AJAE Appendix for Point/Nonpoint Effluent Trading with Spatial Heterogeneity

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Note: The material contained herein is supplementary to the article named in the title and published in the American Journal of Agricultural Economics (AJAE).

This appendix provides detailed background data used to construct the Kymi River Basin agricultural and municipal waste management models, along with disaggregated results of the analysis of effluent trading outcomes. The Kymi River is the largest Finnish contributor of nitrogen to the Gulf of Finland (and thus to the Baltic Sea); environmental damage from nitrogen concentrations within the Kymi River itself is negligible. We focus on nitrogen control policy in the Kymenlaakso Valley, which we model as a 120-kilometer-long straight line divided into 24 locations. The city of Kotka, located at the river's mouth, is the main port for exports from the Finnish forest products industry.

Point Sources

The main point sources of nitrogen are the forest products (pulp and paper) industry and municipal sewage treatment plants. These point sources are located primarily along the downstream stretches of the river within 40 kilometers of the river's outlet to the Gulf of Finland. Current nitrogen loadings from the principal point sources, obtained from local environmental authorities, are reported in table A1 (Åkerberg and Anttila-Huhtinen 2001). Information on nitrogen inflows, treatment levels, and discharges from municipal sewage plants, obtained from Lapinlampi and Raassina (2002), is reported in table A2.

We assume that the marginal cost of nitrogen emissions reduction in the municipal waste water treatment plants is linear so that the marginal cost of reducing nitrogen emissions at plant i at location t, y_{it}, is $\rho_i + \omega_i y_{it}$. Recent estimates indicate that the marginal cost of achieving the current level of reduction in nitrogen emissions (about 40%) is about € 1.6 per kilogram of nitrogen while doubling that reduction in emissions (to 80%) would cost € 5.1 per kilogram (Vehkasalo 1999; Finland Ministry of the Environment 2002). We assume that the marginal cost of reducing nitrogen emissions at plant $_i$ is constant at the current marginal cost level for emissions reductions up to 40% of current inflows, implying $\rho_i = 1.6$ and $\omega_i = 0$ for $y_{it} \leq 0.4B_i$, where B_i denotes nitrogen inflows at plant $_i$. We also assume that the marginal cost of reducing nitrogen emissions increases linearly from 1.6 for reductions equal to 40% of current inflows to 5.1 for reductions equal to 80% of current inflows. Table A2 gives the inflow information used to calculate ρ_i and ω_i for reductions in nitrogen emissions in excess of 40% of current inflows at each plant. The total cost of reducing nitrogen emissions was calculated as the area below the marginal cost curve at each plant.

Data on the costs of pollution abatement in the Finnish forest products industry were not available. Kiirikki et al. (1999) estimate that the average cost of additional reductions in nitrogen emissions is four to five times higher than those of municipal waste water treatment plants. It is widely believed that the forest products industry overcomplies with emissions standards by a wide margin, however, since environmental quality is highly valued in marketing Scandinavian forest products. Because of this overcompliance, we assumed that current levels of nitrogen emissions reductions in the forest products industry were socially optimal and treated them as fixed in the analysis.

Nonpoint Sources

The main nonpoint source is agriculture. We use agricultural census data from years 2000-2002 combined with GIS information to set a baseline allocation of land among the four crops accounting for the bulk of cropland: barley, oats, spring wheat, and rape. The total amount of land under cultivation is 22,964 hectares. Clay soils predominate. We utilise data on the distribution of different soil textural classes and the depth of soil organic matter to develop soil quality index to describe differential soil productivity along the river. This index was used to divide the valley into 24 production units of uniform quality that differed in size as well as soil productivity.

The profit earned from growing a given crop at given location is calculated as the value of output less fertilizer expenditures and all other costs, which are assumed fixed. We used a Mitscherlich nitrogen response function of the form $q = \alpha(1-\gamma\, e^{-\beta z})$ (where q denotes output per hectare and z fertilizer application per hectare) for spring wheat, barley and oats. We used a quadratic nitrogen response function of the form $q = a + bz + cz^2$ for rape. The maximum obtainable yield parameters α of the Mitscherlich nitrogen response functions and parameters a and b of the quadratic nitrogen responses function were calibrated to match observed crop yields associated with known fertilizer application rates on soils of different quality obtained from fertilizer field trials (Heikkilä 1980; Bäckman, Vermeulen, and Taavitsainen 1997). The parameters of the crop response models are reported along with crop prices and per-hectare expenditures on all other inputs in table A3.

Nitrogen runoff from cropland was modelled using the functional specification for clay soils developed by Simmelsgaard (1991) and modified to include the effects of riparian buffer strips and adjusted to reflect Finnish conditions by Lankoski and Ollikainen (2003). Nitrogen runoff from crop j at location t is a nonlinear function

(A1)

$$[1-m_j(t)]f(z_j(t),t)g(t) - h(m_j(t)g(t),t) = [1-m_j(t)^{0.2}]\phi e^{-0.7[1-0.01(1-m_j(t))z_j(t)]}.$$

The first term on the right hand side of equation (A1), $1\text{-}m_j(t)^{0.2}$, models nitrogen uptake by a riparian buffer of a size that takes up a share of land m_j. The marginal uptake rate declines as the share of land allocated to the buffer increases (which means that the buffer is widened). The term $\phi\, e^{-0.7[1-0.01(1-m_j(t))z_j(t)]}$ represents nitrogen runoff from crop j generated by a nitrogen application rate of z_j per hectare when riparian buffers take up a share of land m_j. The parameter ϕ calibrates this expression so that it equals the level of nitrogen emission generated by a nitrogen application rate of 100 kilos per hectare in the absence of riparian buffers. For all crops $\phi = 15$.

Baseline and Socially Optimal Discharges and Water Quality

Nitrogen in the river is subject to retention and degradation. The flow in the Kymi River is quite rapid. As a result, the retention/degradation rate of nitrogen in the river, $\delta(t)$, is extremely low except in a few locations where the water travels at lower velocity, such as lakes or other broad stretches. We were only able to obtain estimates of the average degradation rate in the river as a whole, $\delta = 0.003$ (Åkerberg and Anttila-Huhtinen 2001).

Baseline discharges from point sources equalled actual discharges from municipal waste water treatment plants and forest product plants. Baseline discharges from agriculture were estimated using equation (A1) with cropland allocations and fertilizer application rates set at their profit-maximizing level assuming no regulation (which implies no land set aside in riparian buffers). Fertilizer use is treated as unobservable, so the fertilizer restrictions are unenforceable. For that reason, fertilizer application rates for each crop in the social optimum are set to their profit-maximizing levels assuming no regulation. The social optimum involves choosing the share of land allocated to each crop set aside as a riparian buffer $m_j(t)$, the amount of land planted to each crop $L_j(t)$, and point source pollution control $y(t)$ so as to maximize the agricultural income less treatment costs in municipal waste water plants and the cost of environmental damage in the Gulf of Finland. The marginal value of nitrogen reductions in the Gulf of Finland was assumed to be constant at € 3.57 per kilogram (see Yrjölä and Kola 2004). Discharges and nitrogen concentrations at each location in the Kymenlaakso Valley in the unregulated baseline and social optimum are reported in table A4.

Point/Nonpoint Trading under Two Permit Allocation Schemes

We analyze nitrogen trading between point and non-point sources and across locations under two different schemes for allocating permits initially. In both cases the target level of loads (hence the total number of permits) equals the socially optimum, measured in terms of nitrogen delivered to the Gulf of Finland, i.e., emissions adjusted for degradation en route to the Gulf. As our model has only one relevant receptor point (the river mouth as it enters the Gulf of Finland), there is just one market and one market price (marginal damage in the Gulf of Finland, adjusted for degradation) organizing the trading. Both permit allocation schemes feature a total number of effluent permits equal to the social optimum and distributions of permits proportional to historic emissions.

The first scheme imposes equal percentage reductions in nitrogen loads (measured in terms of nitrogen delivered to the Gulf of Finland) for both agricultural runoff and municipal sewage treatment plant effluent at each site. The socially optimal amount of nitrogen delivered to the Gulf is 39.13% of the unregulated baseline load, hence each source is issued permits equal to 60.87% of its historic (baseline) emissions. The second scheme allocates permits according to socially optimal emissions from agriculture and municipal sewage treatment plants taken separately. In essence, this scheme gives municipal sources credit for effluent reductions undertaken in the past. Under this scheme, each agricultural source is allocated permits equal to 46.17% of its historic (baseline) runoff while each municipal sewage treatment plant was allocated permits equal to 71.66% of its historic effluent. Equilibrium emissions, loadings, and nitrogen concentrations at each location under both trading schemes are reported in table A5. Agricultural income in the unregulated baseline and under regulation with and without permit trading at each location is reported in table A6. Municipal waste water treatment costs in the existing baseline and under stricter regulation with and without permit trading are reported in table A7.

Sensitivity Analysis

We conducted two sensitivity analyses to examine the robustness of trading patterns, changes in agricultural income, and municipal waste treatment costs with respect to two key parameters: the marginal value of nitrogen reductions in the Gulf of Finland and the price of wheat. A higher marginal value of nitrogen reductions in the Gulf of Finland implies stricter water quality regulation. A higher price of wheat means more profitable agriculture, hence less strict regulation. The results obtained in both sensitivity analyses are largely the same as those obtained in the base case.

Higher Marginal Environmental Damage

We assessed the sensitivity of the results to stricter water quality regulation by assuming a marginal value of nitrogen reductions in the Gulf of Finland 20% higher than the base case. Under this assumption, the socially optimal load of nitrogen delivered to the Gulf is 5.4% lower than the base case. In the social optimum, stricter regulation falls more heavily on municipal sources than on agriculture: The socially optimal load of nitrogen delivered to the Gulf from municipal sources is 15.6% lower than in the base case, while the optimal load delivered from agricultural sources is only 3.5% lower than in the base case. Socially optimal cropping patterns remain the same as in the base case but the area allocated to buffer strips is 26.4% higher than in the base case.

Trading patterns remain the same as in the base case under both permit allocation schemes (table A8). When permit allocations are based on uniform emissions reductions, farmers with the most productive soils (who grow wheat and barley) and small and medium-size municipalities sell permits while farmers with less productive soils (who grow oats and rape) and larger municipalities buy permits. When permit allocations give credit for prior emissions reductions, only wheat growers and small municipalities sell permits.

Regulation reduces farm income in the absence of trading by 1.9% when permit allocations are based on uniform emissions reductions and 4.2% when permit allocations give credit for prior emissions reductions. Trading eliminates the overall burden of regulation for farmers when permit allocations are based on uniform emissions reductions and moderates the burden when permit allocations give credit for prior emissions reductions: Aggregate farm income is 0.2% higher than the unregulated baseline when permit allocations are based on uniform emissions reductions and 2.5% lower than the unregulated baseline when permit allocations give credit for prior emissions reductions (table A9).

As in the base case, the after-trading costs of water quality regulation are distributed unevenly. Farmers with the most productive soils actually gain from regulation when trading is allowed: Permit sales result in increases in net farm income of 3.8-5.8% for wheat growers when permit allocations are based on uniform emissions reductions and 0.7-2.2% when permit allocations give credit for prior emissions reductions. Farmers with less productive soils, who must buy permits, suffer income losses as high as 5%.

Trading does less for municipalities: Municipal waste treatment costs in the absence of trading more than double from current levels; trading reduces those costs by only 1.3% (table A10).

Greater Agricultural Profitability

We assessed the sensitivity of the results to greater agricultural profitability by assuming a wheat price 20% higher than the base case. Under this assumption, the socially optimal load of nitrogen delivered to the Gulf is 9.8% higher than the base case. The socially optimal load of nitrogen delivered to the Gulf from agricultural sources is 68.0% higher than in the base case, while the optimal load delivered from municipal sources is unchanged. In contrast to the base case, all land is planted to wheat in the social optimum, resulting in a more than doubling of fertilizer use. The socially optimal area allocated to buffer strips increases correspondingly, to 44.4% greater than in the base case.

Trading patterns remain the same as in the base case under both permit allocation schemes (table A11). When permits are allocated on the basis of uniform reductions in nitrogen loads, trading gives rise to the standard scenario in which farmers sell permits and municipalities buy permits. Also as in the base case, the small municipality of Anjala remains a seller of permits. When permit allocations give credit for prior emissions reductions, so that trading essentially occurs within sectors rather than between them, farmers with the most productive soils sell permits while those with less productive soils buy them. As before, small municipalities (Anjala and Kouvola) sell permits while the larger municipalities buy permits.

Regulation reduces farm income in the absence of trading by 0.8% when permit allocations are based on uniform emissions reductions and 2.2% when permit allocations give credit for prior emissions reductions (table A12). Trading mitigates the overall burden of regulation for farmers, but only slightly: Aggregate farm income with trading is 0.3% lower than the unregulated baseline when permit allocations are based on uniform emissions reductions and 2.2% lower when permit allocations give credit for prior emissions reductions.

In the case where permit allocations are based on uniform emissions reductions, as in the base case, the after-trading costs of water quality regulation are distributed unevenly: Farmers with the most productive soils gain slightly from regulation while all others lose. In the case where permit allocations give credit for prior emissions reductions, however, all farmers lose from regulation and all lose by roughly the same percentage.

Less strict regulation overall resulting from greater agricultural productivity means a lower additional regulatory burden for municipalities. When permit allocations are based on uniform emissions reductions, municipal waste treatment costs in the absence of trading are 50% higher than current levels (compared to more than doubling in the base case). Trading is correspondingly less effective in reducing treatment costs: Treatment costs in this scenario are only 1.4% lower with trading than without it (compared to 2.2% in the base case). When permit allocations give credit for prior emissions reductions, additional compliance costs, trading patterns, and cost reductions due to trading are the same as in the base case (table A13). Greater agricultural productivity has no effect on regulatory stringency for municipal waste water treamtent in this case because optimal agricultural and municipal emissions are determined separately.

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Table A1. Location and Nitrogen Loads of Principal Point Sources along the Kymi River

Location	Source	Load (kg)
t = 24	Stora-Enso*	51,672
t = 24	Sewage plants (Heinola)	84,396
t = 12	UMP-Kymmene and Kymi*	107,274
t = 11	Sewage plants (Kouvola)	210,840
t = 7	Myllykoski*	57,703
t = 7	Sewage plant (Anjala/Halkoniemi)	29,086
t = 6	Stora Enso*	76,722
t = 6	Sewage plant (Anjala/Huhdanniemi)	26,671
t = 1	Stora-Enso*	58,400
t = 1	M-Real*	21,900
t = 1	Sunila*	113,150
t = 1	Sewage plants (Kotka)	128,885
t = 1	Sewage plants (Pyhtää)	6,300
t = 1	**All sources total**	**972,999**
	Industry total	**486,821**
	Municipal sewage plants total	**486,178**

Note: * denotes a forest product plant. Emissions estimates from Åkerberg and Anttila-Huhtinen (2001).

Table A2. Nitrogen Balance of Municipal Sewage Treatment Plants

Location	**Source**	**Nitrogen in (kg)**	**Nitrogen out (kg)**	**Percentage Reduction**
t = 24	Sewage plants (Heinola)	112,783	84,396	25.2
t = 11	Sewage plants (Kouvola)	320,656	210,840	34.2
t = 7	Sewage plant (Anjala 1)	38,781	29,086	25.1
t = 6	Sewage plant (Anjala 2)	34,194	26,671	22.0
t = 1	Sewage plants (Kotka)	261,379	128,885	50.5
t = 1	Sewage plant (Pyhtää)	10,723	6,300	41.7
t = 1	**All sources total**	**778483**	**453178**	**41.8**

Note: All municipal waste water treatment plants at each location were combined. Data are from Lapinlampi and Raassina (2002).

Table A3. Agricultural Price, Cost, and Productivity Parameters

Parameter	*Symbol*	*Value*
Price of crop	p	
Spring wheat		€ 0.134/kg
Barley		€ 0.108/kg
Oats		€ 0.110/kg
Rape		€ 0.245/kg
Price of nitrogen fertilizer	v	€ 1.15/kg
Expenditure for other inputs than fertilizers	χ	
Spring wheat		€ 170/ha
Barley		€ 124/ha
Oats		€ 123/ha
Rape		€ 98/ha
Annualized buffer strip establishment and management cost	k	€ 72.8/ha/year
Mitscherlich nitrogen response function $q = \alpha(1 - \gamma e^{-\beta z})$		
Spring wheat	α	4065-4904
	β	0.7624
	γ	0.0103
Barley	α	4026-4791
	β	0.828
	γ	0.0168
Oats	α	3622-4369
	β	0.7075
	γ	0.0197
Quadratic nitrogen response for rape $q = a + bz + cz^2$		
	a	571-689
	b	8.19-9.88
	c	- 0.04

Note: Nitrogen response parameters vary by soil type. Sources: Bäckman, Vermeulen, and Taavitsainen (1997), Heikkilä (1980).

Table A4. Current and Socially Optimal Nitrogen Emissions and Loadings

Location	Agriculture		Municipal		Forest Products		All Sources
	Runoff	Loading	Emissions	Loading	Emissions	Loading	Total Instream Nitrogen
Current							
24	2,026	1,033	84,396	43,038	51,672	26,350	70,421
23							
22	878	485					70,906
21	9,923	5,686					76,592
20	18,004	10,694					87,285
19	11,236	7,042					94,327
18	5,002	3,247					97,575
17	9,075	6,025					103,600
16	24,911	16,912					120,511
15	10,034	6,965					127,477
14	17,270	12,260					139,736
13	17,952	13,031					152,767
12	23,770	17,644			107,274	79,625	250,036
11	9,814	7,597	210,840	163,215			420,849
10	17,511	14,134					434,983
9	23,285	19,220					454,203
8	19,887	16,785					470,988
7	19,243	16,608	29,085	25,102	157,704	136,110	648,808
6	28,091	24,791	26,671	23,538	76,722	67,711	764,848
5	34,670	31,289					796,137
4	27,379	25,266					821,403
3	9,457	8,924					830,326
2	7,035	6,788					837,114
1	12,958	12,786	135,185	133,390	193,450	190,881	1,174,171

Location	Agriculture		Municipal		Forest Products		All Sources
	Runoff	Loading	Emissions	Loading	Emissions	Loading	Total Instream Nitrogen
Social Optimum							
24	1,186	605	64,825	33,058	51,672	26,350	60,013
23							
22	523	288					60,301
21	5,882	3,370					63,671
20	10,637	6,318					69,989
19	5,784	3,625					73,614
18	2,564	1,665					75,279
17	4,642	3,082					78,361
16	12,692	8,616					86,977
15	5,092	3,535					90,512
14	8,730	6,197					96,709
13	9,038	6,560					103,269
12	8,454	6,275			107,274	79,625	189,170
11	5,878	4,551	149,754	115,928			309,648
10	10,396	8,391					318,039
9	13,748	11,348					329,387
8	11,676	9,855					339,241
7	11,233	9,695	16,703	14,416	-	-	499,462
6	9,753	8,608	14,457	12,759	-	-	588,539
5	11,955	10,789					599,328
4	9,374	8,651					607,979
3	3,214	3,033					611,012
2	2,374	2,291					613,303
1	4,342	4,284	103,476	102,102	193,450	190,881	910,570

Note: The forest industry already overcomplies with current regulations due to the use of environmental stewardship as a marketing tool, hence its current nitrogen emissions are treated as optimal. Loading is nitrogen delivered to the Gulf of Finland.

Table A5. Net Permit Sales under Two Alternative Initial Permit Allocation Schemes

Location	Permit Allocation Scheme I				Permit Allocation Scheme II			
	Agricultural Sales (kg N) in Terms of		Municipal Sales (kg N) in Terms of		Agricultural Sales (kg N) in Terms of		Municipal Sales (kg N) in Terms of	
	Runoff	Load	Emissions	Load	Runoff	Load	Emissions	Load
1	3,544	3,497	-21,201	-20,920	1,638	1,617	-6,596	-6,508
2	1,907	1,840			872	842		
3	2,541	2,398			1,150	1,085		
4	7,289	6,726			3,262	3,010		
5	9,145	8,253			4,046	3,651		
6	7,343	6,481	1,775	1,567	3,211	2,834	4,657	4,110
7	479	413	998	861	-2,352	-2,030	4,140	3,573
8	428	361			-2,497	-2,108		
9	424	350			-3,001	-2,477		
10	262	211			-2,314	-1,868		
11	95	73	-21,435	-16,593	-1,349	-1,044	1,344	1,040
12	6,013	4,463			2,516	1,868		
13	1,888	1,370			-753	-546		
14	1,781	1,264			-759	-539		
15	1,015	704			-461	-320		
16	2,469	1,676			-1,195	-811		
17	881	585			-453	-301		
18	480	312			-255	-166		
19	1,054	661			-599	-375		
20	321	191			-2,327	-1,382		
21	157	90			-1,302	-746		
22	12	7			-117	-65		
23								
24	47	24	-13,461	-6,864	-251	-128	-4,343	-2,215

A positive number indicates net sales, a negative number net purchases. Load equals nitrogen delivered to the Gulf of Finland.

Table A6. Agricultural Income (in euros) under Effluent Trading

		Permit Allocation Scheme I		*Permit Allocation Scheme II*	
Location	**Unregulated Baseline**	**Initial Allocation**	**Trading Equilibrium**	**Initial Allocation**	**Trading Equilibrium**
1	116,065	114,660	124,090	113,950	117,377
2	63,716	62,948	68,098	62,762	64,534
3	86,596	85,653	92,536	85,583	87,850
4	253,432	251,513	270,814	251,306	257,547
5	324,354	322,980	346,651	322,709	330,221
6	265,562	265,329	283,901	265,102	270,883
7	307,655	303,900	304,060	290,133	295,339
8	322,568	318,653	318,776	304,315	309,962
9	383,081	378,462	378,562	361,539	368,470
10	292,124	288,620	288,671	275,795	281,249
11	165,995	164,015	164,026	156,775	160,037
12	217,967	215,684	228,517	215,509	219,252
13	188,529	186,796	188,811	181,514	181,968
14	180,617	179,003	180,843	173,931	174,406
15	104,496	103,589	104,603	100,647	100,946
16	258,343	256,168	258,556	248,877	249,676
17	93,713	92,948	93,773	90,299	90,609
18	50,278	49,952	50,389	48,508	48,684
19	109,845	109,330	110,241	106,124	106,544
20	194,958	192,366	192,421	182,968	186,806
21	104,426	103,022	103,044	97,927	100,059
22	8,972	8,850	8,852	8,407	8,597
24	17,527	17,287	17,295	16,442	16,753
Total	**4,110,822**	**4,071,728**	**4,177,529**	**3,961,121**	**4,027,768**

Table A7. Gains from Trade for Municipal Sewage Treatment Plants

Location	Baseline	Initial Permit Allocation Scheme I			Initial Permit Allocation Scheme II		
		Cost of Uniform Compliance	Net Cost with Effluent Trading	Gains from Trade	Cost of Uniform Compliance	Net Cost with Effluent Trading	Gains from Trade
24	45,419	108,558	101,538	7,019	85,686	84,954	732
11	175,706	363,679	357,423	6,256	294,561	294,537	25
7	15,512	37,213	37,100	113	29,362	27,427	1,934
6	12,037	31,080	30,675	404	24,380	21,606	2,774
1(K)	225,059	395,491	388,149	7,342	339,976	339,149	828
1(P)	7,084	13,777	13,753	24	11,435	11,357	78
Total	**480,817**	**949,797**	**928,638**	**21,159**	**785,401**	**779,030**	**6,371**

All costs in euros.

Table A8. Net Permit Sales with 20% Higher Marginal Environmental Damage

Location	Permit Allocation Scheme I				Permit Allocation Scheme II			
	Agricultural Sales (kg N) in Terms of		Municipal Sales (kg N) in Terms of		Agricultural Sales (kg N) in Terms of		Municipal Sales (kg N) in Terms of	
	Runoff	Load	Emissions	Load	Runoff	Load	Emissions	Load
1	2,770	2,733	-9,105	-8,984	1,593	1,572	-84	-83
2	1,486	1,434			847	817		
3	1,974	1,863			1,115	1,052		
4	5,646	5,210			3,158	2,915		
5	7,062	6,373			3,912	3,530		
6	5,653	4,989	2,302	2,031	3,101	2,736	4,081	3,602
7	-523	-451	1,618	1,397	-2,271	-1,960	3,559	3,072
8	-610	-515			-2,417	-2,040		
9	-796	-657			-2,911	-2,403		
10	-658	-532			-2,249	-1,816		
11	-424	-328	-16,483	-12,760	-1,315	-1,018	-2,414	-1,869
12	4,567	3,390			2,408	1,787		
13	920	668			-711	-516		
14	848	602			-721	-512		
15	471	327			-440	-306		
16	1,117	759			-1,146	-778		
17	388	258			-436	-290		
18	208	135			-246	-160		
19	442	277			-579	-363		
20	-620	-368			-2,255	-1,339		
21	-362	-208			-1,264	-724		
22	-34	-19			-114	-63		
24	-58	-30	-14,893	-7,595	-242	-123	-9,261	-4,723

A positive number indicates net sales, a negative number net purchases. Load equals nitrogen delivered to the Gulf of Finland.

Table A9. Agricultural Income (in euros) under Effluent Trading with 20% Higher Marginal Environmental Damage

Location	Unregulated Baseline	*Permit Allocation Scheme I*		*Permit Allocation Scheme II*	
		Initial Allocation	**Trading Equilibrium**	**Initial Allocation**	**Trading Equilibrium**
1	116,065	114,179	122,672	113,880	117,696
2	63,716	62,811	67,333	62,723	64,691
3	86,596	85,651	91,514	85,530	88,041
4	253,432	251,509	267,877	251,147	258,044
5	324,354	322,975	342,958	322,504	330,781
6	265,562	265,324	280,932	264,931	271,283
7	307,655	299,076	299,315	287,451	292,851
8	322,568	313,627	313,940	301,524	307,407
9	383,081	372,525	372,977	358,249	365,497
10	292,124	284,118	284,530	273,304	279,029
11	165,995	161,473	161,771	155,363	158,814
12	217,967	215,681	226,292	215,374	219,426
13	188,529	185,204	185,826	180,300	180,755
14	180,617	177,474	178,017	172,768	173,246
15	104,496	102,702	102,987	99,972	100,276
16	258,343	253,969	254,607	247,203	248,025
17	93,713	92,150	92,357	89,688	90,012
18	50,278	49,516	49,623	48,177	48,360
19	109,845	108,361	108,570	105,386	105,829
20	194,958	189,059	189,312	181,151	185,150
21	104,426	101,228	101,382	96,942	99,169
22	8,972	8,694	8,709	8,321	8,521
24	17,527	16,983	16,999	16,320	16,597
Total	**4,110,822**	**4,034,290**	**4,120,501**	**3,938,209**	**4,009,500**

Table A10. Gains from Trade for Municipal Sewage Treatment Plants with 20% Higher Marginal Environmental Damage

Location	Baseline	Initial Permit Allocation Scheme I			Initial Permit Allocation Scheme II		
		Cost of Uniform Compliance	Net Cost with Effluent Trading	Gains from Trade	Cost of Uniform Compliance	Net Cost with Effluent Trading	Gains from Trade
24	45,419	125,624	117,691	7,933	110008	106681	3327
11	175,706	412,648	409,577	3,071	367905	367826	79
7	15,512	43,079	42,704	375	37711	36282	1430
6	12,037	36,193	35,401	793	31511	29380	2131
1(K)	225,059	432,438	431,267	1,171	398743	398736	7
1(P)	7,084	15,386	15,368	17	13917	13778	139
Total	**480,817**	**1,065,368**	**1,052,008**	**13,360**	**959,796**	**952,682**	**7,113**

All costs in euros.

Table A11. Net Permit Sales with a 20% Higher Wheat Price

Location	Permit Allocation Scheme I				Permit Allocation Scheme II			
	Agricultural Sales (kg N) in Terms of		Municipal Sales (kg N) in Terms of		Agricultural Sales (kg N) in Terms of		Municipal Sales (kg N) in Terms of	
	Runoff	Load	Emissions	Load	Runoff	Load	Emissions	Load
1	1673	1650	-18565	-18318	431	425	-6596	-6508
2	877	847			203	196		
3	1139	1075			233	220		
4	3182	2937			559	516		
5	3884	3506			562	507		
6	3030	2674	2295	2026	338	299	4657	4110
7	3334	2878	1565	1351	255	220	4140	3573
8	3300	2785			123	104		
9	3693	3048			-20	-17		
10	2655	2143			-133	-107		
11	1373	1063	-17323	-13410	-186	-144	1344	1040
12	2005	1488			-273	-203		
13	1982	1439			-185	-134		
14	1843	1308			-242	-172		
15	1033	717			-177	-123		
16	2474	1679			-530	-360		
17	868	576			-225	-150		
18	469	305			-131	-85		
19	1009	632			-336	-211		
20	1694	1006			-752	-446		
21	891	510			-452	-259		
22	75	41			-44	-24		
24	134	68	-11815	-6025	-103	-53	-4343	-2215

A positive number indicates net sales, a negative number net purchases. Load equals nitrogen delivered to the Gulf of Finland.

Table A12. Agricultural Income (in euros) under Effluent Trading with a 20% Higher Wheat Price

Location	Unregulated Baseline	*Permit Allocation Scheme I*		*Permit Allocation Scheme II*	
		Initial Allocation	**Trading Equilibrium**	**Initial Allocation**	**Trading Equilibrium**
1	184,826	183,274	185,266	180,741	180,892
2	101,144	100,297	101,298	98,915	98,976
3	137,042	135,897	137,141	134,030	134,089
4	399,867	396,536	399,859	391,097	391,215
5	510,269	506,029	509,904	499,108	499,200
6	416,583	413,129	416,016	407,491	407,534
7	480,067	476,095	479,124	469,617	469,637
8	499,696	495,572	498,427	488,848	488,854
9	589,193	584,346	587,382	576,440	576,440
10	446,116	442,456	444,526	436,487	436,493
11	251,722	249,661	250,635	246,303	246,324
12	344,814	341,936	343,300	337,235	337,264
13	305,524	302,915	304,275	298,645	298,657
14	292,807	290,304	291,512	286,204	286,230
15	169,464	168,013	168,660	165,638	165,660
16	419,114	415,522	417,000	409,644	409,721
17	152,088	150,783	151,277	148,648	148,685
18	81,790	81,083	81,341	79,925	79,949
19	179,141	177,581	178,102	175,025	175,092
20	318,402	315,608	316,391	311,028	311,205
21	170,675	169,165	169,548	166,687	166,803
22	14,676	14,546	14,575	14,330	14,342
24	27,912	27,658	27,704	27,241	27,273
Total	**6,492,928**	**6,438,404**	**6,473,263**	**6,349,328**	**6,350,536**

Table A13. Gains from Trade for Municipal Sewage Treatment Plants with a 20% Higher Wheat Price

Location	Baseline	Initial Permit Allocation Scheme I			Initial Permit Allocation Scheme II		
		Cost of Uniform Compliance	Net Cost with Effluent Trading	Gains from Trade	Cost of Uniform Compliance	Net Cost with Effluent Trading	Gains from Trade
24	45,419	77,192	77,192	0	85686	84954	732
11	175,706	267,067	265,104	1,963	294561	294537	25
7	15,512	26,451	22,900	3,551	29362	27427	1934
6	12,037	21,973	17,361	4,612	24380	21606	2774
1(K)	225,059	316,220	316,215	5	339976	339149	828
1(P)	7,084	10,469	10,236	233	11435	11357	78
Total	**480,817**	**719,373**	**709,010**	**10,363**	**785,401**	**779,030**	**6,371**

All costs in euros.