

Transaction Costs and Household Adoption of Stormwater Best Management Practices

Robert J. Johnston
Clark University, USA

Tom Ndebele
Clark University, USA

David A. Newburn
University of Maryland, USA

2021 Social Cost of Water Pollution Workshop, Integrated Assessment Models and the Social Costs of Water Pollution, April 21-23, 2021.

This research is supported by the National Science Foundation under Grant Number 1615560.
Opinions do not imply endorsement of the funding agency.



CLARK
UNIVERSITY



UNIVERSITY OF
MARYLAND

Conservation-Incentive Programs and Transaction Costs



- There is increasing emphasis on the use of incentivized voluntary behavior to achieve water quality objectives.
- Many conservation programs provide economic incentives for landscape and stormwater best management practices (BMPs) by urban, suburban and exurban households.
- Expanding research is devoted to the understanding of behavior under conservation incentive programs such as these.
- These programs typically include administrative requirements that impose transaction costs, such as requirements for project design and inspections.
- Literature provides little insight on how common transaction costs such as these influence BMP adoption on non-agricultural land.

Conservation-Incentive Programs and Transaction Costs



- Some studies address transaction cost effects on conservation, mostly in agriculture (e.g., Banerjee et al., 2017; Fooks et al., 2016; Holzer et al., 2017; Palm-Forster et al., 2016; Peterson et al., 2015).
- Considered individually or grouped into categories such as “paperwork” or “hours spent.”
- Little is known about effects of simultaneous transaction costs due to common program requirements in non-agricultural settings.
 - Requirements for planning, design, inspections, locating contractors, up-front payments, and other mandates.
- May cause multiple transaction costs with distinct impacts – e.g., not just paperwork or hours spent.

Case Study Application— Residential Stormwater BMPs



- We develop a model to estimate the simultaneous effects of transaction costs linked to common administrative requirements within residential cost-share incentive programs.
- Model decomposes the magnitudes and effects of transaction costs that vary across agents and program requirements.
- Identifies the types of program changes that would cause the greatest increases in efficiency due to transaction cost attenuation, measured as reductions in agents' willingness to accept (WTA).
- Implemented using a discrete choice experiment on cost-share programs that incentivize urban stormwater BMPs in the Baltimore metropolitan region (US).

Background—Transaction Costs and Stormwater BMPs



- Low household adoption of stormwater BMPs often attributed to barriers to adoption that economists classify as transaction costs (Ando & Freitas, 2011; Coleman et al., 2018; Shin & McCann, 2018).
- For example, Ando and Freitas (2011) find that variables such as “distance to distribution centers” influence rain barrel adoption.
- But - formal transaction-cost effects are routinely omitted from empirical adoption models (McCann, 2013) and transaction costs remain largely unquantified.
- Transaction costs may be larger and more influential in urban settings than more commonly studied agricultural settings.
- How large and important are these transaction costs? What barriers should agencies target to optimally increase enrollment?



Random-Utility Model of Adoption Choice

- Household i 's indirect utility associated with enrollment in cost-share program j specified

$$U_{ij}(b_{1ij}, \mathbf{TC}_{ij}, NC_{ij}, \mathbf{X}_i) = v_{ij}(b_{1ij}, \mathbf{TC}_{ij}, NC_{ij}, \mathbf{X}_i) + \varepsilon_{ij}$$

- b_{1ij} identifies the type of BMP supported.
- $\mathbf{TC}_j = [tc_{1ij}, tc_{2ij}, tc_{3ij}, tc_{4ij}]$ represents $Z = 4$ transaction-cost determinants.
- NC_{ij} is net installation cost to the household (after cost share payment P_{ij}), per square foot of BMP, $NC_{ij} = (1 - P_{ij}/100)C_{ij}$
- C_{ij} is BMP cost per square foot, before cost share.
- \mathbf{X}_i represents household and parcel characteristics.
- v_{ij} specified as linear with \mathbf{X}_i interactions.

Transaction Cost Determinants (TC_j)



- Common program requirements impose different types of transaction costs (TC_j).
 - Making at risk (up-front) payments.
 - Requirement to pay full cost up front and apply for a rebate later.
 - Identifying and screening contractors.
 - Designing BMP to comply with program requirements.
 - Project design, planning, and completing all required paperwork.
 - Obtain post-installation inspections and approvals.
- Transaction costs and adoption effects linked to these individual requirements may vary across households.

DCE Design and Testing



- DCE designed to reflect choices faced by households considering enrollment in common stormwater BMP incentive programs.
- Implemented in Baltimore metro region (City and County).
- Developed over three years in collaboration with Baltimore Ecosystem Study Long-Term Ecological Research project.
- Pretesting included 6 focus groups, individual pretest interviews and reviews by external stormwater BMP experts and stakeholders.
- Transaction cost attributes grounded in feedback from focus groups and expert/stakeholder interviews (why don't people enroll?).
- Three independent binary enrollment choices.
- Bayesian D-efficient experimental design with 48 profiles.

Describing Lawn Conversion



Lawn Conversion Programs

People use, maintain and enjoy lawns for many reasons. However, some lawns can also have negative environmental impacts, particularly when they are next to hard surfaces such as roofs and driveways.

- Stormwater can run off lawns and hard surfaces (e.g., roofs, driveways) quickly, causing flooding and erosion.
- The same stormwater can carry lawn chemicals (e.g., fertilizers, weed killers) that pollute local streams, rivers, and the Long Island Sound.

To reduce these impacts, public and private organizations have proposed cost-share incentive programs that would help homeowners voluntarily convert some or all of their lawns to other uses. These uses include:

- **Conservation Landscaping:** Areas with native shrubs, flowers or tall grasses that are specially designed to absorb stormwater and provide habitat anywhere on your property.
- **Rain Gardens:** A special type of conservation landscaping located close to hard surfaces like roofs and driveways. Rain gardens are dug deeper (12 to 24+ inches) to decompact the soil and absorb larger amounts of stormwater from these surfaces.

→Next

How are Rain Gardens and Conservation Landscaping Similar?

Conservation landscaping and rain gardens are similar in many ways. Both types of lawn conversion:

- Look like regular gardens and capture stormwater runoff,
- Are planted with native shrubs, flowers, ornamental grasses, or other perennials that you choose based on your preferences,
- Can reduce yard wet spots and flooding,
- Provide habitat for birds, wildlife, and pollinating insects,
- Reduce mowing, watering and the need for fertilizer and other lawn chemicals (because these converted areas no longer need to be mowed, fertilized or watered),
- Are designed to filter water quickly into the ground within hours to a day (mosquitoes cannot develop because they typically take 7 to 12 days to breed).



How are Rain Gardens and Conservation Landscaping Different?

Conservation landscaping and rain gardens are different in terms of where they can be located and how much water they absorb.

- **Rain gardens** are dug deeper (12 to 24+ inches) and prevent more stormwater and pollution from entering streams, rivers, and the Long Island Sound.
- **Rain gardens** can absorb more stormwater.
- **Rain gardens** are typically located close to hard surfaces such as roofs, driveways, and sidewalks (about 10 to 30 feet away), but far enough away to avoid concern with basement flooding.
- **Conservation landscaping** is more flexible, is dug less deep (6 to 12 inches) and can be located anywhere on your property.



Based on this information, do you feel that you understand the basic similarities and differences between conservation landscaping and rain gardens?

Yes

No

Experimental Design Variables



Attribute	Variable Name	Attribute levels
Type of Conservation Supported	<i>Conserve</i>	Rain Gardens (0) Conservation Landscaping (1)
Cost Share Percentage	<i>Cost_Share</i>	50%, 75%, 100%
Mode of Payment	<i>Payless_Upfront</i>	Pay full amount up-front and receive rebate later (0) Pay reduced amount up-front (1)
Finding a Contractor	<i>Find_Yourown</i> <i>Recommended_List</i>	Contractor is provided (0) Find your own (1) Choose from recommended list (2)
Application Paperwork	<i>You_Paperwork</i>	Contractor completes the paperwork (0) You complete the paperwork (1)
Inspection & Certification	<i>You_Inspection</i>	Contractor's responsibility (0) Your responsibility (1)
Cost per square foot (\$)	<i>Cost</i>	\$5, \$10, \$15, \$20

Defining Program Requirements (Transaction-Cost Determinants)









- Program requirements were defined based on the type of information typically available to households considering enrollment in conservation cost share programs. For example:
 - Do you have to locate your own contractor?
 - Do you have to pay up-front (and request a rebate later)?
 - Are you responsible for inspection and certification paperwork (or does the contractor do it)?
- Each requirement described prior to choice questions.
- Households are not typically told the number of hours required for each task (individually or combined), so this is not predefined.
- Questionnaires pretested by both experts and non-experts.



Example Question

- Full information and visible choice sets.
- All attributes defined on prior survey screens.
- Binary choice:
 - Would you Enroll under this program?
- Cost per sq. ft. is fixed across the 3 choice tasks presented to each respondent.
- *Net_Cost* calculated as a function of cost and cost-share percentage.

Program Element	Program A
 Type of Conversion Supported	<input type="checkbox"/> Conservation Landscaping <input checked="" type="checkbox"/> Rain Gardens
 Cost-Share Percentage	50% Program pays 50% of total cost (You pay 50%, or \$2.50 per square foot)
 Mode of Payment	<input checked="" type="checkbox"/> You pay less up-front <input type="checkbox"/> You pay full amount and receive rebate later
 Finding a Contractor	<input checked="" type="checkbox"/> You find on your own <input type="checkbox"/> You choose from recommended list <input type="checkbox"/> State, city or town provides certified contractor
 Application Paperwork	<input type="checkbox"/> You are responsible <input checked="" type="checkbox"/> Contractor is responsible
 Inspection & Certification	<input type="checkbox"/> You are responsible <input checked="" type="checkbox"/> Contractor is responsible

DCE Implementation



- Survey implemented during November - December 2019.
- Mixed-mode, push-to-web over a random sample of single-family households. Three mailings with URL and passcode.
- Mailing sample of 13,000 single-family homeowners in Baltimore City and County.
- Screened using spatially explicit parcel-level tax assessor database linked to high-resolution parcel data.
 - Single-family, owner-occupied households, parcel sizes 0.1 to 5 acres, at least 250 square feet of lawn.
- 1,748 responses (13.45% response rate); 1,596 used for estimation due to missing data for variables.

Mixed Logit Models



- Estimated using panel random-parameters mixed-logit model in both WTP-space and preference-space.
- Parameters for linear non-cost variables assumed random and normally distributed.
- Parameters on interactions between household characteristics and status quo ASC assumed non-random.
- Parameter on (sign-reversed) cost assumed to have a lognormal distribution. Ensures positive marginal utility of income.
- In WTP-space model, ASC and interactions specified in preference-space to ensure convergence.
- Key results are robust across alternative specifications.

Quantifying Transaction Costs



- Transaction costs defined formally in terms of willingness to accept (WTA).
- Defined as reduction in net cost (per sq. ft.) required to exactly offset negative utility due to each transaction cost-determinant.
- Quantified per square foot of BMP.
- WTA estimates and their distributions are provided by estimated parameters within the WTP-space model.
- Anticipated parameter signs depend on the definition of transaction-cost variables within the mixed logit model.

Base WTP-Space Results



Enroll (dependent var)	Coeff.	Std. Error	Std. Dev.	Std. Error
Net_Cost (lognormal)	-0.7318***	0.0623	1.0009***	0.1935
Conserve	-0.7673**	0.3769	1.2561*	0.7303
Payless_Upfront	2.0029***	0.4164	1.5610**	0.7039
Recommended_List	0.6176	0.4270	2.9327***	0.8053
Find_Yourown	-1.1738**	0.4894	2.9731***	1.0859
You_Paperwork	-1.5050***	0.4110	0.6877	1.1209
You_Inspection	-2.0301***	0.5224	0.6744	0.8830
ASCALT1 (Status quo)	-0.2919	0.2897	4.4233***	0.3870
LL			-2328.43	
AIC			4673.8	
Chi squared			1810.21 (df 16) [p < 0.0001]	
McFadden R-squared			0.2799	
N			4665	

Preference-Space Results (incl. Household Interactions with ASC)



Enroll (dependent var)	Coeff.	Std. Error	Std. Dev.	Std. Error
Net_Cost (lognormal)	-0.8212***	0.1849	1.5468***	0.1787
Conserve	-0.3729	0.2375	0.7435	0.4575
Payless_Upfront	1.4268***	0.2475	1.5778**	0.6136
Recommended_List	0.4685*	0.2778	1.6741***	0.6065
Find_Yourown	-0.6470**	0.2594	1.4564***	0.5627
You_Paperwork	-1.0511***	0.2494	1.6789***	0.5508
You_Inspection	-1.3505***	0.2834	2.1436***	0.5772
ASCALT1 (Status quo)	0.0574	0.3587	4.5392***	0.5214
ASCALT1*Age65_plus	2.9287***	0.4670		
ASCALT1*Degree_plus	-1.9070***	0.3874		
ASCALT1*Parcel Size	-0.0487	0.1881		
LL			-2271.22	
AIC			4580.40	
Chi squared		1924.63 (df 19) [p < 0.0001]		
McFadden R-squared			0.2976	
N			4665	

WTA Estimates of Mean Transaction Costs (\$ per square foot; Base WTP-space results)



- Results imply large and statistically significant transaction costs that vary over (a) type of requirement and (b) household.
- **Responsibility for inspections: \$2.03** (no significant heterogeneity)
- **Pay reduced amount up-front / no rebate request: \$2.00** (significant heterogeneity)
- **Responsibility for design and planning paperwork: \$1.51** (no significant heterogeneity)
- **Responsibility to find your own contractor: \$1.17** (significant and high heterogeneity)
- Compared to mean cost share across the data (\$9.38) these transaction costs are non-trivial.

Effect on Adoption—Simulation



- Agencies can take steps to mitigate transaction costs, as is often done to promote rooftop photovoltaic installations.
- To evaluate the effect of reducing transaction cost, we simulate adoption probability under different scenarios, *ceteris paribus*.
- Each involves different assignment of transaction-cost determinants.
- Simulation conducted using DCE data and household-specific parameter estimates (not “representative household”).
- Enrollment compared to baseline in which all transaction costs are borne by the household.
 - All else assumed constant, as reflected in original DCE data.
- Results simulated from preference-space mixed logit.

Transaction Cost Scenario (Selected)		Simulated Enrollment Probability under Each Scenario	Predicted Difference in Enrollment Probability
1	All TCs are imposed (Base Scenario): Find_Yourown = 1, You_Paperwork = 1, You_Inspection = 1, Recommended_List = 0, Payless_Upfront = 0	0.2279	--
2	All TCs are eliminated: Find_Yourown = 0, You_Paperwork = 0, You_Inspection = 0, Recommended_List = 1, Payless_Upfront = 1	0.4973	0.2694
3	Find_Yourown = 1, You_Paperwork = 1, You_Inspection = 1, Recommended_List = 0, Payless_Upfront = 1	0.3026	0.0746
4	Find_Yourown = 1, You_Paperwork = 1, You_Inspection = 0, Recommended_List = 0, Payless_Upfront = 0	0.2854	0.0574
5	Find_Yourown = 1, You_Paperwork = 0, You_Inspection = 1, Recommended_List = 0, Payless_Upfront = 0	0.2732	0.0452
6	Find_Yourown = 0, You_Paperwork = 1, You_Inspection = 1, Recommended_List = 0, Payless_Upfront = 0	0.2540	0.0261
7	Find_Yourown = 1, You_Paperwork = 0, You_Inspection = 0, Recommended_List = 0, Payless_Upfront = 0	0.3407	0.1128

Summary and Conclusions



- Results suggest first-order and heterogeneous effects of different types of transaction-cost determinants on residential stormwater BMP adoption.
- One size does not fit all: Different program requirements are linked to different types transaction costs.
- Transaction costs can easily offset typical cost-share payments. These costs alone can potentially “eliminate the market.”
- Possible that resources currently allocated to direct cost-share payments might be more effectively spent on strategies to attenuate transaction costs.
- Review of the environmental DCE literature suggests that few studies consider effects of policy- or program-related requirements such as these
- The result could be a misstatement of choice probabilities that would occur within actual settings.
 - Is this “hypothetical bias” or a failure to consider transaction-cost effects?

QUESTIONS AND COMMENTS ARE
WELCOME...



UNIVERSITY OF
MARYLAND

CLARK
UNIVERSITY



CHALLENGE CONVENTION. CHANGE OUR WORLD.