ESRI
www.esri.ie

Working Paper No. 223

January 2008

Environmental Accounts for the Republic of Ireland: 1990-2005

Sean Lyons[a], Karen Mayor[a] and Richard S.J. Tol[a,b,c,d]

Subsequently published in S. Lyons, K. Mayor and R.S.J. Tol, 2008, "Environmental Accounts for the Republic of Ireland: 1990-2005", Journal of the Statistical and Social Inquiry Society of Ireland, Vol. 37, pp. 190-213.

Corresponding Author: Karen.Mayor@esri.ie

[a] The Economic and Social Research Institute, Whitaker Square, Sir John Rogerson's Quay, Dublin 2, Ireland
[b] Institute for Environmental Studies, Vrije Universiteit, Amsterdam, The Netherlands
[c] Department of Spatial Economics, Vrije Universiteit, Amsterdam, The Netherlands
[d] Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA, USA

Environmental Accounts for the Republic of Ireland: 1990-2005

1. Introduction

Environmental accounts provide information on emissions and resource use. Environmental accounts are so-called satellite accounts to the national accounts, which provide a comprehensive framework to present economic data in a coherent, consistent, and internationally comparable manner. Environmental accounts are specifically designed to reveal the pressure the economy puts on the environment, and are therefore an essential input to policy analysis and design (Nordhaus and Kokkelenberg, 1999).

The Economic and Social Research Institute (ESRI) has been commissioned by the Environmental Protection Agency (EPA) to design and build a sustainable development model for Ireland (ISus) that will forecast environmental emissions and resource use for the Republic of Ireland up to 2030. The ISus model is driven by the HERMES model, which projects economic production and consumption per sector (e.g., Fitz Gerald *et al.*, 2002). As with any such model, data are the starting point for the development of ISus (O'Doherty and Tol, 2007). These data are gathered in the environmental accounts.

The Central Statistics Office has previously published environmental accounts for the Republic of Ireland (CSO, 2007), drawing on earlier work by Bacon (1981), Scott (1999), Curtis (2001) and Eakins and Curtis (2003). The theory goes back to Nordhaus and Tobin (1972) and Weitzman (1976). However, the CSO environmental accounts cover only six emissions to air and omit resource use altogether; the CSO environmental accounts are limited to the period 1994-2005; and the CSO environmental accounts reallocate some emissions from power generation to electricity users, on the basis of an unspecified method. It was therefore decided to develop new environmental accounts for the Republic of Ireland that (a) cover more emissions and resource use; (b) cover the period 1990-2005; and (c) relate to production without corrections for intermediate deliveries. The results are presented here.

Raw data on the environment can be difficult to accommodate in economic models. Environmental accounts are designed to 'measure objectively and consistently how

environmental functions contribute to the economy and subsequently, how the economy exerts pressures on the environment' (Pedersen and de Haan, 2006, 20). A System of Environment and Economic Accounting (SEEA; United Nations *et al.*, 2003) was developed to provide an objective system for analysing the effect of the economy on the environment and vice versa. The SEEA aims to guarantee international comparability of environmental data. The environmental accounts presented are consistent with the SEEA, but still cover only a small fraction of the full environmental accounts.

The CSO environmental accounts for Ireland are limited to the emissions to air of six substances. This is a limited set compared to that of other European countries as can be seen from Table 4. The environmental accounts presented in this paper are new accounts for the Republic of Ireland and aim to cover more emissions and a longer time period. The environmental accounts presented are consistent with the SEEA, but still cover only a small fraction of the full environmental accounts. Particularly, expenditures on environmental protection, and the monetary value of pollution and resources is omitted.

Section 2 presents data sources and imputation methods. Section 3 discusses pertinent trends in the observation. Section 4 concludes.

2. Data

Gathering the necessary data was the starting point for the compilation of the national environmental accounts. Ireland has a poor history in environmental data reporting but has improved in recent years. The quality and detail of the available data is, however, still variable and the emissions of certain pollutants still go unreported. We distinguish between 'high quality' data, which in general are reported annually in an international standard reporting format, and 'mixed quality' data, which tend to be available for only a limited number of years and to be based on a bespoke reporting format.

2.1. High quality data

Greenhouse gas and related emissions are taken from the Environmental Protection Agency, using the Common Reporting Format (CRF) for Ireland's submission to the

United Nations Framework Convention on Climate Change (EPA, 2007).[1] Table 5 specifies the concordances between the CRF and the nomenclature of economic activities (NACE), the reporting format on which the environmental accounts are based.

These emissions consist of the following pollutants: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halofluorocarbons (HFC23, HFC32, HFC125, HFC134a, HFC143a, HFC152a, HFC227ea), perfluorocarbons (CF_4, C_2F_6, cC_4F_8) and sulphurhexafluoride (SF_6), sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC). There is a full time series (1990 to 2005) for all of the emissions listed above.

Data on the emissions of ammonia (NH_3) are taken from Central Statistics Office's environmental accounts (CSO, 2007).[2] The time series covers 1994 to 2005. Data on the use of fungicides, herbicides, insecticides and other pesticides are taken from EuroStat.[3] For fungicides, herbicides and insecticides, there are data available from 1992 to 2003 and for other pesticides from 1997 to 2003. All missing years are imputed from the available data. Imputed data follow from multiplying the observed economic activity level with the extrapolated emission factors. Emission factors are extrapolated using the median change in the observed emission factors. Data on the use of nitrogen fertiliser, phosphorous fertiliser, and potassium fertiliser are taken from the Department of Agriculture and Food (DAF, 2007).[4] These uses are all attributed to the "agriculture, forestry, and fisheries" sector.

Data on the use of coal, peat, oil, natural gas, renewables, and electricity is taken from the energy balances of Sustainable Energy Ireland (SEI, 2006).[5] The energy balances by and large follow the NACE classification.[6]

2.2. Mixed quality data

Water use data is taken from the Camp Dresser and McKee (2004) report for the Department of the Environment, Heritage and Local Government, which provides data on water use by sector of the economy for 2001. Eutrophying emissions are taken

[1] http://unfccc.int/
[2] http://www.cso.ie/statistics/EnvironmentalAccounts.htm
[3] http://epp.eurostat.ec.europa.eu/ / Environment and Energy / Agriculture and Environment.
[4] http://www.agriculture.gov.ie/index.jsp?file=publicat/compendium2006/listoftabs.xml
[5] http://www.sei.ie/ Statistics Publications / Energy in Ireland
[6] The only difference is the attribution of "Leather and leather products" to the textiles sector in NACE and the furniture sector in the energy balances. The "Leather and leather products" sector is a small sector and not very energy-intensive so this difference is disregarded.

from Scott (1999) and consist of biological oxygen demand (BOD), nitrogen (N), and phosphorous (P) emissions in 1994. Total emissions data was taken from the World Resources Institute (WRI) website and Scott (1999) was used to impute the regional breakdown.

The waste data in the Environmental Accounts are taken from the National Waste Reports published by the Environmental Protection Agency (the latest is le Bolloch *et al.*, 2007), and from the data collected when those reports were compiled.[7] Although Ireland's waste data are improving, there is little historical time series information at a sectorally-disaggregated level. Even in cases where earlier years are available, compliance and reporting arrangements tend to have improved over time. As a consequence, for modelling purposes we have focused on the most recent year for which complete data are available for a given category of waste emissions (2006 for most categories). The data (by NACE sector) distinguishes between the type of waste and its disposition. There are four disposal dimensions, namely, landfilled, incinerated, recovered (including recycled), and unknown disposition. We also use three categories for the type of waste: hazardous waste, biodegradable municipal waste and other waste.[8]

In some cases, judgement was required as to how to assign non-industrial waste materials across sectors. Here are the main categories that needed to be assigned:

- Sheep dip and 'Other hazardous agricultural waste' are assigned to the agriculture, fishing and forestry sector.
- Transport waste includes end-of-life vehicles and scrap metal;[9] oil filters; waste oils and lead-acid batteries. Waste tyres should be included in this category too, but there are no reliable estimates of the relevant tonnages.
- The services sector includes street cleansing waste; sludges from wastewater and drinking water services; non-industrial halogenated solvents (e.g. from drycleaners), dental amalgam; photographic chemicals; and 'Other office and commercial waste', all of which are presently assigned to the unknown disposition category.
- Contaminated soil is assigned to the construction sector.

[7] Some reclassification was required from the industrial sector classifications used by the EPA for waste data to the ones we use, so we re-aggregated firm level data collected by the EPA into our sectors.

[8] Other waste includes all waste that is not hazardous or biodegradable municipal waste.

[9] In the absence of detailed disposition information, we assume that this waste is all recycled.

- Residential sector waste includes small batteries and 'Other hazardous household waste'.

Some waste could not be attributed to a specific sector, including fluorescent lamps, paint and ink, and a significant proportion of reported hazardous waste that the NWRs differentiate by disposition but do not attribute across sectors.

All data can be found at:

http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/tol/EnvAcc02.xls

2.3 Missing data

Although these environmental accounts are a thorough compilation of the available data on emissions and pollutants in Ireland, they are not exhaustive. Many of the limitations of the data outlined in the previous section could be dealt with by more systematic data collection and quality control. Having a more sectorally-disaggregated dataset for all emissions would also be useful. However, the most important need is for information on a range of emissions for which quantities or dispositions are not presently known.

High quality data is by and large limited to emissions to air originating from energy use. Data on emissions to water are largely absent, as are observations on toxic chemicals and heavy metals. There is no data available on Persistent Organic Pollutants (POPs) in Ireland. POPs are chemicals that remain in the environment for long periods of time and can accumulate in the fatty tissue of organisms. These pollutants are contained in a variety of insecticides and pesticides but there is no published data relating to their existence or density in Ireland. Land use data is also scarce. Considering the rapid development of Ireland in the last decades, it would be an important variable to examine. It is also not possible to examine the potential effects on wildlife and the environment as well as the health effects on the population of endocrine disrupters as no data is available on their presence in Ireland.

There is also a lot of waste that is known to be generated but cannot be identified from the available data. Hazardous waste originating from the household sector, the services sector, the agricultural sector and transport is not reliably quantified or classified by disposition at present. Figures for hazardous waste relate mainly to industrial sources. The proportion of waste that is allocated to the "unknown disposition" category is significant. This is an unusual problem as it is possible to estimate the quantity of waste generated but not to locate it. Finally, data on

agricultural waste is also problematic, with the method of disposition of organic agricultural waste being largely a matter of guesswork and little data available on non-organic agricultural waste. Since organic agricultural waste is not longer classified as waste for regulatory purposes, even the limited imputation exercise previously carried out to quantify these emissions is apparently not going to be continued.

3. Results

The compilation of the environmental accounts, first, allows the identification of past trends in economic activity, in the emission of pollutants and in energy use by sector and, second, provides the basis for projections of future emissions and resource use. Figure 1 shows the composition of economic production in Ireland. Economic growth in the period 1990 to 2005 was dominated by growth in the services sector, and the production of chemicals, office equipment and electrical goods. Economic production across all sectors was two and a half times bigger in 2005 than in 1990. The following section details how emissions and energy use have evolved over the period 1990 to 2005 compared to the economy.

3.1 High growth

A number of emissions have grown very fast over the period. Only one category (halocarbons) has grown faster than the economy, but the growth in energy use is also significant.

Figure 2 shows the composition of halocarbon emissions. The growth rate of emissions has been remarkable, particularly in the electrical goods sector. Chemicals and machinery are also significant contributors to emissions of halocarbon.

Figure 3 shows the composition of oil use. Transport and power generation are the dominant uses with residential use also steadily increasing. Oil consumption doubled between 1990 and 2005. Figures 4, 5 and 6 show the composition of the use of natural gas, renewable energy and electricity demand respectively, all of which more than doubled between 1990 and 2005. Natural gas has increased largely because of the growth in its use in power generation. The food and wood processing industries are the largest users of renewables, followed by households and power generation. Finally, the growth in electricity demand has been fastest in services and residential electricity consumption has also been growing steadily at 4% a year.

Figure 7 shows the origin of carbon dioxide emissions. Power generation is the largest single source of emissions. The closure of the old peat stations in 2001 is clearly visible on the graph. Transport emissions grew the fastest over the period, followed by non-metallic mineral production (cement) which is included in the construction sector. In 15 years the total amount of carbon dioxide emissions in Ireland grew by approximately 40%, which is a high growth rate compared to most other emissions but not as fast as the growth rate of the economy.

Figure 8 shows the use of pesticides. There is substantial variability (probably due to the weather), but a clear upward trend in the use of herbicides and insecticides. The agricultural and forestry industries are the only users of pesticides.

3.2 Constant

The following emissions have remained more or less constant between 1990 and 2005. Figure 9 shows the composition of the emissions of nitrogen oxides. Transport and power generation are the dominant sectors for these emissions. Figure 10 shows the composition of ammonia emissions. Emissions from agriculture have fallen slightly, while the much smaller transport emissions have grown. So the overall trend is fairly constant over the period. Figure 11 shows the composition of methane emissions and Figure 12 shows nitrous oxide emissions. Both are mainly contributed by agriculture, and emissions of both are more or less constant, if not declining somewhat.

3.3 Decline

Despite the phenomenal economic growth experienced by Ireland over the period, emissions of certain pollutants fell due to changes in habits, legislation or substitute production methods. To give an example, emissions of nitrous oxide emissions (Figure 12) from the chemicals sector decreased substantially in 2003, due to the closure of *Irish Fertiliser Industries* in late 2002. Figure 13 shows the composition of sulphur dioxide emissions, which fell by more than half between 1990 and 2005. Emissions from power generation are most important, but less dominant than they used to be. Metal production, food and transport are sectors whose contribution to the emission of sulphur dioxide has fallen. Figure 14 shows the composition of carbon monoxide emissions. Transport is the main source, but emissions have fallen despite the growth in transport. Figure 15 shows the use of fertilisers, which declines very

slowly. As with pesticides, fertilisers are used by the agriculture and forestry only. Figure 16 shows the composition of NMVOC emissions, which declined over the period and more steeply from the late 1990s. This is mostly due to a significant reduction in emissions from the transport sector and partly from the residential sector.

Energy use as a whole has increased considerably since 1990, as seen by the trends above in the use of oil, natural gas and renewables. These increases have been partly compensated by falls in the use of other energy sources such as coal and peat. Figure 17 shows the composition of coal use, which is dominated by power generation. Coal use in services increased in the last five years of the period. The slight decline over time is largely due to a fall of home heating by coal. Figure 18 shows the composition of peat use, which is dominated by power generation and domestic use. Both decreased steadily over the period resulting in a 25% fall in the overall use of peat between 1990 and 2005.

3.4 Waste

In terms of quantity, the main sectors generating hazardous waste in Ireland are construction (contaminated soil) and chemical production, but a significant proportion of the latter category cannot presently be attributed across sectors.

Table 1 below shows the sectoral breakdown of hazardous waste in 2006, the two-year growth rate and the proportions going to each of our four disposition categories. Total hazardous waste generation[10] seems to have increased by about 24% from 2004, driven by a sharp increase in construction waste; the other quantitatively significant category, chemical production, recorded a 9.5% decline. Other sectoral components tend to be highly volatile from year to year. The absence of information on the disposition of hazardous waste from transport, services and the residential sector is a significant weakness in the available data. Over half of hazardous waste is landfilled, while 16% is incinerated and 25% is recycled. This is a striking change from 2001, when the most common method of disposal for hazardous waste was recycling, followed by unknown disposition and incineration.[11]

[10] Total quantity is used here only to facilitate comparison across sectors. We recognize that the potential harm to the environment per unit weight varies considerably across different types of hazardous waste.

[11] See the environmental accounts spreadsheet for details.

Table 1: Hazardous waste by sector for 2006, change from 2004-2006 and 2006 disposition shares

	2006 Tonnage	2004-2006 % Change	% Landfilled	% Incinerated	% Recycled	% Unknown
Agriculture	6,818	-70.6	0.0	0.0	0.0	100.0
Mining	9,929	822.8	6.2	87.1	6.4	0.4
Food	2,482	169.2	23.9	59.4	16.4	0.3
Textiles	1,343	26.3	80.6	0.1	19.3	0.0
Wood	420	-65.1	8.6	43.0	44.1	4.4
Pulp and paper	17,152	205.8	26.0	12.6	61.4	0.0
Chemicals	168,179	-9.5	2.5	58.0	38.9	0.5
Rubber & plastic	1,866	90.4	1.0	29.0	69.2	0.8
Mineral production	21,156	59.5	90.2	0.6	9.1	0.1
Metal production	19,302	2.0	95.7	0.6	3.4	0.2
Machinery	1,964	-21.4	69.5	14.0	16.5	0.0
Office equipment	971	-51.1	3.6	21.2	75.3	0.0
Electrical goods	10,789	-44.8	35.1	40.4	24.4	0.0
Transport equipment	1,333	-62.3	73.7	11.1	15.2	0.0
Other manufacturing	1,687	24.9	71.1	0.6	27.4	1.0
Fuel, power, water	13,426	690.7	12.3	15.4	59.0	13.2
Construction	406,905	84.0	83.8	0.0	16.2	0.0
Services	501	98.5	0.0	0.0	0.0	100.0
Transport	2,539	-63.3	0.0	0.0	0.0	100.0
Residential	10,251	-14.9	0.0	0.0	0.0	100.0
Not attributed	78,491	-24.5	39.6	5.0	42.9	12.5
Total	777,504	24.0	55.3	15.7	24.8	4.2

Biodegradable municipal waste (BMW) is by definition generated only by services and the residential sector. This waste category continues to grow rapidly in Ireland (See Table 2 below).

Table 2: Biodegradable municipal waste (BMW) by sector for 2006, change from 2004-2006 and disposition shares for 2006

			2006 disposition			
	2006 Tonnage	2004-2006 % Change	% Landfilled	% Incinerated	% Recycled	% Unknown
Services	1,080,478	18.4	42.8	0.0	57.2	0.0
Residential	1,199,072	21.3	79.2	0.0	20.8	0.0
Total	2,279,550	19.9	62.0	0.0	38.0	0.0

Broadly similar shares of BMW arise from the services and residential sectors, but there is a significant difference between these sectors in the disposition of BMW, with the services sector sending a much higher proportion of its waste (over half) for recycling than the residential sector (about 21%). Despite very rapid growth in recycling of BMW in recent years, the majority of this material is still sent to landfill. Incineration is not used for BMW in Ireland at present.

Other (non-BMW, non-hazardous) waste is a very heterogeneous category (see Table 3 below). Historically, the largest sectoral contribution by far came from agriculture, which generated an estimated 60 million tonnes in 2004.[12] However, changes in the regulatory treatment of agricultural organic waste have led to this material being reclassified as non-waste, and it is no longer included in EPA estimates. Given that agricultural organic waste can have significant environmental effects akin to those of BMW depending upon how it is managed, we find its exclusion from reporting requirements regrettable. Its use as an input to agricultural production is not a true source of distinction: almost every type of waste can in principle be reused, recycled or recovered for use in some productive process.

Table 3: Other (non-BMW, non-hazardous) waste by sector for 2006, change from 2004-2006 and disposition shares for 2006

	2006 Tonnage	2004-2006 % Change	% Landfilled	% Incinerated	% Recycled	% Unknown
Agriculture	*60,170,025*[*]	n/a	n/a	n/a	n/a	n/a
Mining	4,782,614	18.2	66.1	0.0	33.9	0.0
Food	1,737,955	-41.1	13.5	24.8	61.7	0.0
Textiles	10,547	-83.8	25.7	0.0	74.2	0.1
Wood	245,819	-5.0	2.0	91.1	6.7	0.3
Pulp and paper	146,208	-30.9	4.4	2.8	92.8	0.0
Chemicals	175,412	29.1	12.4	63.2	23.9	0.5
Rubber & plastic	22,652	78.9	15.3	39.5	43.2	1.9
Mineral production	84,216	-27.2	51.4	0.0	48.5	0.0
Metal production	1,242,469	9.9	98.7	0.0	1.2	0.0
Machinery	40,069	0.6	64.8	0.0	35.0	0.2
Office equipment	23,566	31.8	23.5	6.7	69.8	0.1
Electrical goods	53,544	42.3	20.4	1.7	77.9	0.0
Transport equipment	12,031	-30.1	59.2	0.2	40.6	0.0
Other manufacturing	24,223	-51.4	6.7	3.4	87.8	2.0
Fuel, power, water	333,341	17.1	60.7	0.1	39.2	0.0
Construction	16,819,904	50.6	2.6	0.0	79.5	17.9
Services	445,708	-5.6	40.9	0.0	38.9	20.2
Transport	744,136	51.3	0.0	0.0	100.0	0.0
Residential	833,294	9.8	54.8	0.0	20.6	24.7
Not attributed	0	n/a	n/a	n/a	n/a	n/a
Total	27,777,708	24.8%	21.7%	2.8%	63.5%	11.9%

[*] *The estimate for agricultural waste refers to 2004 and is excluded from the 2006 total because organic agricultural waste is no longer classified as waste under EU regulations.*

Nevertheless, we report the total for 'Other waste' excluding agriculture, which totals about 28 million tonnes. The largest component of this total is construction and demolition waste, which has risen rapidly during the recent boom in housing

[12] These data were taken from EPA (2005).

construction (including about a 51% increase from 2004-2006). As in the case of hazardous waste, the expansion of construction activity has led to an overall increase in this category, with a still higher increase from the transport sector and smaller increases from other contributing sectors including the fuel, power and water sector, the mining sector and the metal production sector. In contrast, 'Other waste' from the food sector fell sharply during this period. More than half of 'Other waste' is recycled, but there are substantial differences in disposition shares by sector. This heterogeneity probably reflects the diversity of waste materials we have included under this heading.

4. Conclusions

We present new environmental accounts for the Republic of Ireland. The new accounts have a wider coverage than the CSO environmental accounts. Because the new accounts assign emissions and resource use to production, they can readily be used in economic models.

Emissions of carbon dioxide and particularly halocarbons have increased significantly between 1990 and 2005. Energy use has increased considerably, and there has been a marked shift away from coal and peat to oil and gas. Emissions of sulphur dioxide, carbon monoxide, and VOCs have fallen. Emissions of methane, nitrous oxide, oxides of nitrogen, and ammonia have stayed constant. Fertiliser use has declined slowly, but pesticide use has increased.

The quantity of hazardous waste emissions is dominated by the construction sector (to which we have attributed generation of contaminated soil) and chemical production. We note, however, that weight of output is not a good indicator of a material's potential to cause environmental harm. A significant component of hazardous waste emissions is not presently attributed by sector or disposition, which is less than ideal given the very harmful nature of some component materials.

The biodegradable municipal waste (BMW) category is defined by regulation. While there has been rapid growth in the share of this material being recycled, particularly from the services sector component, fast continued growth in BMW generation means that a substantial share of this material is still going to landfills.

Other (non-BMW, non-hazardous) waste was historically dominated by agricultural organic waste, but regulatory reclassification has led to this component being dropped from reported waste data. This is unfortunate: we suggest that the nature and scale of

this material are such that some mechanism for tracking it should be maintained. The construction sector is the next largest contributor to 'other waste'. This component has risen very rapidly due to extraordinarily fast growth in that sector. Ongoing work by the authors will examine how construction waste quantities are likely to change given the recent downturn in residential construction, set against the continued growth in infrastructure construction under the National Development Plan.

The omissions from the new accounts are informative too. Waste and water are typically listed among the major environmental issues in the Republic of Ireland. However, waste data are limited in time and in coverage. Water data, be it water use or emissions to water, are very limited. Land use data by sector are missing. Emissions to air are more complete, but the accounts exclude toxic chemicals and heavy metals. There are no data on expenditures on environmental protection. Because of these omissions, and because the data on the value of environmental damages and natural resources in Ireland is scarce, the new accounts do not allow for the estimation of the green net national product (Dasgupta and Maeler, 2000). These omissions need to be overcome in later versions of the environmental accounts.

Acknowledgements

The authors are grateful to John Curtis and Odile le Bolloch at the EPA for help with the collection of data. Financial support by the EPA ERTDI (2006-SDM-LS-11) programme is gratefully acknowledged.

References

Bacon, P. (1981), *The Economics of Pollution: An Approach to a Quantitative Model for Ireland*, unpublished PhD thesis, Trinity College, Dublin.

Camp Dresser & McKee (2004), *Economic Analysis of Water Use in Ireland*, Department of the Environment, Heritage and Local Government, Dublin.

Curtis, J.A. (2001), *Pilot Environmental Accounts for Ireland 1996*, Stationary Office, Dublin.

CSO (2007), *Environmental Accounts for Ireland 1997-2005*, Central Statistics Office, Cork.

DAF (2007), *Compendium of Irish Agriculture Statistics*, Department of Agriculture and Food, Dublin.

Dasgupta, P. and K.G. Maeler (2000), 'Net National Product, Wealth and Social Well-Being', *Environment and Development Economics*, **5** (1-2), 69-93.

Eakins, J. and J.A. Curtis (2003), *Environmental Accounts for Ireland 1994-2000*, Stationary Office, Dublin.

EPA (2007), *Ireland's Greenhouse Gas Emissions Provisional Estimate for 2005*, Environmental Protection Agency, Johnstown Castle.

EPA (2005), *National Waste Report 2004*, Environmental Protection Agency, Johnstown Castle.

Fitz Gerald, J., Hore, J., and I. Kearney (2002), *A Model for Forecasting Energy Demand and Greenhouse Gas Emissions in Ireland*, *ESRI Working Paper* No. **146**, Economic and Social Research Institute, Dublin.

le Bolloch, O., Cope, J., Kurz, I., and B.Meaney (2007), *National Waste Report 2006*, Environmental Protection Agency, Johnstown Castle.

Nordhaus, W.D. and E.C. Kokkelenberg (1999), *Nature's Numbers – Expanding the National Economic Accounts to Include the Environment*, National Academy Press for the National Research Council, Washington, D.C.

Nordhaus, W.D. and J. Tobin (1972), 'Is Growth Obsolete?' in *Economic Growth – 50th Anniversary Colloquium of the National Bureau of Economic Research*, Columbia University Press, New York.

O'Doherty, J. and R.S.J. Tol (2007), 'An Environmental Input-Output Model for Ireland', *Economic and Social Review*, **38**, (2), 157-190.

O'Doherty, J., Mayor, K. and R.S.J. Tol (2007), *Irish Sustainable Development Model (ISus): Literature Review, Data Availability and Model Design*, *ESRI Working Paper* No. **186**, Economic and Social Research Institute, Dublin.

Pedersen, O.G. and M. de Haan (2006), 'The System of Environmental and Economic Accounts–2003 and the Economic Relevance of Physical Flow Accounting', *Journal of Industrial Ecology*, 10(1-2) [online]; Available from http://www.mitpressjournals.org/doi/pdf/10.1162/108819806775545466

Scott, S. (1999), *Compilation of Satellite Environment Accounts*, Economic and Social Research Institute, Dublin, **116**.

SEI (2006), *Energy in Ireland 1990-2005*, Sustainable Energy Ireland, Dublin.

United Nations, European Commission, International Monetary Fund, Organization for Economic Cooperation and Development, and World Bank (2003), *Handbook of National Accounting – Integrated Environmental and Economic Accounting 2003*, United Nations Statistics Division, New York. Available from http://unstats.un.org/unsd/envaccounting/seea2003.asp

Weitzman, M.L. (1976), 'On the Welfare Significance of National Product in a Dynamic Economy', *Quarterly Journal of Economics*, **90**, 156-162.

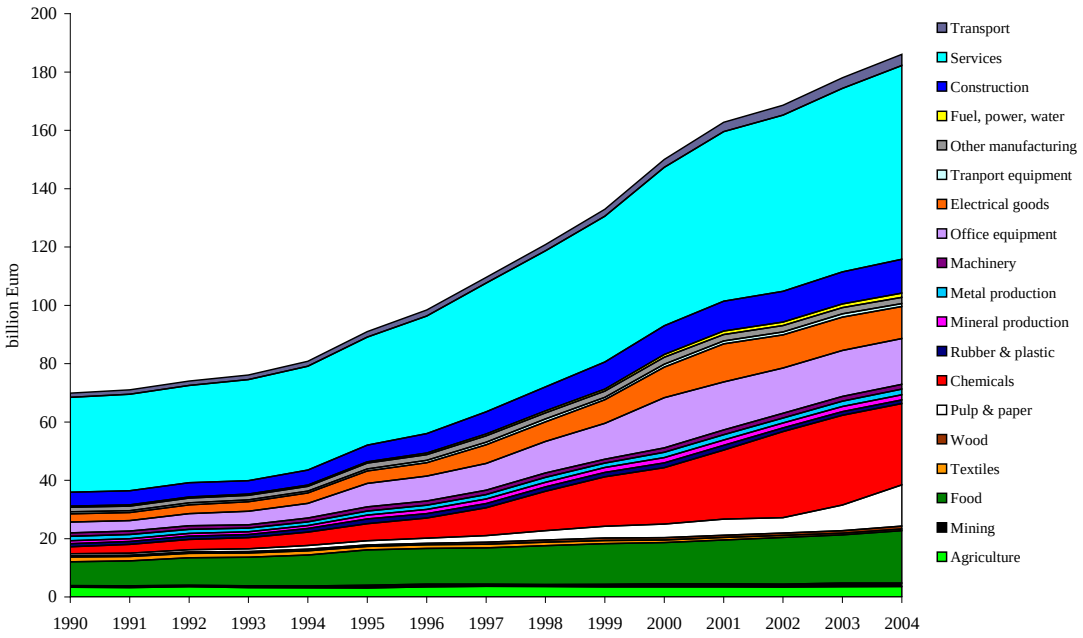

Figure 1: The composition of production in the Irish economy, 1990-2005

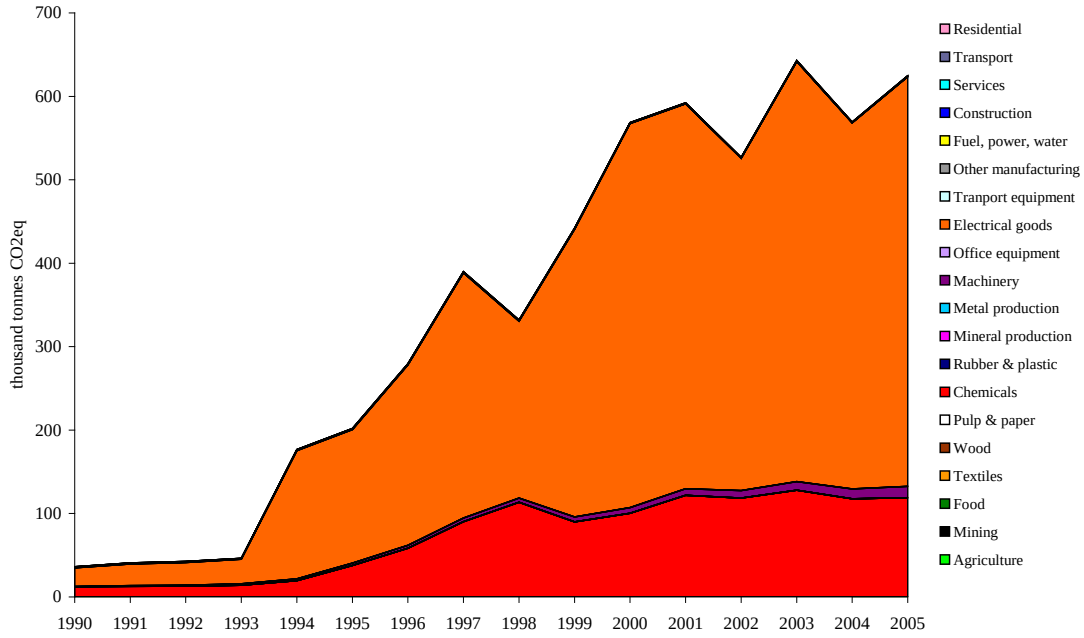

Figure 2: The composition of Irish halocarbon emissions, 1990-2005

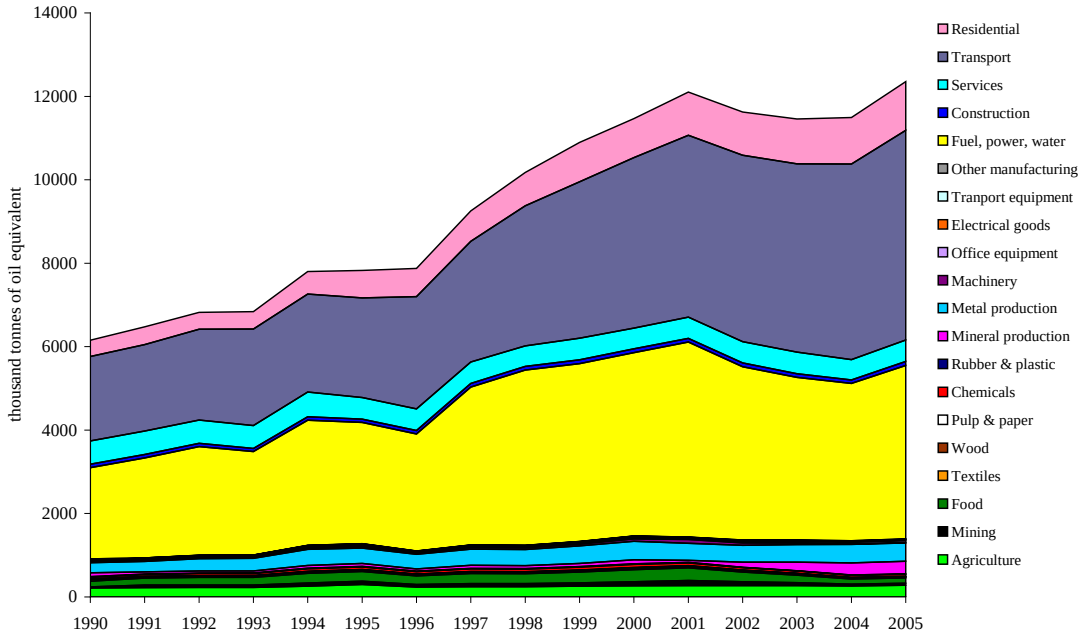

Figure 3: The composition of Irish oil use, 1990-2005

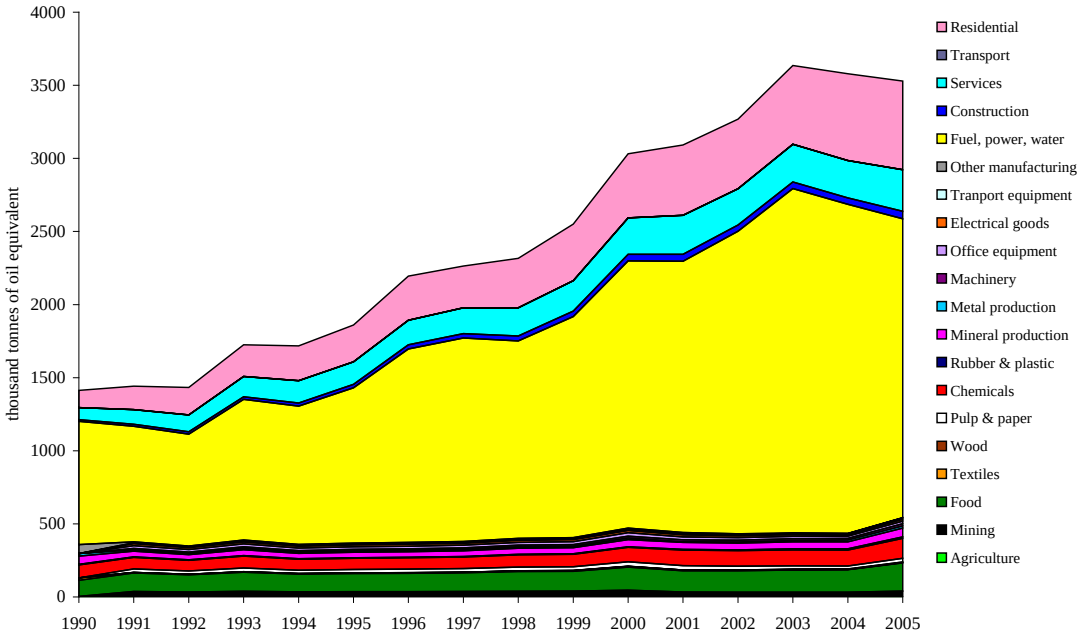

Figure 4: The composition of Irish natural gas use, 1990-2005

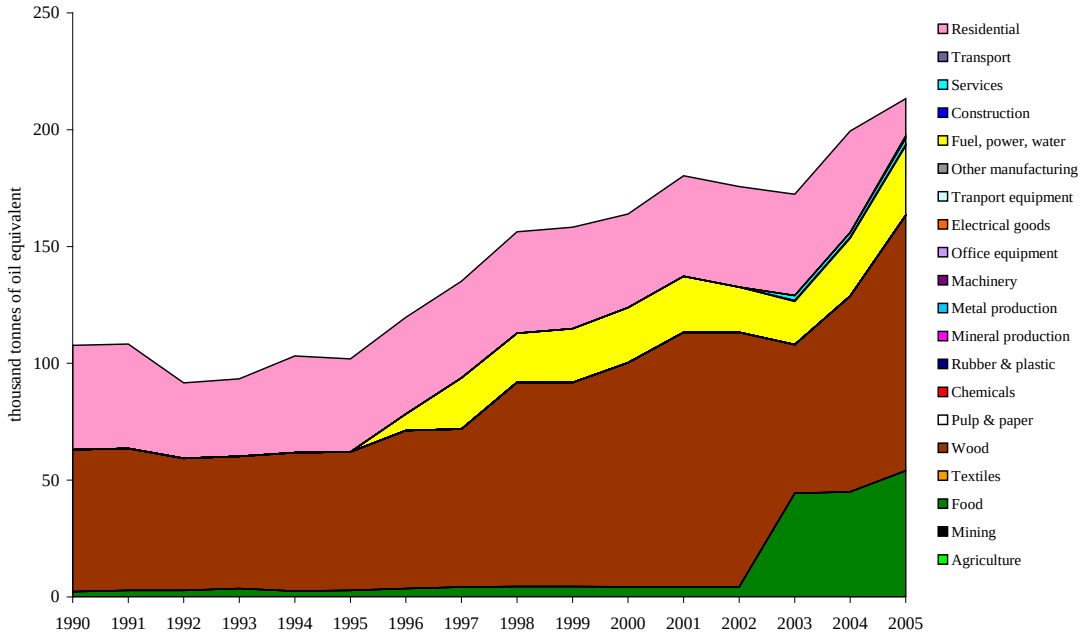

Figure 5: The composition of Irish renewable energy use, 1990-2005

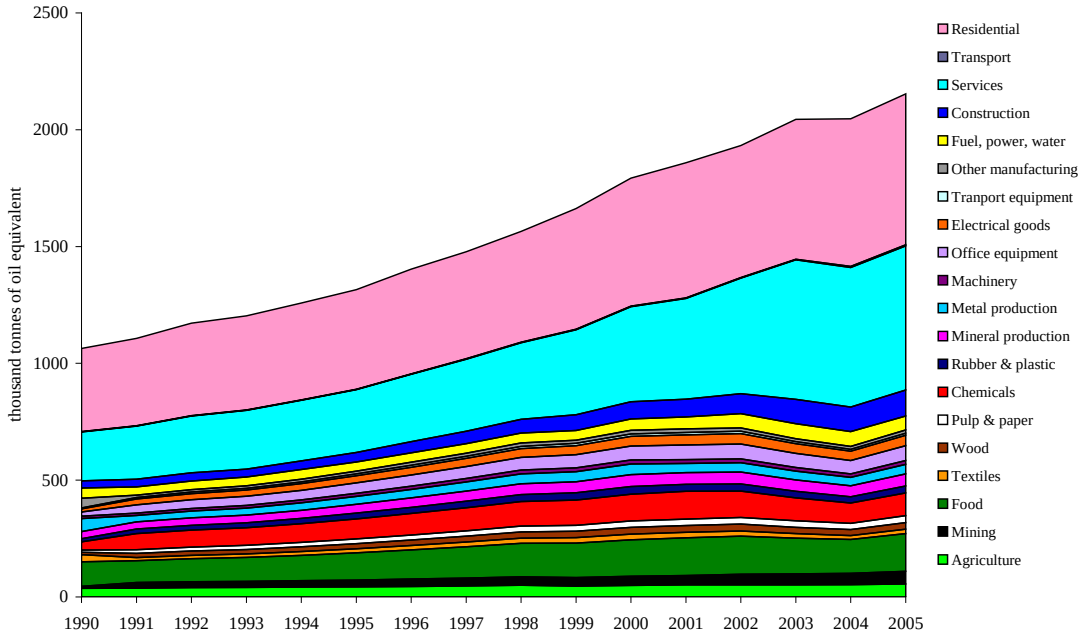

Figure 6: The composition of Irish electricity use, 1990-2005

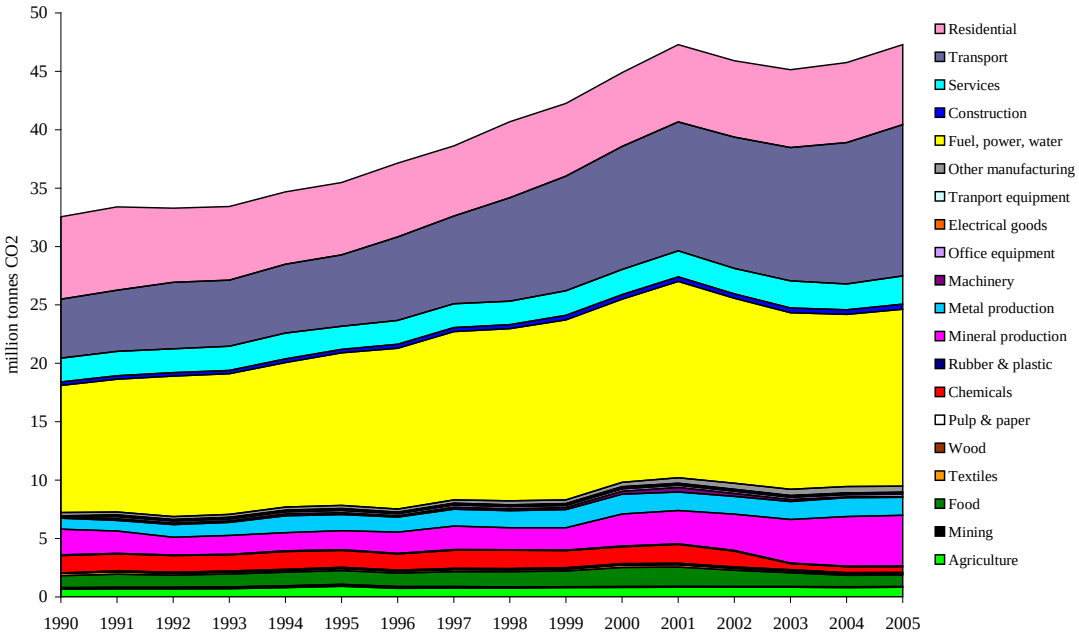

Figure 7: The composition of Irish carbon dioxide emissions, 1990-2005

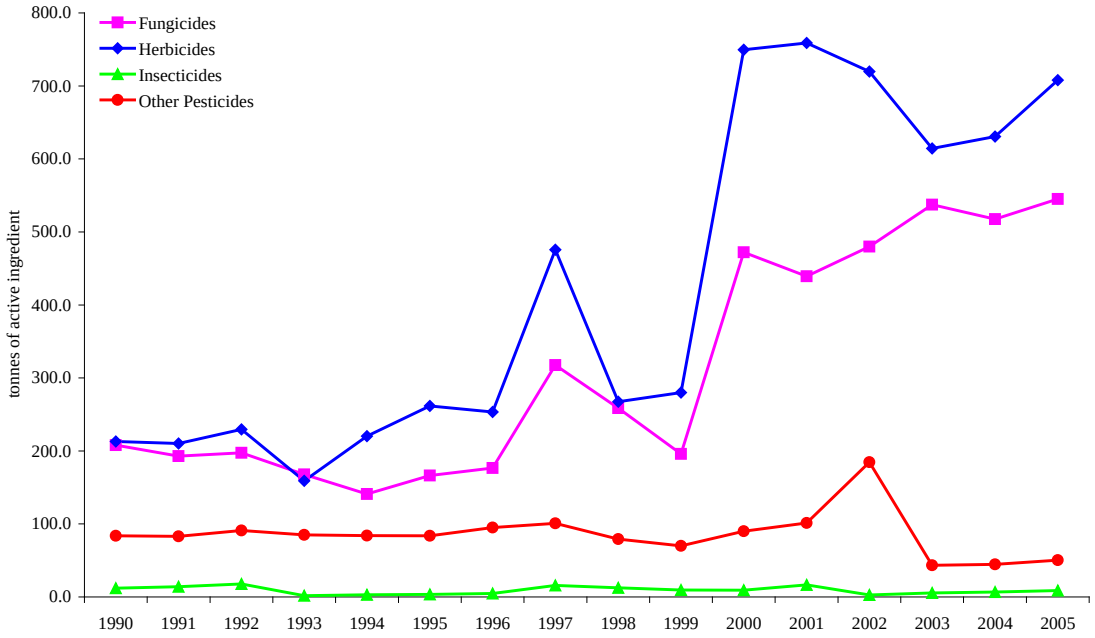

Figure 8: The use of pesticides in Ireland for 1990-2005

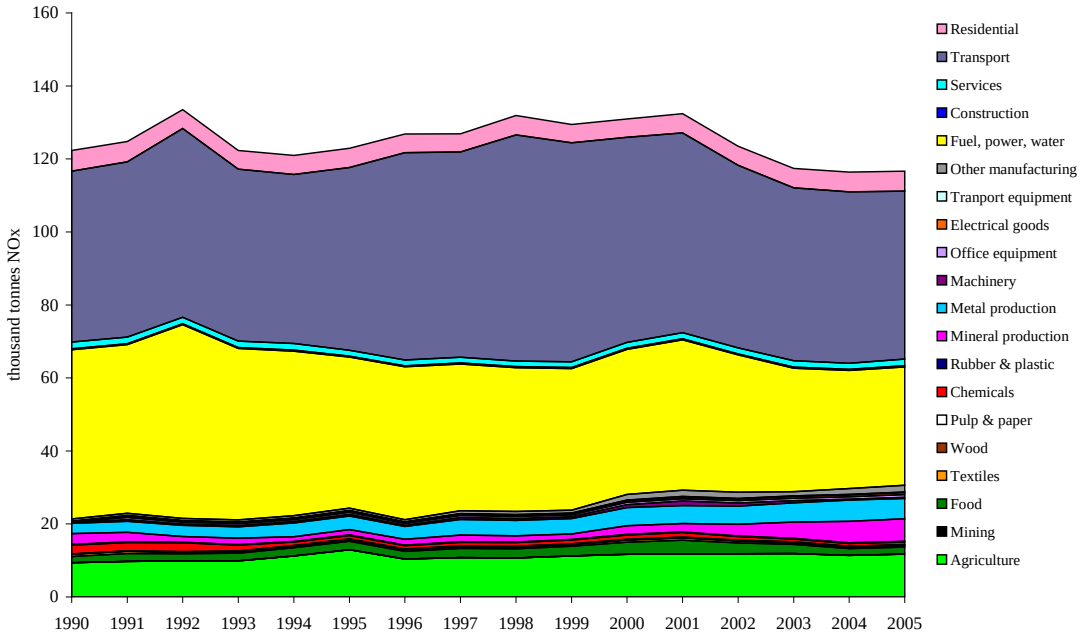

Figure 9: The composition of Irish nitrogen oxides emissions, 1990-2005

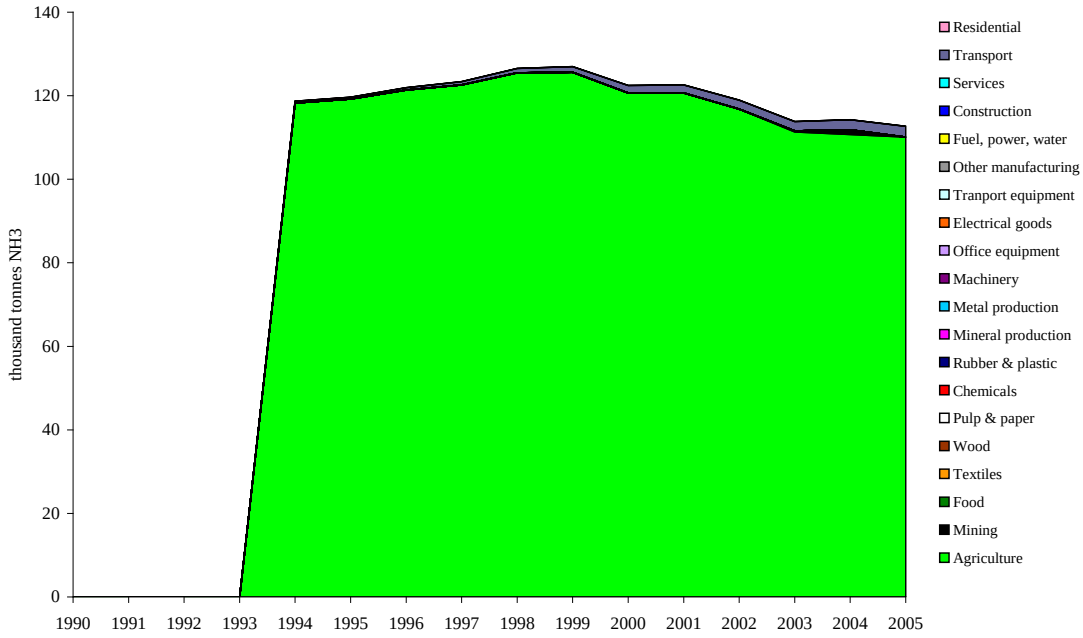

Figure 10: The composition of Irish ammonia emissions, 1994-2005

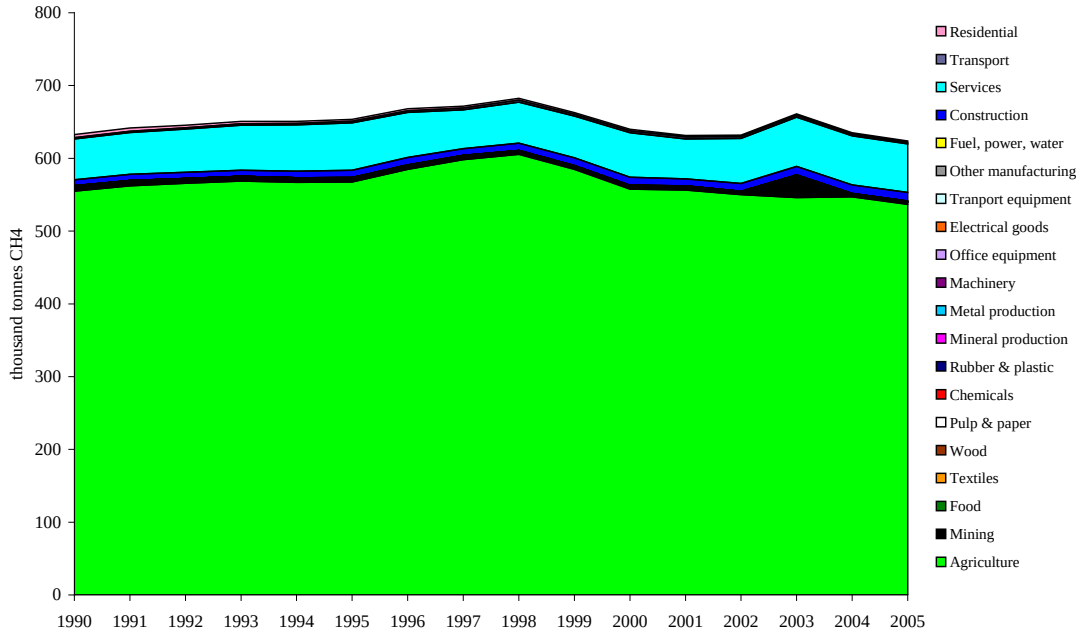

Figure 11: The composition of Irish methane emissions, 1990-2005

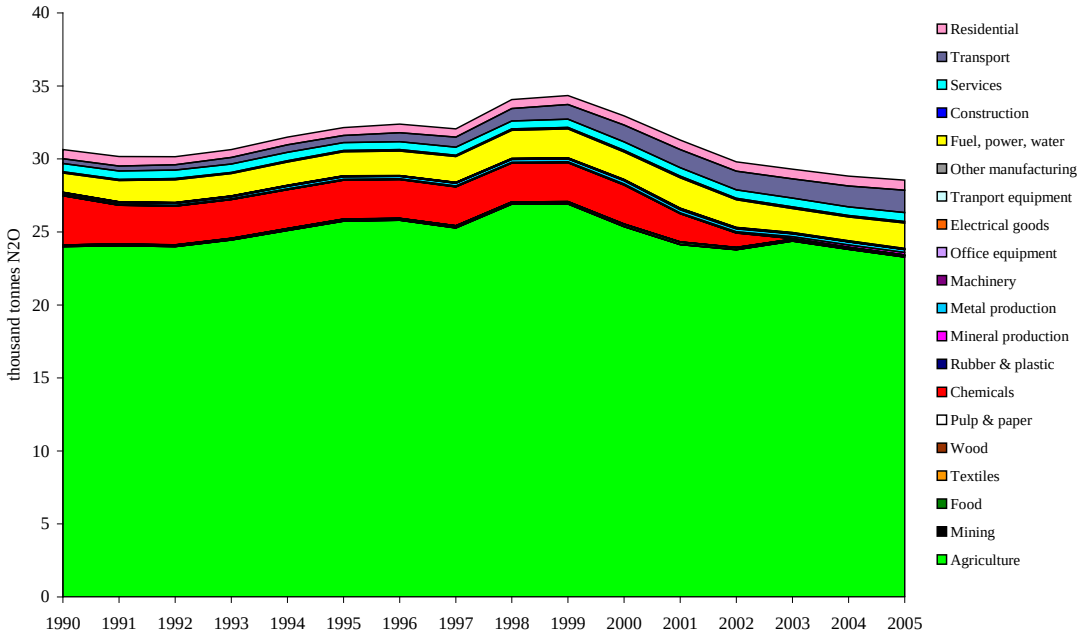

Figure 12: The composition of Irish nitrous oxide emissions, 1990-2005

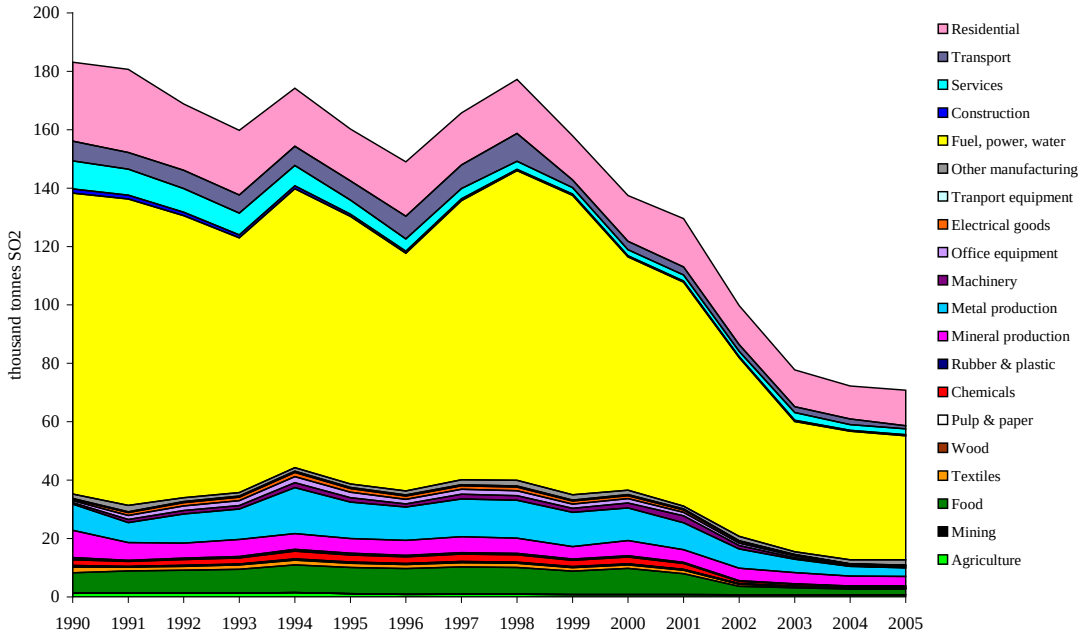

Figure 13: The composition of Irish sulphur dioxide emissions, 1990-2005

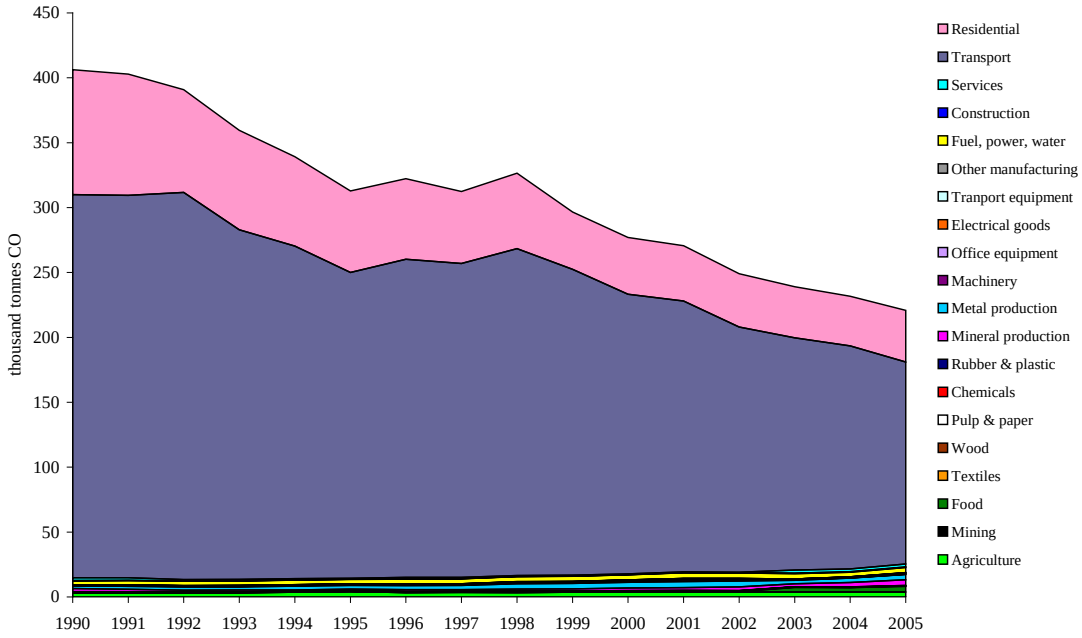

Figure 14: The composition of Irish carbon monoxide emissions, 1990-2005

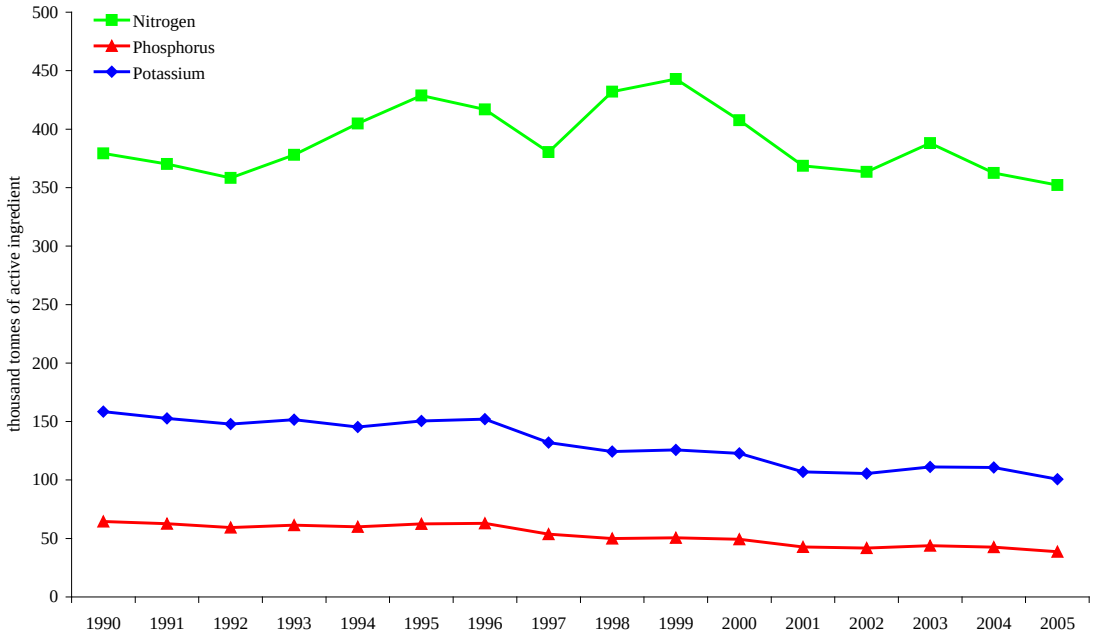

Figure 15: The use of fertilisers in Ireland for the period 1990-2005

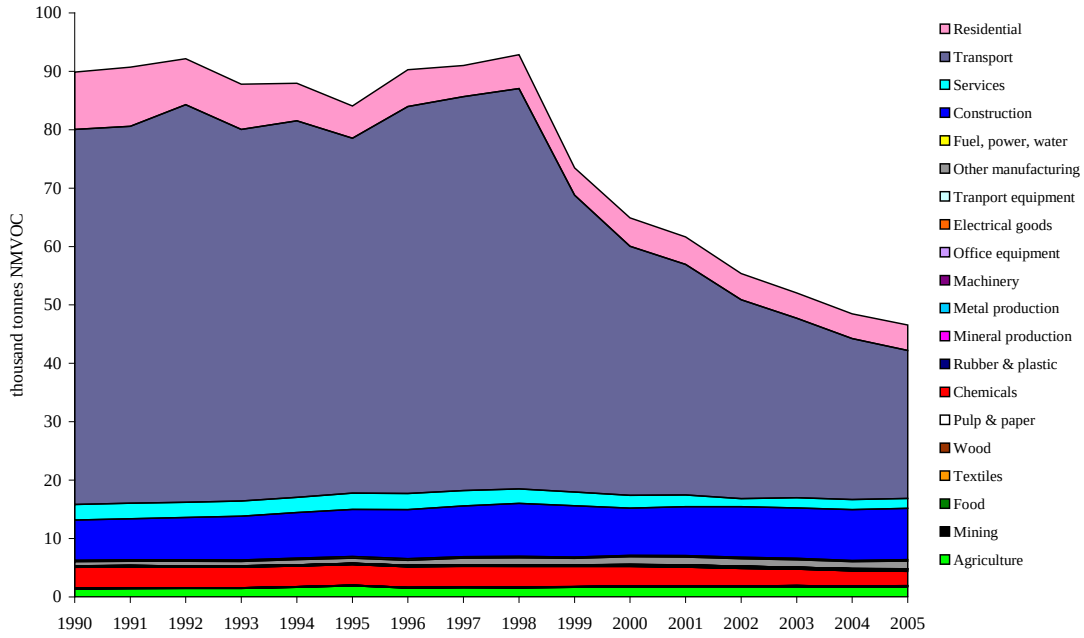

Figure 16: The composition of Irish non-methane volatile organic compound emissions, 1990-2005

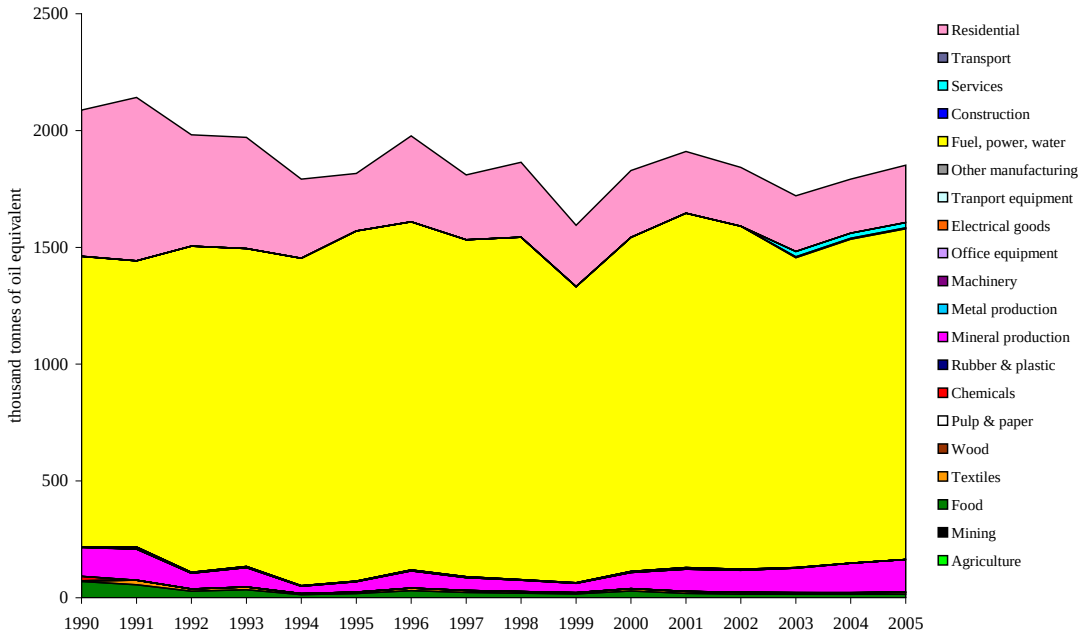

Figure 17: The composition of Irish coal use, 1990-2005

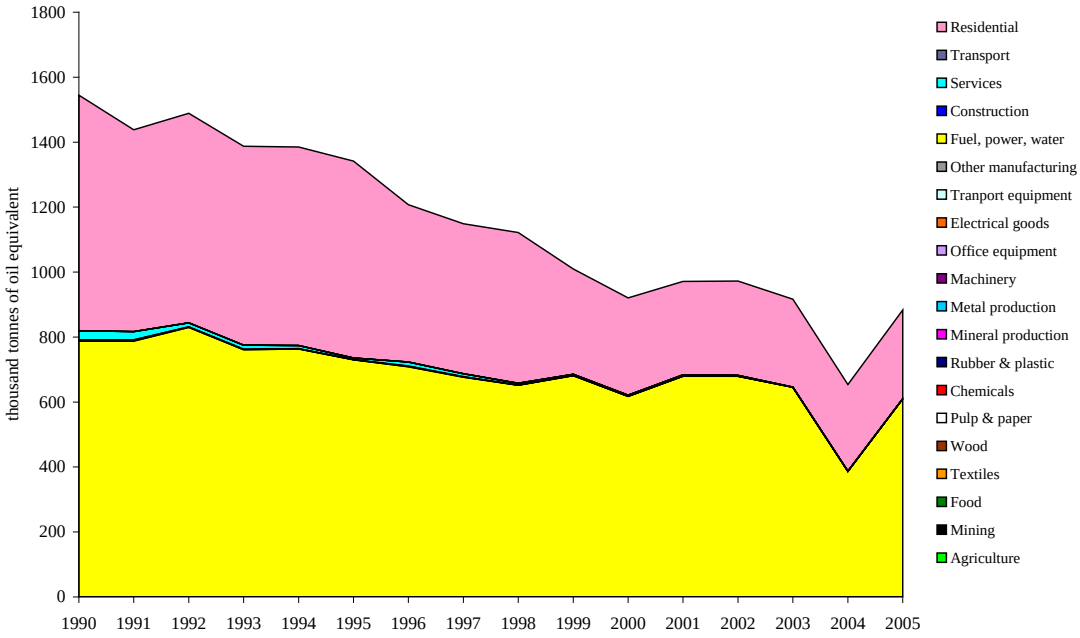

Figure 18: The composition of Irish peat use, 1990-2005

Table 4: Comparison of the environmental accounts of selected countries

Country	Emissions	Resource use	Waste	Economics	Source
Ireland	CO_2, N_2O, CH_4, SO_2, NO_x, NH_3	None	None	None	CSO (2006)
Brazil	CO_2	Energy	None	None	Lenzen and Schaeffer (2004)
China	CO_2, NO_x, SO_x, NH_3	Energy	Industrial waste	None	Ike (1999)
Japan	CO_2, N_2O, CH_4, HFCs, PFCs, CFCs, SF_6, SO_x, NO_x, NMVOC, NH_3, N, P	Energy	Industrial waste	None	Ike (1999)
Germany	CO_2, CO, SO_2, NO_x, PM, CH_4, N_2O, NMVOC	None	None	None	Tjahajdi *et al.* (1999)
Netherlands	CO_2, N_2O, CFCs, NO_x, SO_2, NH_3, P, N	Energy	Waste, wastewater	Environmental protectionexpenditures, taxes	Keuning *et al*. (1999)
Sweden	CO_2, SO_2, NO_x, NMVOC, NH_3, N, P	Energy	Industry, household, hazardous; landfilled, incinerated, recovery	Environmental protection expenditures	Hellsten *et al.* (1999)
UK	CO_2, N_2O, CFCs, HFCs, NO_x, SO_2, NH_3, black smoke, CO, NMVOC, Benzene, Lead	Energy	None	Environmental taxes	Vaze (1999)

Source: O'Doherty et al. (2007), pp. 48, Table 5.2.

Table 5: Concordance between the UNFCCC CRF and the NACE

CRF	Description	NACE	Description
1	Energy		
1A	Fuel combustion		
1A1	Energy industries		
1A1a	Public electricity and heat production	40-41	Fuel, power, water
1A1b	Petroleum refining	23,36-37	Other manufacturing
1A1c	Manufacture of solid fuels and other energy industries	23,36-37	Other manufacturing
1A2	Manufacturing industries and construction		
1A2a	Iron and steel	27	Metal production
1A2b	Non-ferrous metals	27	Metal production
1A2c	Chemicals	24	Chemical production
1A2d	Paper and print	21-22	Pulp, paper and print production
1A2e	Food processing, beverages and tobacco	15-16	Food, beverage, tobacco
1A2f	Other manufacturing	17-20,25-26,28-35	Emissions allocated on the basis of fuel use
1A3	Transport		
1A3a	Civil aviation	60-63	Transport
1A3b	Road transportation	60-63	Transport
1A3c	Railways	60-63	Transport
1A3d	Navigation	60-63	Transport
1A3e	Other transportation	60-63	Transport
1B	Fugitive emissions from fuels	10-14	Coal, peat, petroleum, metal ores, quarrying
	International bunkers		Not attributed
2	Industrial processes		
2A	Mineral products	26	Other non-metallic mineral products
2B	Chemical industry	24	Chemicals, chemical products and man-made fibres
2F	Consumption of halocarbons and SF_6	31	Electrical machinery and apparatus nec
3	Solvent and other product use	24	Chemicals, chemical products and man-made fibres
4	Agriculture	1,2,5	Agriculture, forestry, fishing
5	Land-use, land use change, and forestry		Not attributed
6	Waste	90	Sewage and refuse disposal services, sanitation and similar services

Source: http://unfccc.int/

Year	Number	Title/Author(s) ESRI Authors/Co-authors Italicised
2007	222	Assessing Vulnerability of Selected Sectors under Environmental Tax Reform: The issue of pricing power *J. Fitz Gerald,* M. Keeney and *S. Scott*
	221	Climate Policy Versus Development Aid *Richard S.J. Tol*
	220	Exports and Productivity – Comparable Evidence for 14 Countries The International Study Group on Exports and Productivity
	219	Energy-Using Appliances and Energy-Saving Features: Determinants of Ownership in Ireland *Joe O'Doherty, Seán Lyons* and *Richard S.J. Tol*
	218	The Public/Private Mix in Irish Acute Public Hospitals: Trends and Implications *Jacqueline O'Reilly* and *Miriam M. Wiley*
	217	Regret About the Timing of First Sexual Intercourse: The Role of Age and Context *Richard Layte*, Hannah McGee
	216	Determinants of Water Connection Type and Ownership of Water-Using Appliances in Ireland *Joe O'Doherty, Seán Lyons* and *Richard S.J. Tol*
	215	Unemployment – Stage or Stigma? Being Unemployed During an Economic Boom *Emer Smyth*
	214	The Value of Lost Load *Richard S.J. Tol*
	213	Adolescents' Educational Attainment and School Experiences in Contemporary Ireland *Merike Darmody, Selina McCoy, Emer Smyth*
	212	Acting Up or Opting Out? Truancy in Irish Secondary Schools *Merike Darmody, Emer Smyth* and *Selina McCoy*
	211	Where do MNEs Expand Production: Location Choices of the Pharmaceutical Industry in Europe after 1992 *Frances P. Ruane*, Xiaoheng Zhang

210 Holiday Destinations: Understanding the Travel Choices of Irish Tourists
Seán Lyons, Karen Mayor and *Richard S.J. Tol*

209 The Effectiveness of Competition Policy and the Price-Cost Margin: Evidence from Panel Data
Patrick McCloughan, *Seán Lyons* and William Batt

208 Tax Structure and Female Labour Market Participation: Evidence from Ireland
Tim Callan, A. Van Soest, *J.R. Walsh*

207 Distributional Effects of Public Education Transfers in Seven European Countries
Tim Callan, Tim Smeeding and Panos Tsakloglou

206 The Earnings of Immigrants in Ireland: Results from the 2005 EU Survey of Income and Living Conditions
Alan Barrett and *Yvonne McCarthy*

205 Convergence of Consumption Patterns During Macroeconomic Transition: A Model of Demand in Ireland and the OECD
Seán Lyons, Karen Mayor and *Richard S.J. Tol*

204 The Adoption of ICT: Firm-Level Evidence from Irish Manufacturing Industries
Stefanie Haller and *Iulia Traistaru-Siedschlag*

203 EU Enlargement and Migration: Assessing the Macroeconomic Impacts
Ray Barrell, *John Fitz Gerald* and Rebecca Riley

202 The Dynamics of Economic Vulnerability: A Comparative European Analysis
Christopher T. Whelan and *Bertrand Maître*