
Hiresp	-0.464^{***} (0.16)	-0.448^{***} (0.15)
Interview	0.717^{***} (0.18)	0.727^{***} (0.16)
Fresh	-0.522^{***} (0.18)	-0.484^{***} (0.16)
R1	-0.092 (0.20)	
R2	-0.073 (0.18)	
R3	0.012 (0.20)	
K (no. of indep. variables)	12	9
N (number of observations)	98	98
R^2 (Adj- R^2)	0.513 (0.444)	0.511 (0.461)
F	7.46^{***}	10.22^{***}
Durbin-Watson	1.662	1.626

III. Values for benefits transfer

Given an estimated meta equation, calculating BT values is a matter of choosing appropriate values for the RHS variables. To evaluate particular proposals, the values chosen should reflect realistic project plans. To calculate more generic values, the RHS values selected involve an element of judgment.

The wetlands values reported (Table 4) are for four wetland types, with the method dummy (EA) set at zero and the service dummies (Quality and Recfish) set at their sample mean values. Ninety percent confidence intervals were calculated using the Krinsky-Robb procedure. Sample mean values were chosen for two reasons (i) the service dummies reflect not whether the service was provided at the study sites but whether the valuation exercise drew attention to the service, and (ii) with log-linear models dummy values of 1 may produce surprisingly large BT values. With respect to these two services, use of sample mean values effectively assumes the typically wetland provides these services at typical levels. BT values reported below have been updated to 2007 dollars. We note that the BT values for prairie potholes were less precise (wider 90% confidence interval) than for the other wetland types. An appropriate interpretation of Table 4 would be that the public willingness to pay, for example, to enroll an additional acre of typical freshwater marsh in the Wetlands Reserve Program is about $425 annually (with 90% confidence limits of $255 and $707), with adjustments (up or down, as the case may be) for atypical levels of provision of water quality improvement and/or recreational fishing.

Table 4. BT values: Wetlands

Wetland Type	$value/acre/year	(90% Conf. Interval)
Freshwater marsh	424.46	(255. – 707.)
Saltwater marsh	70.03	(34. – 146.)
Prairie pothole	31.30	(2. – 413.)
Swamp	1,752.81	(487. – 6,383)
Merge FWM and Swamp*	525.81	(337. – 837.)

* The next step in backward elimination of insignificant variables eliminates Freshwater marsh, effectively merging FWM and Swamp into a single category.

BT values for open space/habitat are provided (Table 5) for projects that provide the three services one at a time, and for a project that provides all three at the sample mean values. For the typical terrestrial conservation project habitat and open space, we believe the BT values for three services at sample mean values are most useful. Public WTP to enroll an additional terrestrial acre in the Conservation Reserve Program is about $196 annually (with 90% confidence limits of $93 and $419).

Table 5. BT values: Habitat / Open Space

Services	$value/acre/year (90% Conf. Interval)	
Viewing (scenic), only	47.55	(11. – 210.)
Open space, only	61.22	(7. – 601.)
Habitat, only	72.14	(22. – 240.)
All 3 services, at mean values	195.89	(93. – 419.)

BT values are provided (Table 6) for a 2.5 unit improvement in surface water quality (e.g., from suitable for rough fishing to swimmable) in a 100 mile water-body, with the voluntary contribution dummy set at zero and the other methodological dummies at their mean values, i.e., BT values derived from a typical contingent valuation study that does not use a voluntary contribution payment mechanism.). For a freshwater body, this water quality improvement would be valued at about $102 per household per year (with 90% confidence limits of $91 and $114), with adjustments for other water-body sizes and levels of water quality improvement.

Table 6. BT values: Water Quality

Water-body type	$value/household/year (90% Conf. Interval)	
Freshwater	101.68	(91. – 114.)
Other	165.01	(129. – 211.)

IV. Concluding comments

Meta analysis for benefits transfer often presents the analyst with relatively small and noisy data sets. Policy makers seek value estimates responsive to a substantial suite of policy-relevant variables. We cannot solve this rather intractable problem, but we have shown that – by seeking generalizable results at some modest cost to goodness of fit to admittedly noisy data – robust meta equations yielding plausible and relatively stable value estimates can be obtained.

We have demonstrated that the glass is half-full. We were able to identify systematic components of wetland value per acre, terrestrial habitat/open-space value per acre, and WTP for surface water quality improvement; and we generated a body of value estimates that provide a sound starting point for benefits transfer on a national scale.

However, the glass remains half-empty, too. After 35 years of focus on methods development, valuation research still (it seems) places a relatively low priority on building a body of generalizable evidence. Too many studies fail to meet minimal standards for inclusion in meta analysis and, among those that do, there is too little consistency in methodological details and the specification of environmental descriptors – these are serious impediments to empirical generalization.

Suppose we had satisfactory value estimates for a broad array of environmental services, adjustable for type, quantity, quality, and region. That would be an excellent start, but no more than that, for estimating the benefits of the outputs of multifunctional agriculture. There would still remain the challenges of relating service values to environmental effects and ultimately to policy benefits, and doing so in ways that are sensitive to spatial considerations and the consistency requirements for evaluating complex policy and scaling it up to the national level and down again. Ultimately, coherent and effective agro-environmental policy must hit the ground as green prices (reflecting quantity, quality, and location of services produced) at the farm level.

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Appendix. Variable descriptions and estimated full models

Appendix Table A. Wetlands

Variable	Description	Freq	Mean	Est. b_i	SE
Dependent variable					
LNVALUE	Logarithm of value per acre of wetland, U.S. year 2003 dollars	72	5.608		
Intercept				0.890	(2.37)
Socio-economic variables					
INCOME	Annual household income, U.S.	72	43.950	0.145**	(0.06)
YEAR	Year in which study was conducted, 1969=1	72	16.319	omitted	
Wetland size					
ACRES	No. of wetland acres (,000) valued	72	356.640	-1.58E-7	(2.68E-7)
SHARE	Share of wetland acres in the area by FIPS codes as reported by the NRI 1997 data	72	0.133	-4.824	(4.07)
Wetland types					
FRESHWATER MARSH	1 if a freshwater marsh, 0 if not	39	0.542	-1.653	(1.12)
SALTWATER MARSH	1 if a saltwater marsh, 0 if not	19	0.264	-2.969**	(1.33)
SWAMP	1 if a swamp, 0 if not	7	0.097	omitted	
PRAIRIE POTHOLE	1 if a prairie pothole, 0 if not	7	0.097	-4.430***	(1.56)
Wetland functions					
FLOOD	1 if flood reduction, 0 if not	18	0.250	omitted	
WATER QUALITY	1 if water quality improvement, 0 if not	20	0.278	0.821	(1.01)
WATER SUPPLY	1 if water supply augmented, 0 if not	14	0.205	1.106	(0.80)
RECFISH	1 if recreational fisheries improved, 0 if not	23	0.319	0.195	(0.71)
COMFISH	1 if commercial fisheries improved, 0 if not	20	0.278	0.852	(0.65)
BIRDHUNT	1 if bird/wildlife hunting, 0 if not	23	0.319	0.596	(0.82)
BIRDWATCH	1 if bird/wildlife hunting observation, 0 if not	17	0.236	-0.335	(0.74)
AMENITY	1 if amenities augmented, 0 if not	14	0.194	-0.792	(1.11)
HABITAT	1 if habitat is augmented, 0 if not	23	0.319	0.516	(0.78)
Methodological variables					
CVM	1 if study used Contingent Valuation Method, 0 if not	28	0.389	-0.242	(0.91)
HP	1 if study used Hedonic Pricing Method, 0 if not	3	0.042	0.213	(1.79)
TCM	1 if study used Travel Cost Method, 0 if not	4	0.056	-0.274	(1.35)
RC	1 if study used Replacement Cost Method, 0 if not	16	0.222	0.213	(1.79)
PFMPNFI	1 if study used Production Function or Market Prices or Net Factor Income Method, 0 if not	19	0.264	-1.446	(1.04)
EA	1 if study used Energy Analysis Method, 0 if not	2	0.028	5.985***	(1.86)
PUBLISH	1 is study is a journal article, 0 if not	50	0.694	-0.209	(0.97)
Regions					
R1	1 if study conducted in Northern crescent or Northern great plains, 0 if not	28	0.389	0.564	(1.79)
R2	1 if study conducted in Fruitful rim or Southern seaboard, 0 if not	22	0.306	0.977	(1.61)
R3	1 if study conducted in Heartland or Mississippi portal, 0 if not	17	0.236	1.232	(1.56)
R4	1 if study conducted in Prairie gateway=1 or Eastern uplands, 0 if not	5	0.069	omitted	

K (number of independent variables)	23
N (number of observations)	72
R^2 (Adj- R^2)	0.592 (0.397)
F	3.03^{***}
Durbin-Watson	1.820

Appendix Table B. Open Space and Habitat

Variable	Description	Freq	No. studs	Mean	Est. b_i	SE
Dependent variable						
LNBENPACRE	Logarithm of benefit per acre, U.S. year 2003 dollars	23	11	4.87		
Intercept					2.442	(3.81)
Study characteristics						
YEAR	Year study was conducted, 1982=1	23	11	9.26	omitted	
LNACRE	Log number of acres valued	23	11	10.27	0.005	(0.33)
CVM	1 if contingent valuation method, 0 if not	21	10	0.91	-0.334	(2.06)
PUBLISH	1 if study in refereed journal, 0 if not	19	9	0.83	-1.315	(1.90)
Services						
VIEWING	1 if noted in the study, 0 if not	14	6	0.61	2.774^{*}	(1.54)
OS (open space)	1 if noted in the study, 0 if not	6	3	0.26	2.933	(1.82)
HABITAT	1 if noted in the study, 0 if not	11	7	0.48	3.323^{*}	(1.87)

K (number of independent variables)	7
N (number of observations)	23
R^2 (Adj- R^2)	0.420(.0.202)
F	1.93
Durbin-Watson	1.835

Appendix Table C. Surface water quality

Variable	Description	Freq	No. studs	Mean	Est. b_i	SE
Dependent variable						
LNWTP	Log WTP, surface water quality improvements /household/year, $ 2003	98	40	4.63		
Intercept					4.96^{***}	(0.65)
YEAR	Year study was conducted, 1982=1,	98	40	15.28	omitted	
Surveyed population						
INCOME	Annual household income, 2003 dollars	98	40	48162	1.28E-6	(5.85 E-6)
NONUSERS	1 if nonusers sample was used in the survey, 0 if not	19	11	0.19	-0.253	(0.18)
Methodological variables						

PUBLISH	1 if in refereed journal, 0 if not	56	21	0.57	0.012	(0.19)
VOLUNTCONTR	1 if voluntary contribution, 0 if not	11	6	0.11	0.619^{**}	(0.27)
LUMPSUM	1 if a single lump sum payment), 0 if not	74	26	0.76	0.288	(0.19)
MEDIANWTP	1 if value was reported as median WTP , 0 if not	5	4	0.05	0.154	(0.34)
NONPARAMETRIC	1 if nonparametric estimation of WTP, 0 if not	41	13	0.42	0.527^{**}	(0.22)
PROTESTBIDS	1 if protest bids were excluded, 0 if not	46	18	0.47	-0.438^{*}	(0.23)
OUTLIERBIDS	1 if outlier bids were excluded, 0 if not	26	13	0.27	0.437^{**}	(0.22)
HIRESP	1 if response rate higher than 74%, 0 if not	32	10	0.33	0.448^{**}	(0.19)
Method of eliciting WTP values						
DISCRETECHOICE	1 if discrete choice method used, 0 if not	11	3	0.11	0.059	(0.29)
Method of survey administration						
MAIL	1 if mail method, 0 if not	37	20	0.38	-0.189	(0.26)
PHONE	1 if phone method, 0 if not	21	6	0.21	omitted	
INTERVIEW	1 personal interview method, 0 if not	28	9	0.29	0.676^{**}	(0.28)
MULTMETH	1 if multiple methods, 0 if not	12	5	0.12	-0.083	(0.33)
Waterbody type, size and scale of improvement						
FRESH	1 if freshwater, 0 if not	82	30	0.84	0.531^{**}	(0.20)
OTHERTYPE	1 if an estuary or saltpond, 0 if not	16	10	0.16	omitted	
WATERSIZE	Water body size (river, lake and coast lines in miles)	98	40	4154 7.	$3.17E-6^{***}$	(8.83E-7)
WQCHANGE	Change in water quality (RFF water quality ladder).	98	40	2.61	0.172^{***}	(0.05)
WQLADDER	1 if Water Quality Ladder used in elicitation, 0 if not	40	12	0.41	-0.225	(0.21)
Region						
MULTREG	1 if a study was conducted in multiple regions, 0 if not	32	10	0.32 7	-0.386	(0.46)
R1	1 if Northern crescent or Northern great plains, 0 if not	18	11	0.18 4	-0.339	(0.40)
R2	1 if Fruitful rim or Southern seaboard, 0 if not	23	10	0.23 5	-0.512	(0.43)
R3	1 if Heartland or Mississippi Portal, 0 if not	20	6	0.20 4	-0.222	(0.42)
R4	1 if Basin & Range, Prairie Gateway, or Eastern Uplands, 0 if not	5	3	0.05 0	omitted	

K (number of independent variables)	22
N (number of observations)	98
R^2 (Adj- R^2)	0.548(0.416)
F	4.14^{***}
Durbin-Watson	1.660