Web Appendix A
Simulating Working-Land Payment Programs

A.1 Regional Simulation Model

To evaluate the economic and environmental implications of alternative WLPPs, we employ a regional, agricultural-sector model for the United States. This is a comparative-static, spatial and market-equilibrium model, which incorporates agricultural commodity, supply, demand, environmental impacts, and policy measures (House et al., 1999). The model includes 45 geographic sub-regions, 23 production inputs, and the production and consumption of 44 agricultural commodities and processed products.[1] More than 5,000 crop production enterprises at the sub-region level are differentiated according to cropping rotations, tillage practices, and fertilizer rates; 90 livestock and poultry production enterprises are delineated at the region level by species. Production levels and enterprises are calibrated to regularly updated production practices surveys using a positive math programming approach (Howitt, 1990), the USDA multiyear baseline (USDA, 2001), and the National Resources Inventory (USDA, 1994).[2]

Changes in production are in turn linked to the potential environmental changes via the Environmental Policy Integrated Climate (EPIC) Model. The model simulates daily weather, hydrology, soil temperature, erosion-sedimentation, nutrient cycling, tillage, crop management and growth, and pesticide transport to the edge of the field (Mitchell et al., 1998). Crop yields and environmental externalities are estimated on a per-acre basis for short-run (mean over 7 years) and long-run production (mean over 67 years) given historical climate and soils data from across the United States. The yield data are combined and calibrated to current production patterns. For certain pollutants (e.g., nitrogen, phosphorus, soil sediment, and pesticides) a runoff transport component is calibrated to observed pollutant levels using estimates from the U.S. Geologic Survey (Smith et al., 1997) in order to estimate instream environmental effects of agricultural production.

A.1.1 Baseline Production

The simulation model is first calibrated to projected production patterns (USDA, WAOB, 2003), solving for optimal regional (subscript *k*) production levels for cropping enterprises (X_{ki}) and livestock activities (X_{kl}):

(eq A.1) $$\max_{X_{ki},X_{kl}} \sum_{ki}(P_i - VC_{ki})X_{ki} + \sum_{kl}(P_l - VC_{kl})X_{kl}\,.$$

Here P_i is the equilibrium price vector for cropping system *i*, and P_l are equilibrium prices for livestock; VC_{ki} and VC_{li} represent regional variable costs of production.

[1]The model accounts for production of the major crop (corn, soybeans, sorghum, oats, barley, wheat, cotton, rice, hay, silage) and livestock (beef, dairy, swine, and poultry) categories comprising approximately 75 percent of agronomic production and more than 90 percent of livestock production in the United States (USDA 1997). We do not consider potential applications of manure to rangeland, vegetable, horticulture, sugar, peanut, or silviculture operations.

[2]This model has been used to examine other agri-environmental policies (Johansson and Kaplan, 2004; Claassen et al., 2001), climate change mitigation (Lewandrowski et al., 2004), water quality policy (Ribaudo et al., 2001), wetlands policy (Heimlich et al., 1997), and sustainable agriculture policy (Faeth, 1995).

The acreage constraints imposed under the policy simulations are represented by:

(eq A.2) $\sum_i X_{ki}^0 = \sum_i X_{ki} \ \forall k$,

where $\sum_i X_{ki}^0$ is the amount of cropland acres in region *k* before implementing the WLPP and $\sum_i X_{ki}$ is the amount of cropland acres in region *k* after implementing the WLPP. In other words, producers cannot receive program payments for environmental benefits generated from retiring land from production or for land that had not previously been cropped prior to the WLPP implementation.

A.1.2 Practice-Based Agri-Environmental Payments

Those management practices that are targeted towards reducing soil erosion and generally improving water quality are modeled (table A.1).[3] These practices represent approximately 90 percent of the non-livestock, non-structural EQIP contracts between 1997 and 2000. Practice costs are calculated assuming a 3-year implementation period.[4] The 3-year total cost is then discounted at 7 percent over a 10-year contract period. In addition to management practices, "base payments" are included in the program payment, structured to resemble the tiered system of payments found in the Conservation Security Program. Base payments are pegged to regional crop rental rates and are calculated to represent a 10-year net present value of average rental rates for cropland (Farm Service Agency, 2003). [5]

[3]Note that the cost of these practices, the benefits provided, and the associated rental rates are often not correlated such that practice-based conservation payments solicit the most cost-effective environmental benefits (see Web Appendix C).

[4]This follows the benefit-cost methodology used by USDA (NRCS, 2003).

[5]Base payments in the Conservation Security Program increase with tiers. At the lowest tier, producers receive cost-share plus a base payment of 5 percent of the land rental rate. This rate increases to 15 percent at the highest tier of participation.

Table A.1. Practice-based conservation payments (per acre)

Eligible practices	Farm production region[a]									
	AP	CB	DL	LA	MN	NT	NP	PA	SE	SP
Base payment[b]	2.08	3.84	1.95	2.74	0.84	1.55	1.57	2.63	1.30	0.87
Conservation rotation[c]	2.81	1.41	1.40	1.40	1.83	1.87	1.40	1.88	2.81	1.87
Nutrient management[d]	2.81	2.25	1.40	1.68	2.81	2.25	1.24	2.81	2.81	4.49
Hay[e]	30.32	21.15	28.38	19.91	10.95	15.36	10.71	17.41	30.89	13.48
Mulch till[f]	2.81	2.25	2.81	3.37	2.81	3.37	1.63	1.68	8.42	2.62
No-till[g]	2.81	2.25	4.21	2.81	4.21	3.37	3.37	5.62	5.62	2.62

a/ Appalachia (AP) = KY, NC, TN, VA, WV; Corn Belt (CB) = IA, IL, IN, MO, OH; Delta States (DL) = AR, LA, MS; Lake States (LA) = MI, MN, WI; Mountain (MN) = AZ, CO, ID, MT, NM, NV, UT, WY; Northeast (NT) = CT, DE, MA, MD, ME, NH, NJ, NY, PN, RI, VT; Northern Plains (NP) = KS, ND, NE, SD; Pacific (PA) = CA, OR, WA; Southeast (SE) = AL, FL, GA, SC; Southern Plains (SP) = OK, TX.
b/ Base pay values derive from mean rental rates for non-irrigated cropland under the Conservation Reserve Program (FSA, 2003) multiplied by 5 percent to correspond to a tiered structure described in Chapter 4.
c, d, e, f, g/ The reported payments are the median contract values for EQIP calculated to reflect a 100 percent cost share (Cattaneo, 2003).

More formally, the working-land program payment (P_{ki}) for an eligible practice (*k*) in region (*i*) will be a function of the cost of implementing the eligible practice in that region (EP_{ki}), the percentage of that cost that is reimbursed under the program, and the base payment amount determined from regional crop rental rates. Cost-share percentages are chosen to be at the 50-percent level as found in the 2002 EQIP guidelines (USDA, NRCS, 2003). The program payment for any given eligible practice in our simulation model can be written:

(eq A.3) $P_{ki} = (0.5 \times EP_{ki}) + (Base\_Pay_i)$.

The total agri-environmental payment (*AEP*) available for a producer in region (*i*) for eligible practices (*k*) is then:

(eq A.4) $AEP_{ki} = \sum_k P_{ki}$.[6]

A producer can receive higher payments by combining several cropping production practices. For example, in our simulation, a producer in the Corn Belt could receive practice-based payments of $13.53 per acre for a no-till ($2.25 per acre) or mulch tillage cropping system that included nutrient management practices ($2.25 per acre) and hay rotation ($21.15), which is also a conservation rotation ($1.41 per acre) at a 50-percent cost-share rate. In addition, the producer would be eligible under this program for a base payment of $11.52 per acre (or 3 × $3.84) for a total of $25.05 per acre.[7]

[6]Note that producers can receive two payments for incorporating hay into their rotation (*conservation rotation* and *hay*), but can only receive 1 × *base payment* for this combination.

[7]This is an upper bound on per acre payments for this combination of practices as the payment of $21.15 for planting hay will be multiplied by the share of hay in a particular rotation. For example, a continuous hay rotation would receive the full $21.15 payment (at a 50 percent cost-share rate), whereas a corn-soybean-hay rotation would receive $6.98, or 0.33 × $21.15 (also at a 50 percent cost-share rate).

A.2 Policy Simulations

A.2.1 Good-Act

Under this scenario, farmers already employing eligible practices (good actors) are eligible to receive WLPP payments along with an additional payment based on a regional land rental rate. Various levels of an exogenously determined budget (*B*) are simulated, restricting total payments so that the budget is not exceeded. Regional program payments are further restricted to be a percentage of the total budget ($distrib_k$), which is equal to the distribution percentage of regional EQIP payments:

(eq A.5) $B \times distrib_k \geq Perc_k \sum_i X_{ki} AEP_{ki} \ \forall k$,

where X_{ki} is the acreage level of the eligible practices after the WLPP is offered, and *Perc* is the optimal percentage of acres that actually receive agri-environmental payments (AEP_{ki}) to meet the regional budget constraint. This distributional constraint is imposed to insure that program payments are spread across the entirety of U.S. cropland. The resulting optimization is:

(eq A.6) $\max_{X_{ki}, X_{kl}} \sum_i (P_i - VC_{ki} + AEP_{ki}) X_{ki} + \sum_l (P_l - VC_{kl}) X_{kl}$

subject to eq A.2 and eq A.5.

A.2.2 Practice

Next, restrict eligibility for the practice-based payments (and base payments) to those farmers that adopt new practices:

(eq A.7)

$$\max_{X_{ki}, X_{kl}} \sum_{ki} (P_i - VC_{ki}) X_{ki} + \sum_{ki} (X_{ki} - X_{ki}^0) AEP_{ki} + \sum_{kl} (P_l - VC_{kl}) X_{kl},$$

subject to eq A.2 and to

(eq A.8) $B \times distrib_k \geq Perc_k \sum_i (X_{ki} - X_{ki}^0) AEP_{ki} \ \forall k$.

A.2.3 Performance

Under this scenario, payments are simulated for reducing the number of Aggregate Environmental Index points, AEI_{ki} (see Web Appendix B), generated from crop production. No good-actor provisions or base payments are attached to these contracts. Furthermore, the distributional budget constraint from above is relaxed, as producers are able to garnish payments for environmental points broadly defined to include nine environmental criteria. The optimization model for this scenario is depicted by:

(eq A.9)

$$\max_{X_{ki}, X_{kl}} \sum_{ki} (P_i - VC_{ki}) X_{ki} + PPT \sum_{ki} (X_{ki}^0 - X_{ki}) AEI_{ki} + \sum_{kl} (P_l - VC_{kl}) X_{kl},$$

subject to

eq A.10) $B \geq PPT \sum_{ki} (X_{ki}^0 - X_{ki}) AEI_{ki}$ and to eq A.2,

where *PPT* is the agri-environmental price per point offered under the program. A national price for environmental performance points is assumed, which could just as easily be specified on a regional basis.

A.2.4 Bid

To capture the fact that it is cheaper to achieve some benefits points than others, which would be reflected by bidding provisions, the area under the payment-marginal benefits curve distilled from the performance-based policy is integrated to determine aggregate program payments. Essentially, as the national price for environmental performance increases, an increasing number of farmers will be willing to accept performance-based contracts. Here WTA_{ki} replaces *PPT* as the per-point payment level each enterprise would accept to generate environmental benefits:

(eq A.11)

$$\max_{X_{ki}, WTA_{ki}, X_{kl}} \sum_{ki} (P_i - VC_{ki}) X_{ki} + WTA_{ki} \sum_{ki} (X_{ki}^0 - X_{ki}) AEI_{ki} + \sum_{kl} (P_l - VC_{kl}) X_{kl}$$

subject to (eq A.12) $B \geq WTA_{ki} \sum_{ki} (X_{ki}^0 - X_{ki}) AEI_{ki}$ and eq A.2.

A.2.5 Hurdle

To model hurdle rates, payments are simulated for reducing the number of Aggregate Environmental Index points (see Web Appendix B) generated from crop production above and beyond a pre-determined reference level. The optimization model for this scenario is depicted:

(eq A.13)

$$\max_{X_{ki}, X_{kl}} \sum_{ki} (P_i - VC_{ki}) X_{ki} + PPT \sum_{ki} [\max(0, (\overline{AEI} - AEI_{ki})] X_{ki} + \sum_{kl} (P_l - VC_{kl}) X_{kl}$$

,

subject to eq A.2 and to

(eq A.14) $B \geq PPT \sum_{ki} [\max(0, (\overline{AEI} - AEI_{ki})] X_{ki}$,

where *PPT* is the agri-environmental price per point offered under the program for practices above a pre-determined reference level, $\overline{AEI}$ (recall that the lower the AEI_{ki} score, the better its environmental performance).