

Figure 1: US Emissions of SO₂, 1900--1990 (1900 = 1).

Source: Gschwandtner et al, 1986.

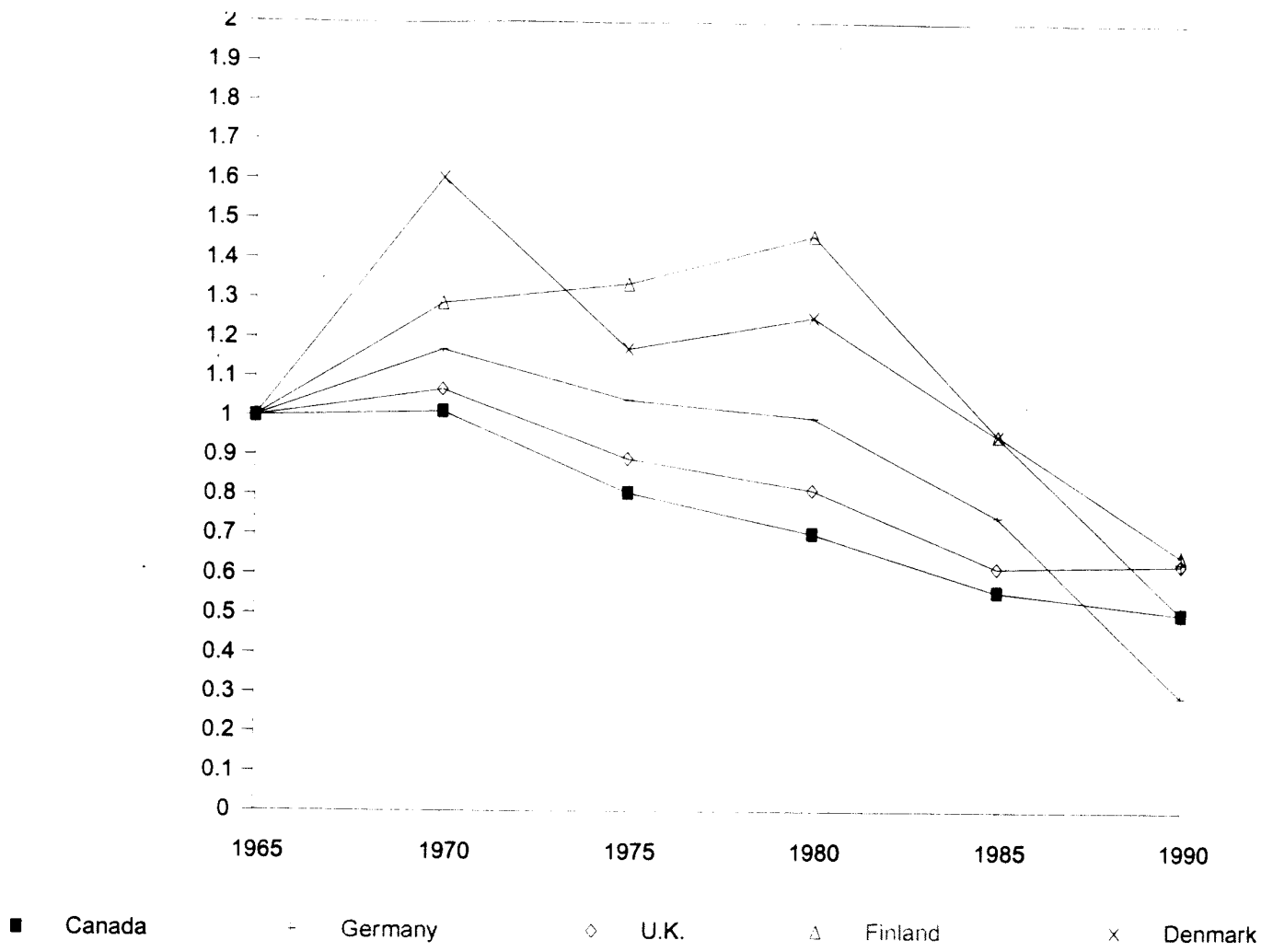


Figure 2: SO₂ Emissions, Selected OECD Countries, 1965--1990 (1965 = 1).

Source: OECD, 1993.

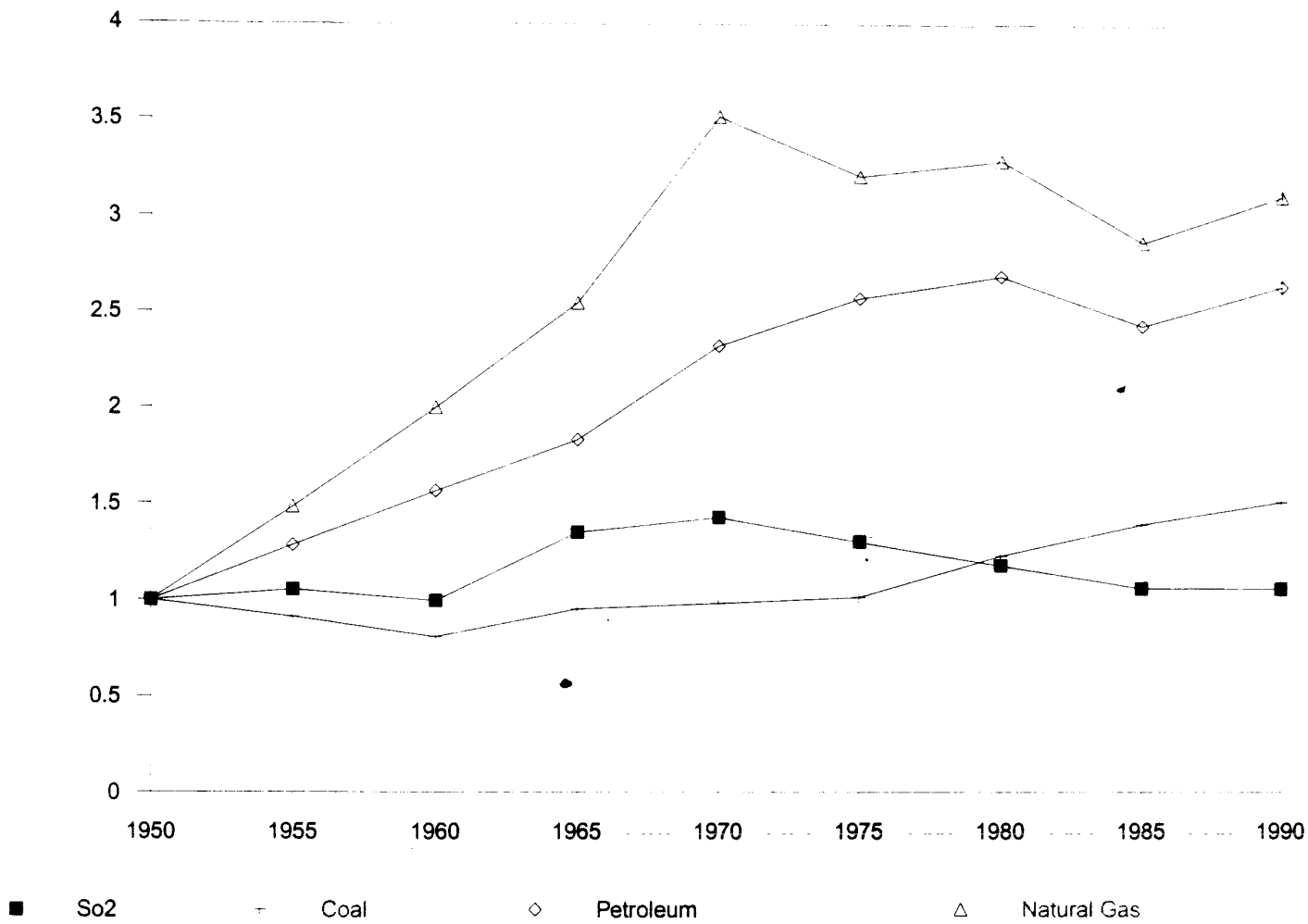


Figure 3: US SO₂ Emissions and Energy Consumption, 1950--1990 (1950 = 1).

Source: Gschwandtner et al, 1986.

Table I
Pollution Abatement Expenditure Intensity in US Industries, 1991

<u>Manufacturing Sector</u>	(A) <u>Capital</u>	(B) <u>Operating</u>
Chemicals & Allied Products	12.9%	1.4%
Primary Metal Industries	11.5%	1.5%
Food & Kindred Products	5.1%	0.3%
Industrial Machinery & Equipment	1.8%	0.2%
Electronic & Other Electric Equipment	2.9%	0.4%
Transportation Equipment	2.8%	0.3%

LEGEND:

Column A reports capital expenditures for pollution abatement as a percentage of all capital expenditures.

Column B reports pollution abatement operating costs as a percentage of the value of all shipments from the sector.

Source: Pollution Abatement Costs and Expenditures, 1993 (US Dept. of Commerce, 1994)

Table II
OLS and IV Estimation of Eqn (9), Chemicals and Electrical Machinery

	Chemicals		Electrical Machinery	
	OLS	IV	OLS	IV
β_O	102.9 (1.29)	44.7 (0.75)	-90.5 (-0.77)	-129.8 (-1.01)
β_T	-81.1 (-1.15)	-80.5* (-1.59)	122.5* (1.66)	116.3** (2.22)
β_P	-0.21 (-0.09)	1.93 (0.86)	2.28 (0.94)	2.81* (1.58)
β_Y	0.38** (4.76)	0.33** (4.06)	0.27* (1.45)	0.23* (1.63)
β_E	7.37 (0.63)	26.7** (1.93)	-0.33 (-0.02)	6.20 (0.36)
$\alpha\beta_E$	12.3 (0.96)	29.5** (2.05)	3.15 (0.19)	9.14 (0.46)
$\alpha_E\beta_E$	-4.75 (-0.62)	-4.2 (-0.78)	8.62 (1.15)	7.95** (1.99)
$\alpha_R\beta_E$	1.50 (0.79)	1.14 (1.0)	-1.69 (-0.65)	-2.47 (-0.83)
n	22	22	19	19
Adj. R ²	0.74	0.77	0.27	0.28

NB: t-statistics are in parentheses; significance at 90% (91%) level indicated by * (**); n refers to sample size.

OLS estimate of Eqn (9) uses observed S_i .

IV estimate of Eqn (9) uses fitted value of $\ln S_i$, after regressing it on all exogenous variables in Eqn (9), except S_i , plus the mortality rate and population density. Standard errors corrected for heteroskedasticity.

Table III
Estimation of Eqn (9)

Coefficient	Chemicals	Primary Metals	Electrical Machinery	Non-electrical Machinery	Food Products	Transportation Equipment
β_O	44.7 (0.75)	-59.6 (-1.14)	-129.8 (-1.01)	2396 (0.70)	128.0 (0.74)	-262.1 (-0.31)
β_T	-80.5* (-1.59)	88.2* (1.55)	116.3** (2.22)	1046 (1.44)	-107.8 (-0.96)	-385.1 (-1.06)
β_P	1.93 (0.86)	1.47 (1.17)	2.81* (1.58)	-23.1 (-1.09)	-0.53 (-0.10)	-16.8 (-1.03)
β_Y	0.33** (4.06)	1.17** (6.46)	0.23* (1.63)	1.44 (1.23)	0.81** (1.99)	0.78** (2.71)
β_E	26.7** (1.93)	19.6* (1.81)	6.20 (0.36)	-340.6 (-0.70)	-13.1 (-0.41)	5.0 (0.04)
$\alpha\beta_E$	29.5** (2.05)	27.8** (2.66)	9.14 (0.46)	-37.3 (-0.18)	-9.12 (-0.31)	3.9 (0.04)
$\alpha_E\beta_E$	-4.2 (-0.78)	-46.9** (-2.6)	7.95** (1.99)	-262.1** (-2.26)	-40.1 (-0.96)	-179.1 (-0.77)
$\alpha_R\beta_E$	1.14 (1.0)	0.02 (0.02)	-2.47 (-0.83)	26.1 (0.53)	2.28 (0.78)	-10.6 (-0.74)
n	22	17	19	13	17	13
Adj. R ²	0.77	0.78	0.28	0.49	0.45	0.01

Note: t-statistics in parentheses; significance at 90% (95%) level indicated by * (**); n refers to sample size.

Annex: I. Data Resources

The data used in our estimation are listed in the attached tables, A-I, A-II, A-III and A-IV. The definitions of the variables and documentation of the source of the data are given below.

P (GDP per capita, in thousands of 1985 US dollars per person). Extracted from “The Penn World Data (Table 5)”; a detailed description of the data is available in “The Penn World Table (Mark 5): An Expanded Set of International Comparison: 1950-1988”, The Quarterly Journal of Economics, May: 327-368.

S (annual SO₂ emissions, in thousands of tonnes). Taken from Environmental Data Report 1993/94 of United Nations Environmental Program (UNEP), published in 1994 by Basil Blackwell (Oxford).

I_i (annual capital outflows of the U.S. industry i, in millions of 1985 US dollars). Taken from the Survey of Current Business July, 1993 (p.102) and August, 1990 (p.68). Industry i = chemicals, primary metals, electrical machinery, nonelectrical machinery, food products and transportation equipment.

T (corporate tax rates). Except for China, taken from Hines and Rice (1994), p. 180. Assumed the same for 1985 and 1990. Tax rate for China taken from “Article 5, Income Tax Law of the People’s Republic of China for Enterprises with Foreign Investment and Foreign Enterprises,” July 1, 1991.

Y_i (annual income of U.S. industry i foreign affiliates, in millions of 1985 US dollars). Taken from Survey of Current Business July, 1993 (p.118) and August, 1990 (p.90). Both capital outflows and income of 1990 are all deflated by the GDP price deflator to 1985

dollars. Industry i = chemicals, primary metals, electrical machinery, nonelectrical machinery, food products and transportation equipment.

POP (population, in thousands). From Penn World Data (Table 5).

SHA (share of industry outputs in GDP, percent). Taken from World Development Report, 1987 and 1992 issues. World Bank. For the country whose SHA is not available, we use the mean SHA for countries of the same income level.

ESI (electricity structure index). Defined as the ratio of the annual utilization of hydro-power capacity (Hydro) to the annual utilization of thermal power capacity (Therm). The data is taken from United Nations' Energy Statistics Yearbook of 1987 and 1992.

D (population density). Defined as population per square kilometer times 10. Area taken from World Bank's World Development Report.

Table A-I: The Observations for 1985

Country	GDP per Capita	SO ₂ Emissions	Population	Population Density	Industry Share	Electricity Structure Index	Mortality Rate	Tax Rate
Canada	15.589	3704	25165	26	30	1.75	7	0.52
China	1.536	19990	1051013	1108	42	0.72	32	0.33
India	1.050	2930	765147	2315	27	0.92	99	0.52
Japan	11.771	1180	120754	3225	41	0.67	5	0.52
Korea	4.217	324	40806	4150	41	0.49	24	0.24
Malaysia	4.146	263	15682	472	43	0.52	24	0.37
Philippines	1.542	610	54700	1824	32	0.77	45	0.33
Singapore	8.616	155	2483	44345	37	0	9	0.21
Thailand	2.463	507	51683	1003	30	0.53	39	0.44
Austria	11.131	99	7555	893	37	0.98	11	0.41
Belgium	11.285	452	9858	2985	31	0.10	10	0.45
France	12.206	1470	55170	998	34	1.47	8	0.5
Germany	12.535	2396	61058	2458	40	0.62	9	0.48
Greece	6.224	500	9934	753	29	0.28	17	0.43
Ireland	7.275	140	3540	349	34.56	0.40	9	0.04
Italy	10.808	2400	57141	1888	33	0.39	11	0.39
Netherlands	11.539	276	14492	3888	34	0.91	8	0.4
Portugal	5.070	198	10157	1094	40	1.27	15	0.4
Spain	7.536	2190	38574	773	34.56	0.49	10	0.33
Sweden	13.451	270	8350	184	31	5.19	6	0.6
Switzerland	14.864	96	6470	1523	34.56	2.38	7	0.17
UK	11.237	3724	56618	2273	36	0.24	9	0.52

Table A-II: The Observations for 1990

Country	GDP per Capita	SO ₂ Emissions	Population	Population Density	Share	Index	Mortality Rate
Canada	20.752	3800	26522	29	30	1.39	7
China	1.536	19990	1133683	1221	42	0.72	27
India	1.505	3070	849515	2869	29	0.91	88
Japan	17.625	1140	123537	3279	42	0.57	5
Korea	8.271	324	42869	4334	41	0.49	21
Malaysia	5.991	263	17763	545	43	0.52	14
Philippines	2.112	370	61480	2093	35	0.76	40
Singapore	14.384	155	2705	44639	37	0	7
Thailand	4.270	612	56303	1090	39	0.40	26
Austria	15.560	99	7712	917	37	0.98	8
Belgium	16.533	420	9967	3255	33	0.17	8
France	16.956	1206	56735	1021	29	1.11	7
Germany	18.235	1002	63230	2510	39	0.66	7
Greece	8.203	500	10123	768	29	0.28	8
Ireland	11.273	168	3503	540	32.4	0.47	7
Italy	15.309	2400	57661	1940	33	0.39	8
Netherlands	16.096	238	14952	4408	31	0.81	7
Portugal	9.005	198	9868	1119	40	1.27	12
Spain	11.765	2190	38959	785	32.4	0.46	6
Sweden	18.024	204	8559	205	35	6.66	6
Switzerland	20.729	62	6712	1662	32.4	2.13	7
UK	15.741	3774	57411	2369	32.4	0.40	7

Table A-III: Capital Outflows by Sector (FDI)
Units: Millions of 1985 US Dollars

	1985							1990						
	Chemical Industry	Electric Equip.	Non-elec Machinery	Primary Metals	Food Products	Transport. Equipment		Chemical Industry	Electric Equip.	Non-elec Machinery	Primary Metals	Food Products	Transport. Equipment	
Canada	56	131	165	97	148	756		131	16.53	119.1	452.1	482.6	N.A.	
China	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	-1.7	0.8	N.A.	
India	8	N.A.	12	4	N.A.	N.A.		N.A.	N.A.	13.2	0.8	N.A.	N.A.	
Japan	-16	-83	N.A.	-51	35	184		-83	223.97	9.9	-24.0	15.7	N.A.	
Korea	5	-13	0	N.A.	5	N.A.		-13	-63.64	N.A.	N.A.	52.9	N.A.	
Malaysia	N.A.	58	N.A.	N.A.	N.A.	0		58	119.01	N.A.	N.A.	-2.5	0	
Philippines	-8	-13	N.A.	N.A.	-39	N.A.		-13	19.83	-1.7	-2.5	11.6	0	
Singapore	N.A.	26	50	-2	-1	N.A.		26	55.37	115.7	3.3	-0.8	N.A.	
Thailand	-2	-20	N.A.	N.A.	N.A.	0		-20	30.58	N.A.	4.1	N.A.	0	
Austria	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	24.79	N.A.	N.A.	7.4	N.A.	
Belgium	48	17	-49	9	12	N.A.		17	14.05	-58.7	N.A.	55.4	N.A.	
France	116	-6	399	19	1	13		-6	40.50	N.A.	100	5.0	-85.1	
Germany	55	47	436	7	31	N.A.		47	50.41	194.2	220.7	74.4	N.A.	
Greece	1	N.A.	0	0	N.A.	0		N.A.	N.A.	0	0	N.A.	0	
Ireland	179	31	86	7	77	N.A.		31	-44.63	-131.4	N.A.	22.3	38.8	
Italy	N.A.	75	N.A.	N.A.	49	N.A.		75	39.67	N.A.	-3.3	172.7	-20.7	
Netherlands	-7	-1	142	N.A.	82	-5		-1	108.26	46.3	54.5	90.9	4.1	
Portugal	-11	12	N.A.	N.A.	4	N.A.		12	N.A.	N.A.	N.A.	10.7	N.A.	
Spain	93	-28	N.A.	N.A.	N.A.	-213		-28	-22.31	N.A.	-18.2	52.9	-213	
Sweden	1	-1	N.A.	N.A.	N.A.	N.A.		-1	-6.61	N.A.	N.A.	N.A.	N.A.	
Switzerland	44	N.A.	N.A.	N.A.	N.A.	0		N.A.	N.A.	N.A.	N.A.	N.A.	0.8	
UK	71	-13	475	6	201	-227		-13	109.92	-160.3	207.4	-63.6	-1088.4	

N.A. = Not Available

Table A-IV: Income of US Foreign Affiliates, by Sector
Units: Millions of 1985 US Dollars

	1985							1990						
	Chemical Industry	Electric Equip.	Non-elec Machinery	Primary Metals	Food Products	Transport. Equipment		Chemical Industry	Electric Equip.	Non-elec Machinery	Primary Metals	Food Products	Transport. Equipment	
Canada	379	175	326	129	235	975		484.2	86.78	242.1	140.5	280.2	N.A.	
China	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		4.96	N.A.	N.A.	-1.7	0.8	N.A.	
India	17	N.A.	11	4	N.A.	N.A.		17.36	N.A.	14.0	0.8	N.A.	N.A.	
Japan	35	-40	N.A.	-44	58	73		90.91	88.43	448.8	12.4	135.5	N.A.	
Korea	9	14	0	N.A.	13	N.A.		16.53	-4.96	N.A.	N.A.	25.6	N.A.	
Malaysia	N.A.	24	N.A.	N.A.	N.A.	0		5.79	61.16	N.A.	N.A.	0.8	0	
Philippines	25	7	N.A.	N.A.	-44	N.A.		45.45	27.27	0	2.5	33.9	0	
Singapore	N.A.	138	50	-2	-2	N.A.		5.79	238.84	237.1	2.5	-1.6	N.A.	
Thailand	3	17	N.A.	N.A.	N.A.	0		17.36	14.88	N.A.	7.4	N.A.	0	
Austria	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		4.13	27.27	N.A.	N.A.	6.6	N.A.	
Belgium	138	-1	-8	8	4	N.A.		469.42	-0.83	-2.5	N.A.	57.9	N.A.	
France	147	8	331	15	39	24		405.79	31.40	N.A.	33.9	149.6	49.6	
Germany	157	102	537	76	68	N.A.		288.43	137.19	705.8	162.8	182.6	N.A.	
Greece	3	N.A.	0	0	N.A.	0		N.A.	N.A.	0	0	N.A.	0	
Ireland	105	36	111	10	111	N.A.		365.29	33.88	62.8	N.A.	37.2	6.6	
Italy	N.A.	79	N.A.	N.A.	51	N.A.		252.89	-8.26	N.A.	22.3	90.9	-7.4	
Netherlands	188	26	120	N.A.	75	-3		426.45	62.81	145.5	79.3	151.2	9.9	
Portugal	-4	14	N.A.	N.A.	6	N.A.		N.A.	N.A.	N.A.	N.A.	9.1	N.A.	
Spain	56	-32	N.A.	N.A.	N.A.	-76		71.90	-27.27	N.A.	30.6	111.6	-76	
Sweden	4	-1	N.A.	N.A.	N.A.	N.A.		2.48	-4.13	N.A.	N.A.	N.A.	N.A.	
Switzerland	25	N.A.	N.A.	N.A.	N.A.	0		22.31	N.A.	N.A.	N.A.	N.A.	0.8	
UK	387	45	500	49	198	9		479.34	21.49	700.8	127.3	230.6	327.3	

N.A. = Not Available