Chapter 4
National Effects of Coordinated Manure Management

Having examined the implications of addressing nitrogen concerns over water and air quality for one farm-level sector, we now take a larger view. The implications of coordinated (air and water) policies across regions and animal/crop sectors must account for interactions between crop and animal production and their subsequent economic and environmental impacts. Here, potential changes in commodity prices and shifts in production among regions are estimated assuming (1) adoption of land application standards for manure generated on concentrated animal feeding operations (CAFOs) and/or (2) reductions in nitrogen emissions to air from manure generated on all animal feeding operations (AFOs). Some consequences of national policy can only be viewed at this scale of analysis. Tradeoffs are not limited to the farm, but extend to regions and consumers. Market adjustments can produce contrary outcomes, even without the complication of conflicting single-medium policies.

At any level of analysis, adjustments to environmental policies entail increased costs to the producer. The magnitude of this increase depends on a number of factors, including the amount of manure transported for application, the availability of cropland for applying manure nutrients, the willingness of crop producers to substitute manure nutrients for commercial fertilizer, and regional heterogeneity in crop and animal production. Again, we consider current manure spreading regulations both independent of and in coordination with potential ammonia emission regulations across regions and sectors.[1] Specifically, we assess the environmental and economic implications of:

(1) Impacts of the 2003 Clean Water Act regulations for the spreading of animal manure on cropland for CAFOs (*Water*);

(2) Hypothetical reductions in atmospheric nitrogen emissions from animal feeding operations by 10-40 percent in the absence of manure nutrient application standards (*Air10, Air20, Air30,* and *Air40*); and

(3) CAFO water quality regulations plus AFO nitrogen emission regulations (10-40 percent reductions) in each region (*WaterAir10, WaterAir20, WaterAir30,* and *WaterAir40*).

We are looking for tradeoffs associated with implementing policies piecemeal rather than jointly, and indications that the different environmental goals (air quality vs. water quality) move the animal sector along different adjustment paths. Hence, we look at ammonia restrictions in the absence and presence of existing CAFO regulations for the protection of surface-water quality.

Simulating Coordinated Environmental Policies

We use the U.S. Regional Agricultural Sector Model (see Appendix B, web only) to assess secondary price and quantity effects between crop and animal

[1]Here, though, we evaluate both nitrogen and phosphorus application standards. Because each region in the model is large, there is sufficient land to assimilate manure nitrogen in the baseline, meaning there is no overapplication. A nitrogen standard alone would result in no change in the model results.

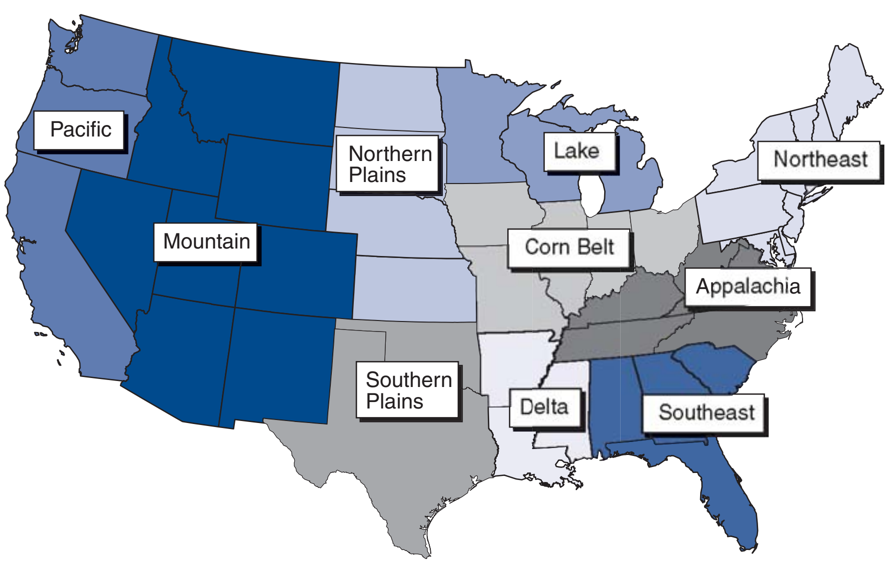
production (USMP; House et al., 1999) at the national and regional levels (fig. 4-1). We simulate restrictions on manure nutrient use on cropland and on nitrogen emissions from animal production.[2] The model estimates nitrogen emissions to the atmosphere, which allows us to constrain ammonia emissions directly. This model has also been used in previous analyses of the Clean Water Act (Ribaudo et al., 2003; Kaplan et al., 2004).

Various crop rotation, tillage, production and technology adjustments can be made to meet the nitrogen application or ammonia emission constraints. The composition of cropping or animal production could change to alter the amount of manure nutrients demanded or supplied. Storage, handling, or application technologies can reduce ammonia emissions or alter the nitrogen content of manure. Our model selects the optimal combination of technology, crop, and animal changes across the sectors and regions in order to minimize the net cost to society of meeting the different environmental policies. This includes changes in net returns for producers and changes in consumer surplus for purchasers of agricultural products. Storage, handling, and application technologies available in the model for meeting the CAFO nutrient standards and for reducing AFO emissions of nitrogen are consistent with those in the farm-level analysis.[3] We also consider treatment of poultry litter with aluminum sulfate (alum) to reduce nitrogen storage losses and to decrease the bioavailability[4] of phosphorus. Our baseline for comparison (*Base*) uses the USDA 2010 baseline projections for prices and production (USDA, WAOB, 2003) (table 4-1).

What Might We Expect?

CAFOs represent 4.5 percent U.S. feeding operations, but the quantity of manure generated by these facilities exceeds 200 million tons—more than 47 percent of the U.S. total (table 4-2). While the Corn Belt has the most AFOs and CAFOs and generates the most manure, the concentration of

Figure 4-1
USDA farm production regions



Source: Economic Research Service, USDA.

[2]Manure generation is calculated according to Kellogg et al. (2000); crop nutrient demands by region are calculated using the Environmental Policy Integrated Climate Model (EPIC; Mitchell et al., 1998).

[3]We assume a crop producer willingness to accept manure of 30 percent, meaning that approximately 30 percent of available cropland in each region will utilize manure nutrients (USDA, ERS, 2003b). Alternative levels of manure utilization have been considered, but are not included here.

[4]Bioavailability of phosphorus refers to the amount of phosphorus in runoff that is available for aquatic and terrestrial plant growth.

Table 4-1
Policy scenarios for simulation analysis

Scenario	Manure nutrient spreading standards for CAFOs	Reduction in nitrogen emissions for AFOs
Base	No	No
Water	Yes	No
WaterAir10	Yes	10%
WaterAir20	Yes	20%
WaterAir30	Yes	30%
WaterAir40	Yes	40%
Air10	No	10%
Air20	No	20%
Air30	No	30%
Air40	No	40%

Table 4-2
Baseline for policy simulations

	AFOs						CAFOs		
							Operations	Manure	
Region	Operations	Total manure	Nitrogen runoff	Nitrogen leached	Nitrogen emissions	Phosphorus runoff	Share of total	Share of total	
		Million tons	*Million pounds*				*Percent*		*Tons/acre*
NE	31,350	39.10	32.60	0.17	189.61	5.46	1.59	16.45	0.45
LS	52,498	61.54	72.50	0.80	362.55	12.30	1.64	26.68	0.43
CB	71,252	83.75	87.60	1.02	517.85	25.98	3.18	39.49	0.34
NP	26,087	71.13	80.05	0.82	371.35	15.42	4.77	62.91	0.64
AP	22,776	78.32	120.49	2.01	571.36	34.81	7.46	65.95	2.88
SE	12,635	24.35	126.97	0.67	187.64	21.87	10.97	43.48	1.43
DS	12,252	19.66	33.33	0.34	137.95	9.86	7.48	39.44	0.44
SP	10,500	48.42	72.65	0.43	263.98	17.01	7.00	38.77	0.62
MT	7,780	33.52	80.45	0.09	215.23	14.69	8.43	70.22	0.89
PS	7,654	39.53	118.55	0.18	283.10	16.40	14.85	60.49	2.50
US	254,784	499.31	825.19	6.52	3,100.62	173.78	4.47	47.44	0.72

Northeast (NE) = CT, DE, MA, MD, ME, NH, NJ, NY, PN, RI, VT; Lake States (LS) = MI, MN, WI; Corn Belt (CB) = IA, IL, IN, MO, OH; Northern Plains (NP) = KS, ND, NE, SD; Appalachia (AP) = KY, NC, TN, VA, WV; Southeast (SE) = AL, FL, GA, SC; Delta States (DS) = AR, LA, MS; Southern Plains (SP) = OK, TX; Mountain (MT) = AZ, CO, ID, MT, NM, NV, UT, WY; Pacific States (PS) = CA, OR, WA).

CAFO manure per cropland acre is greatest in the Appalachia, Southeast, and Pacific regions. Therefore, we would expect land application standards for CAFO manure nutrients to result in greater production adjustments in these relatively land-scarce regions. On the other hand, because all animal feeding operations are subject to ammonia emission policies in our analysis, regions with large numbers of animals, such as the Corn Belt, are likely to be more affected by such policies.

What We Found

Higher production costs from meeting environmental standards result in changes to production levels, both animal production (fig. 4-2) and cropped acres (fig. 4-3). Animal production would fall under all scenarios, but to different degrees across sectors.[5] Dairy production would remain relatively unchanged (reductions of less than 1 percent), but reductions in beef

[5]We elected to focus on the results for a 10-percent reduction in ammonia emissions (*Water, WaterAir10, and Air10*). At higher levels of constraints on air emissions, it is likely that producers would consider many alternative technologies, which are not feasible to model at this point.

Figure 4-2
Changes in animal production by policy

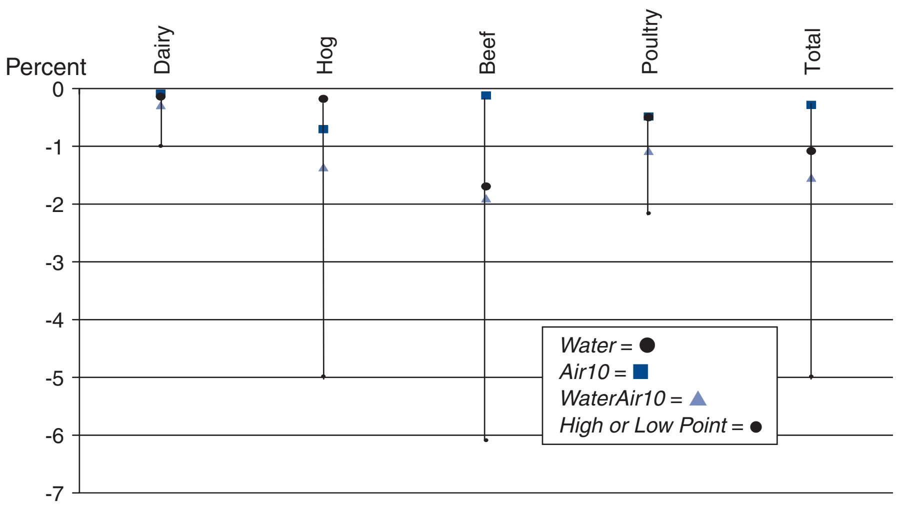
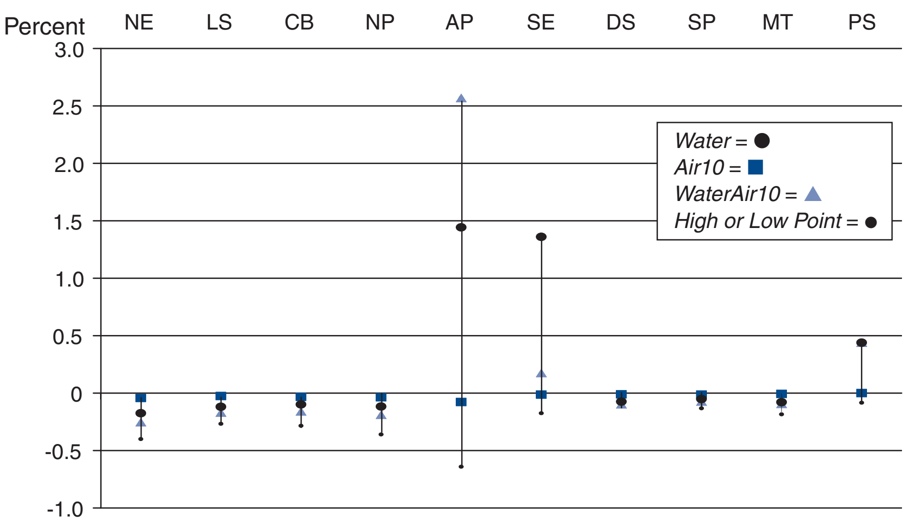


Figure 4-3
Change in cropped acres by region and policy



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production would range from 0.1 percent (*Air10*) to 6.1 percent (*Air40*). Hog production would also exhibit a wide range of production changes.

Beef and hogs exhibit greater reductions because the cost of meeting some environmental constraints are higher. Many hog CAFOs are in regions with limited land for spreading manure (such as Appalachia), and would require expensive emission abatement technologies (covering lagoons). Much of feedlot beef production is in regions where crop demand for nutrients would be relatively low (such as the Southern Plains); under a nutrient application standard, adjustment costs are high. On the other hand, beef producers could meet the ammonia emission constraint-only scenarios (*Air10* through *Air40*) at relatively low cost. The combined scenarios (*WaterAir10* through *WaterAir40*) would be the most costly, primarily because of the high transportation costs borne by CAFOs to meet the land application requirements when atmospheric emissions are constrained, increasing the nitrogen content of manure.

Dairy CAFOs generally have more land available for spreading, which keeps hauling costs down. The ammonia abatement measures for poultry are generally less costly than for other sectors. In addition, poultry litter has a higher nutrient value-to-weight ratio, so it would be less costly to haul.

At greater reductions in air emissions, the combined scenario (e.g., *WaterAir40*) can have a smaller impact on costs in all animal sectors than the air-only scenario (e.g., *Air40*) because the increased nutrient value of manure would increase the amount AFOs receive for their manure from crop producers, mitigating land application costs (crop producers are assumed to pay for manure).

Under two scenarios (*Water* and *WaterAir10*), the incentive to increase cropped acres where the CAFO manure application standard is most binding (Appalachia, Southeast, and Pacific) boosts cropped acres by 0.5 to 2.5 percent (fig. 4-3). For all other scenarios, cropped acres would fall as demand for feedgrain declines with decreasing animal production.

Technology Adjustments

Technology adoption would be influenced by the policy requirements and the relative costs of the management practices, determined by factors such as mix of animals, dominant production technologies, and cropland available for spreading manure. Consequently, total regional expenditures on practices for meeting environmental goals would adjust after simulated adjustments in production levels have taken place (table 4-3). Under the *Water* scenario, where only the CAFO regulations for protecting water quality are simulated, CAFOs would develop and implement nutrient management plans that minimize the cost of spreading manure. Hauling manure to cropland would be the predominant cost. If restrictions are placed on ammonia emissions from animal feeding operations, producers would begin using alum, incorporating/injecting manure, and covering their lagoons. The costs of these alternative storage, handling, treatment, and application technologies would increase as required reductions in ammonia emissions increase. Expenditures would be highest when both air and water quality goals have to be met (*WaterAir10-40*) because more actions to manage manure must be taken.

The producers' cost per animal unit for each scenario reveals the same relationship between the air and water scenarios as in the farm-level analysis. The sum of the costs of the CAFO regulation scenario (*Water*) and the hypothetical ammonia-only regulation scenarios (*Air*) would be less than the cost of the joint policy scenarios (*WaterAir*) that achieve the same level of

Table 4-3

Net manure storage, handling, treatment, hauling, and application costs

Region[1]	*Water*	*WaterAir10*	*WaterAir20*	*WaterAir30*	*WaterAir40*	*Air10*	*Air20*	*Air30*	*Air40*
					$ million				
NE	9.28	40.40	46.62	53.12	59.52	2.51	5.58	20.53	36.22
LS	34.55	77.76	92.87	110.90	127.56	3.97	8.03	20.41	58.08
CB	52.33	138.30	161.11	193.86	212.70	8.77	21.43	73.79	142.73
NP	129.26	127.38	137.11	132.13	201.74	2.78	9.38	33.20	139.40
AP	6.08	34.73	57.79	95.40	161.42	8.20	18.80	37.54	71.58
SE	23.24	29.33	41.64	53.96	66.75	5.53	16.47	27.93	39.65
DS	13.70	25.71	33.28	41.74	55.50	5.12	13.82	23.02	34.73
SP	47.35	47.65	56.24	74.11	54.49	1.73	7.05	16.68	61.33
MT	96.99	97.14	97.10	99.32	92.66	1.36	3.14	5.44	5.57
PS	121.69	124.00	124.37	126.57	128.76	2.27	4.87	7.73	17.15
Total U.S. cost	534.46	742.39	848.12	981.11	1,161.10	42.23	108.56	266.27	606.42
U.S. cost per AU ($)	4.99	6.96	7.96	9.31	11.19	0.39	1.01	2.52	5.89

[1] Northeast (NE) = CT, DE, MA, MD, ME, NH, NJ, NY, PN, RI, VT; Lake States (LS) = MI, MN, WI; Corn Belt (CB) = IA, IL, IN, MO, OH; Northern Plains (NP) = KS, ND, NE, SD; Appalachia (AP) = KY, NC, TN, VA, WV; Southeast (SE) = AL, FL, GA, SC; Delta States (DS) = AR, LA, MS; Southern Plains (SP) = OK, TX; Mountain (MT) = AZ, CO, ID, MT, NM, NV, UT, WY; Pacific States (PS) = CA, OR, WA.

ammonia reduction. Again, this indicates that the policies are in conflict. The optimal economic adjustments to the different environmental policies would involve tradeoffs; i.e., strategies for addressing ammonia control may make nutrient standards for CAFOs more costly and vice versa.

Regional Shifts

Examining the pattern of geographic shifts in production following our policy simulations provides further evidence that addressing ammonia and water goals independently rather than jointly would impose additional costs on producers. These shifts result from many simultaneous economic forces, reflecting relative costs of meeting regulations, animal mix, and resource base. As expected, meeting two environmental goals rather than one would impose additional costs on the sector and would result in a larger reduction in production. The CAFO regulations alone could reduce production by about 1.2 million animal units (table 4-4). Simultaneously reducing ammonia losses by 20 percent could reduce production by an additional 650,000 animal units (a total loss of 1.85 million).

Most regions would follow this same pattern; production losses would be greatest when both environmental regulations are in place. However, in the Mountain, Appalachian, Northern Plains, and Pacific regions, production would be higher under the joint regulations than under the *Water* scenario. In these regions, the costs associated with closing operations and losing production that would have occurred under the *Water* scenario could be avoided if the water and ammonia regulations are implemented simultaneously rather than independently.

Table 4-4
Changes in regional production

Region[1]	*Base*[2]	*Water*	*WaterAir10*	*WaterAir20*	*Air10*	*Air20*
			Million AU			
NE	4.176	-0.004	-0.123	-0.144	0.015	-0.068
LA	7.847	-0.099	-0.302	-0.359	0.045	0.110
CB	16.874	-0.375	-1.550	-1.725	-0.137	-0.251
NP	19.461	-0.848	-0.549	-0.648	-0.121	-0.643
AP	14.284	-0.323	-0.164	-0.225	-0.101	0.079
SE	3.871	0.005	0.019	-0.013	-0.043	-0.033
DL	3.082	-0.020	-0.120	-0.151	-0.053	-0.046
SP	21.224	0.400	0.729	0.880	0.042	-0.141
MN	10.365	0.450	0.651	0.755	0.041	0.254
PA	7.149	-0.358	-0.262	-0.220	0.006	0.082
US	108.333	-1.172	-1.671	-1.850	-0.306	-0.657

[1] Northeast (NE) = CT, DE, MA, MD, ME, NH, NJ, NY, PN, RI, VT; Lake States (LS) = MI, MN, WI; Corn Belt (CB) = IA, IL, IN, MO, OH; Northern Plains (NP) = KS, ND, NE, SD; Appalachia (AP) = KY, NC, TN, VA, WV; Southeast (SE) = AL, FL, GA, SC; Delta States (DS) = AR, LA, MS; Southern Plains (SP) = OK, TX; Mountain (MT) = AZ, CO, ID, MT, NM, NV, UT, WY; Pacific States (PS) = CA, OR, WA).

[2] Baseline values are taken from 2010 USDA baseline projections (USDA, 2003).

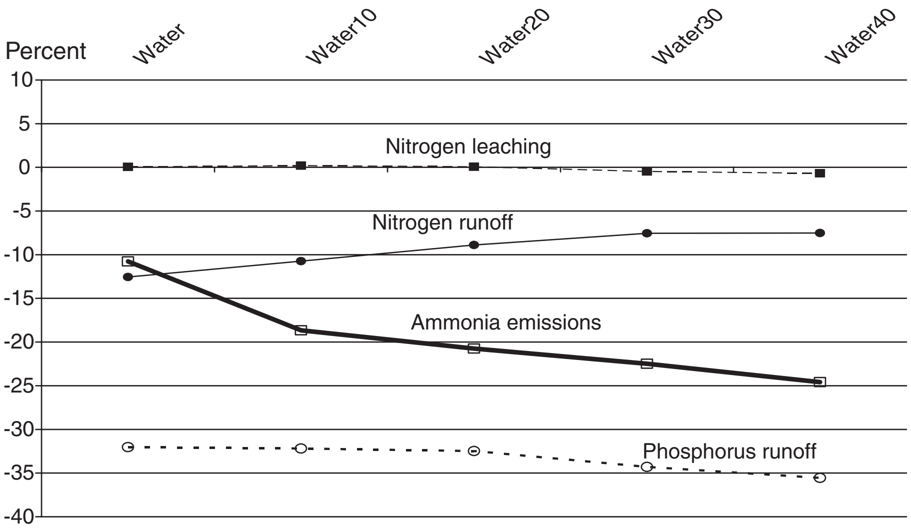
Environmental Implications

Environmental impacts result from changing manure management at the farm level, but also from changing the number of animals raised in each region. As AFOs adopt storage, handling, treatment, and application technologies to reduce ammonia emissions, the reductions in nitrogen runoff (from land application constraints) would gradually diminish. Runoff could even increase above baseline levels, supporting the findings of the farm-level analysis (fig. 4-4). With nutrient application standards in place on CAFOs (*Water*), nitrogen runoff would fall by about 12 percent. As restrictions on ammonia emissions are imposed, nitrogen runoff could increase. When emissions are reduced 40 percent, runoff would be about 7 percent lower than the baseline. Many of the environmental gains attributable to the CAFO regulations would disappear, primarily because non-CAFO operations are not subject to land application constraints. Manure spread on land from these operations would have higher nitrogen content due to technological changes adopted to reduce air emissions. Not restricting land application to agronomic rates would therefore increase nitrogen runoff. Again, policies addressing pollution to only one medium could increase emissions to a different medium. Without land application restrictions in place at all, reducing ammonia emissions would increase overall nitrogen runoff, even with fewer animals.[6]

[6] Some of the nitrogen applied to cropland leaches to ground water, which is an important source of drinking water in many areas. The policies examined would have little impact on nitrogen leaching nationally (see fig. 4-4).

Phosphorus runoff is a leading cause of surface-water eutrophication (overenrichment of nutrients causing algal blooms). While phosphorus is not part of the nitrogen cycle, manure contains high levels of this nutrient and meeting a nitrogen standard may still result in an overapplication of phosphorus (Ribaudo et al., 2003). This can degrade water resources so that they are unfit for swimming, boating, or fishing. Manure phosphorus, along with nitrogen, is a focus of the Clean Water Act's CAFO regulations. Under most simulated policies, phosphorus discharges would fall substantially (fig. 4-4). In the model, phosphorus applications are restricted under the CAFO regu-

Figure 4-4
Change from baseline in ammonia and nutrient losses to the environment, U.S.



lations when phosphorus is the limiting nutrient (posing greatest environmental threat). Also, one of the practices for reducing ammonia emissions—adding alum to poultry litter—would further limit the loss of phosphorus to water.

Economic Implications From Market Interactions

The farm-level analysis assumed constant prices, so the costs of meeting single-medium or joint policies would be borne fully by animal operations. However, animal production would be expected to fall under all scenarios (fig. 4-2) as producers adjust to increased production costs brought about by more intensive manure management. Such changes would likely lead to higher commodity prices, transferring some of the burden of higher costs to consumers (table 4-5). Crop producers would also be affected by what happens in the animal sector. Corn and soybeans are important feedgrains for animal production, and fewer animals being produced would dampen corn and soybean prices. In addition, policies to protect water quality could increase corn and soybean acres in some regions (receiving manure), which would also reduce prices.

Economic tradeoffs from a joint rather than uncoordinated policy approach can only be inferred from our results. The livestock sector would seemingly benefit from a joint policy versus uncoordinated policy. Reductions in net returns for any one of the joint policies would be less than for the *Water* scenario. Costs to the livestock sector from implementing only the CAFO regulations could have been reduced if hypothetical ammonia reductions had been required at the same time.

Table 4-5
Economic impacts and nitrogen reductions

	Water	WaterAir10	WaterAir20	WaterAir30	WaterAir40
	Change (million units)				
Nitrogen reductions (lbs. runoff, leaching, and air emissions)	1,169	1,553	1,599	1,653	1,779
Net returns to crop production ($)	449	328	307	267	196
Net returns to livestock production ($)	-897	-700	-724	-566	-268
Consumer surplus ($)	-402	-786	-876	-1,304	-2,053
Returns to agriculture and consumer surplus ($)	-850	-1,158	-1,293	-1,602	-2,125

Summary

A national manure management policy affecting a significant share of animal feeding operations would affect prices, producer net returns, and consumers. The environmental and economic impacts would vary greatly by region and animal type. The ability of the different sectors and regions to respond to the direct costs of water and air quality regulations depends on the size and structure of the agricultural operations, regional characteristics like available cropland, and responsiveness to price changes by the crop and animal sectors.

National results generally confirm farm-level results. Policies aimed at reducing ammonia emissions from animal manure would result in technological and production adjustments that could, in the aggregate, lead to increased discharge of nitrogen into surface and ground waters. This outcome is explored further for the Chesapeake Bay watershed.