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National Determinants of Vegetarianism

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Abstract: In this paper we use panel data regressions to investigate the determinants of vegetarianism in various countries over time. Using national level aggregate data, we construct a panel consisting of 116 country-time observations. We find that there is a negative relationship between income and vegetarianism. In relatively poor countries, vegetarianism appears to be a necessity as opposed to a dietary choice. For the well educated however, vegetarianism is becoming a more popular lifestyle choice. Results also suggest that in relatively poor countries local production of meat increases consumption of meat. This is the first paper to examine national level determinants of vegetarianism.

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National Determinants of Vegetarianism

1. Introduction

Vegetarianism is increasing in the western world. Anecdotally, this is attributed to concerns about animal welfare, health and the environment. However, in relatively poor countries, where populations are large, the opposite is the case. Global meat consumption increased by 250% between 1960 and 2002 (World Resources Institute (WRI), 2009). This is partly due to the increase in pasture land of 10% and the doubling of the world population during this period (WRI, 2009). The role played by red meat in global environmental change has been highlighted (Food and Agriculture Organization of the United Nations (FAO), 2006), however, scope for reducing methane emissions by technical measures is limited (DeAngelo et al., 2006). This implies that a reduction in herd sizes is needed for cutting emissions and thus, diets will have to change.

Research into average diets has been extensive. The factors affecting meat consumption have been studied at a micro level, for example in Ireland by Newman et al. (2001), in the USA by Nayga (1995), in the UK by Burton et al. (1994), in Japan by Chern et al. (2002) and in Mexico by Gould et al. (2002), however, no attempts have been made to explain the determinants of vegetarianism. Existing literature instead tends to focus on the health effects of following a meat free diet.

As far as we know, this is the first paper to explain the determinants of vegetarianism. An understanding of the factors driving vegetarianism will be of benefit to those forecasting future numbers of vegetarians and emissions from livestock.

The paper continues as follows. Section 2 presents the data and Section 3 the methodology. Section 4 presents the results and Section 5 provides a discussion and conclusion.

2. Data

We assembled a dataset that was intended to capture as wide a set of countries over as long a period of time as possible. Our final dataset is an unbalanced panel containing 116 country-time bservations. As one would expect, there are pronounced differences in the level of vegetarianism across the set of countries we analyse. The amount of data also varies by country. For the UK, for example, we have estimates of the

number of vegetarians for 41 years. For other countries however, only one observation is available. Table 1 shows the years and countries for which we have data as well as the corresponding percentage of vegetarians.

We count the number of vegetarians in the following manner. See Appendix for further detail. We use surveys of households' budgets, expenditures, and living standards for 21 countries, which together represent over half of the world population. We have surveys covering more than one year for many of these countries, so that we have a total of 116 samples. The average sample size is 4,876. Our database thus contains almost 566,000 observations. The surveys typically record purchases, gifts and subsistence production of food per item over a two week period. We excluded households that acquired an unusually small amount of food (compared to their peer group) in the sample period. This is particularly prevalent in the USA, where many households appear to buy groceries less than once per fortnight.

The number of households that do not consume any meat is easily identified. We refer to these as all-vegetarian households. Mixed households are harder to identify. Using the consumption patterns of one-person households and the estimated economies-of-scale of food consumption, we conditionally predict the share of meat in total food consumption for multi-person households given the number of vegetarians. We then use the observed meat share to test the hypotheses that there are one, two, … vegetarians in the household. We impute the number of vegetarians from the first rejection. That is, if the hypothesis is rejected that there is (are) one (two, three) vegetarian(s), we impute zero (one, two) vegetarians.

[Table 1 about here]

In order to gather the required national level explanatory variables we must look to a variety of sources. Some of the variables we would like to include in our model vary substantially over time while others remain constant.

Time-varying variables.

It is important to account for national income levels. For the very poor, intake of animal protein is limited (Mueller and Krawinkel, 2005) but as people grow richer, meat consumption, whether measured in calories (Popkin, 2001) or expenditures (Reimer and Hertel, 2001) increases. On the other hand, excessive meat consumption

is a health concern at middle and high income levels (Giovannucci et al., 1994, Drewnowski and Specter, 2004, Hu et al., 2000, Rose et al., 1986 and James et al., 1997). Income per capita data is taken from WRI (2009). The variable we use is the log of Gross Domestic Product (GDP) per capita in American dollars at 1995 levels adjusted for purchasing power parity (PPP). We log this variable as we expect the income schedule to be non linear. We also include the squared term of this variable.

The relationship between education and diet is well established (Turrell and Kavanagh, 2006), Galobardes et al., 2001). The relatively well educated are more likely to adopt healthy eating habits and they may also be better informed about the environmental implications of dietary choices. In this paper, we control for the second level gross enrolment ratio (GER). The GER is defined by Unesco (2009) as "the total enrolment in a specific level of education, regardless of age, expressed as a percentage of the eligible official school-age population corresponding to the same level of education in a given school year." Data for second level GERs are taken from Unesco (2009), WRI, (2009), World Bank (2001) and World Bank (2006). In some instances, the GER for second level education exceeds 100. This happens when the proportion of adults returning to education is high.

We also model the GER for tertiary education to see if its impact on vegetarianism is different to that of second level education. In order to gather a complete list of tertiary GERs for each country-time observation in our analysis we take data from various sources including the World Bank (2009a) WRI (2009) and World Bank (2006).

Supply conditions may affect consumption of meat too. We have less data on supply than on consumer characteristics, but we have data for a supply proxy: the log of meat production per capita, measured in kilograms. We assume that in countries where meat is easily accessible, consumption will be higher; reverse causality is of course possible. Data for this variable are taken from WRI (2009).

Constant variables

We expect that the demand for meat is a function of its own price and the price of alternatives. If the price of meat is low relative to alternatives, demand for meat should be high and vice versa. Using International Comparison Program (ICP) 2005 data, which is available from the World Bank (2009b) we find the PPP price of meat for all countries included in our analysis relative to the USA in 2005 (i.e. the price of meat in the USA is given as 1). We do the same for all nonmeat items. Then we find

actual prices of meat and non meat items in the USA in 1988 (United States Department of Agriculture (USDA), 1994) and convert these to 2005 prices. Once we have the actual ratio of meat to nonmeat items in the USA we can derive same for all other countries included in our analysis. Due to data limitations, we assume that the relative price of meat to nonmeat items is constant over time. Figure A1 displays the relationship between the relative price of meat to non meat items and vegetarianism. Where the relative price of meat to non meat items is below 2, the level of vegetarianism varies largely. Where the relative price of meat to non meat items increases from 2 to 2.5, the level of vegetarianism also increases sharply for the countries included in our sample.

Religion and diet are closely linked in some places. In India, where over 85% of the population are Hindu, the level of vegetarianism exceeds 34%. While not all Hindus are vegetarian, the level of Hinduism may still be an important predictor of vegetarianism. We have data on the percentage of Hindus in each country in our analysis and we assume that this does not change over time. Figure A2, however, shows that there is no discerning relationship between Hinduism and vegetarianism.

We noted earlier that average income may affect the incidence of vegetarianism, but income distribution could be a factor too. We use the Gini coefficient as a measure of each country's level of inequality. It varies between 0, which reflects complete equality and 1, which indicates complete inequality. The World Development Indicators (WDI) 2006 data, which is available from the World Bank website, provides Gini coefficients for each country. However, a graphical representation of the relationship between inequality and vegetarianism shows that no clear pattern exists (See Figure A3).

We would also like to take account of cultural differences in our model. Hofstede (2001) argues that the 5 cultural dimensions; individualism, uncertainty avoidance, power distance, masculinity and long term orientation should be included in any study that involves cross cultural comparisons because the 5 dimensions will capture country specific characteristics which affect peoples' thoughts, feelings and actions. Data for 19 of the countries included in our analysis are available from Hofstede (2009).

Finally, we wanted to include a proxy for the importance people place on the environment, in case such attitudes have a specific effect on the likelihood of being

vegetarian. The World Values Survey 2005[1] allows us to observe the percentage of respondents in each country that believe that environmental protection is more important than economic growth. The higher the score, the more importance respondents place on the environment. This data is available for 15 of the 21 countries included in our analysis (World Values Survey, 2009). Figure A4 shows that the level of vegetarianism varies a lot in countries with a score of 0.6 or lower. For countries with a score of 0.6, of which there are many in our sample, the level of vegetarianism tends to be low and fairly stable.

As discussed the next section, the nature of our econometric model permits the inclusion of time-varying variables only.

3. Model

We estimate a panel regression model specified as follows:

$$V_{it} = B_0 + B_1 loggdp_{it} + B_2 loggdp\_sq_{it} + B_3 edlevel2_{it} + B_4 logmeatprod_{it} + u_{it} + e_{it}$$

where the dependent variable, V_{it}, is the percentage of vegetarians in each country, i, at time t. $loggdp_{it}$ is the log of GDP per capita adjusted for PPP, and $loggdp\_sq_{it}$ is its square. $edlevel2_{it}$ is the GER for second level education and $logmeatprod_{it}$ is the log of meat production per capita in country i at time t. There is a country specific effect (u_{it}) and an error term, e_{it}, which is specified as a classical disturbance term.

Upon inspection, we found that this model exhibits a substantial degree of serial correlation. In order to overcome this, we re-estimated it using a first differences estimator. This method involves the subtraction of observations in the previous period from those in the current period. Thus, the resulting model includes only those variables which vary over time, and it eliminates the country fixed effects. The dependent variable is now the first difference in the percentage of vegetarians and explanatory variables include first differences in the log of PPP GDP per capita, the second level GER and the log of meat production per capita. Using a differenced OLS regression model, our observations are reduced to 97.

We also estimate variations of the above model, one of which includes the replacement of the second level education variable with the GER for tertiary

[1] Sample sizes vary by country. Most samples are representative of the population. Any non representative samples are weighted accordingly.

education. Another variation involves the investigation of the impact of meat exports per capita on vegetarianism as opposed to that of meat production. We also divide our sample in two, based on the median level of GDP per capita, in order to establish whether the effect of income on vegetarianism differs in relatively poor and relatively rich countries.

A list of the variables included in the models and some descriptive statistics on them are set out in Table 2.

[Table 2 about here]

4. Results

The results of our main first differences model are displayed in table 3. Due to the presence of heteroskedasticity, we report robust standard errors. D_ indicates that all variables have been differenced.

[Table 3 about here]

As expected, the coefficient on the log of PPP GDP per capita is statistically significant. The negative coefficient indicates that the higher the level of income in a country, the lower the level of vegetarianism, which is consistent with the literature. The coefficient on the square of the log of PPP GDP per capita is positive and significant. This indicates the presence of a Kuznets type relationship between income and vegetarianism. The positive coefficient on the education variable indicates that as more people in a country are enrolled in second level education, the level of vegetarianism can be expected to increase. This is consistent with our expectation that the relatively well educated may adjust their meat consumption based on animal, health or environmental concerns. The coefficient on the log of meat production is negative, indicating that the level of vegetarianism is lower in countries where meat production is high. However, this variable is not statistically significant, indicating that the negative relationship between meat production and consumption is not robust.

4.1 Variations

As our meat production variable is not a significant predictor of vegetarianism we instead model the impact of meat exports. The results of this model are displayed in

table 4. In this model the income and education variables remain statistically significant. Interestingly, however, the signs of coefficients on both income terms have reversed. This implies that as income increases so too does the level of vegetarianism in a country, but at a decreasing rate. The sign on the log of exports per capita indicates that as more meat is exported, the number of vegetarians decreases significantly. This can be explained by the fact that meat exports are likely to be high where meat production is high. Although the inclusion of the meat exports variable instead of the meat production variable increases the explanatory power of our model, it appears that the meat exports variable is picking up some of the income effect. It is not intuitive that vegetarianism increases with income for the countries included in our sample.

[Table 4 about here]

In an attempt to see if GDP per capita affects vegetarianism differently in poor and rich countries we split the sample based on the median level of PPP GDP per capita. The results of these models are set out in table 5.

Where PPP GDP per capita is lower than the median level, an increase in income will significantly reduce the number of vegetarians as more people can afford to buy meat. The coefficient on the square of the log of PPP GDP per capita is positive as is the case in the main model. As more people obtain second level education in relatively poor countries, the number of vegetarians significantly decreases as people are better able to choose alternatives based on health or environmental concerns. This is the only model in which the meat production variable is significant. The negative coefficient indicates that as meat production increases, vegetarianism falls. When we examine relatively rich countries in isolation, however, none of the explanatory variables in our model prove to be significant predictors of vegetarianism.

[Table 5 about here]

We also investigate whether the impact of tertiary education on vegetarianism differs to that of second level education. While the tertiary education variable is still significant and positively associated with vegetarianism, its inclusion reduces the

significance of both income terms. Also, the explanatory power of the model is reduced from over 61% to almost 40%.[2]

Discussion and Conclusion

In this paper we have shown that national levels of vegetarianism are significantly affected by both the income level and education levels in a country. As income increases, the level of vegetarianism falls indicating that if people can afford to buy meat they will. In other words, in countries where GDP is relatively low, people are vegetarians due to necessity. When we examine only those countries whose GDP is higher than the median level of GDP in our sample, we find that income is not significant. Thus, in these countries people choose to be vegetarians for reasons other than financial ones. Results also show that in countries where people are relatively well educated, levels of vegetarianism are seen to be higher. This can be partly explained by the growing concern over the level of environmental damage caused by meat consumption and production, which may be more prevalent amongst the well educated. Other reasons may be that the better educated are more aware of the health benefits of following a meat free diet. As enrolment in both secondary and tertiary education appears to be increasing over time the level of vegetarianism is expected to rise. However this increase will be counteracted by increasing income levels in less developed countries. Combined with growing populations, the demand for meat is set to rise. As a result, environmental damage from meat production will worsen. We also find that in countries where meat exports are high, vegetarianism is low. This probably reflects a correlation between meat production and preferences for meat consumption, but we do not have enough data to tease out the exact causation.

On the whole, it seems likely that the negative association between vegetarianism and income will dominate globally in the medium term, and the incidence of vegetarianism will fall. It is only when national income levels increase beyond a certain level and higher levels of education become widespread that we might expect global vegetarianism to increase.

[2] We have not included a table outlining the detailed results of this model. However, it can be made available upon request from the authors.

Tables

Table 1. % of vegetarians by year and country

Year	Country	% vegetarians
2005	Albania	7.8%
1995	Azerbaijan	22.6%
1997	Brazil	3.6%
2001	Bulgaria	2.9%
2003	Bulgaria	3.1%
2001	East Timor	49.1%
1979	France	1%
1985	France	1.4%
1995	France	0.9%
2001	France	1.5%
2005	France	1.9%
2000	Guatemala	1.4%
1998	India	34.4%
1987	Ireland	0.3%
1994	Ireland	0.5%
1999	Ireland	0.4%
2004	Ireland	0.6%
1985	Ivory Coast	10.8%
1986	Ivory Coast	13%
1987	Ivory Coast	16.8%
1988	Ivory Coast	20.3%
1988	Jamaica	3.7%
1989	Jamaica	2.7%
1990	Jamaica	3.3%
1991	Jamaica	2%
1992	Jamaica	1.6%
1993	Jamaica	1%
1994	Jamaica	1.7%
1995	Jamaica	1.2%
1996	Jamaica	1.6%
1997	Jamaica	1.7%
1998	Jamaica	1.4%
1999	Jamaica	1.5%
2000	Jamaica	1.6%
2001	Jamaica	1.7%
2002	Jamaica	2.1%
2003	Jamaica	3.7%
2004	Jamaica	2.1%
2005	Jamaica	2.5%
1993	Kyrgyzstan	39.8%
1996	Nepal	8.1%
2004	Nepal	6.6%
1985	Peru	41.8%
1992	Russian Federation	22.2%
1993	Russian Federation	24.7%
1994	Russian Federation	25.4%
2000	Russian Federation	22.3%
2001	Russian Federation	17.3%
2002	Russian Federation	12.6%
1993	South Africa	5.9%
1999	Tajikistan	48%
2003	Tajikistan	49.5%
1993	Tanzania	15.9%
1961	UK	0.3%
1962	UK	0.3%
1963	UK	0.3%
1968	UK	0.3%
1969	UK	0.2%
1970	UK	0.3%
1971	UK	0.5%
1972	UK	0.0%
1973	UK	0.0%
1974	UK	1%
1975	UK	1.1%
1976	UK	0.7%
1977	UK	0.8%

Year	Country	% vegetarians
1978	UK	0.9%
1979	UK	1.2%
1980	UK	1.2%
1981	UK	0.9%
1982	UK	1.1%
1983	UK	1.1%
1984	UK	1.1%
1985	UK	1.1%
1986	UK	1.5%
1987	UK	1.8%
1988	UK	1.6%
1989	UK	1.6%
1990	UK	1.8%
1991	UK	1.7%
1992	UK	1.9%
1993	UK	1.9%
1994	UK	1.9%
1995	UK	2%
1996	UK	1.7%
1997	UK	1.7%
1998	UK	1.7%
1999	UK	1.6%
2000	UK	1.6%
2001	UK	2%
2002	UK	2%

Year	Country	% vegetarians
2003	UK	2%
2004	UK	2%
2005	UK	3%
1980	USA	2%
1981	USA	2%
1990	USA	2.9%
1991	USA	3.2%
1992	USA	3.3%
1993	USA	3.2%
1994	USA	2.8%
1995	USA	2.6%
1996	USA	3.5%
1997	USA	3.8%
1998	USA	3.9%
1999	USA	4.3%
2000	USA	3.9%
2001	USA	3.3%
2002	USA	3.8%
2003	USA	3.5%
2004	USA	3.8%
2005	USA	5%
1992	Viet Nam	1.5%
1998	Viet Nam	3%
2002	Viet Nam	0.3%
2004	Viet Nam	1%

Table 2. Descriptive Statistics

Variable	Description	Mean	Std. Dev.	Min	Max
v	% of vegetarians	0.06	0.11	0	0.5
loggdp	Log of PPP GDP per capita	9.13	1.05	6.19	10.54
loggdp_sq	Square of the log of PPP GDP per capita	84.43	18.43	38.32	111.06
edlevel2	GER 2nd level education	82.82	24.38	5.3	134
tertiary	GER Tertiary education	34.77	25.45	0	82
logXpercap	Log of meat exports per capita in $	1.51	2.22	-6.07	6.17
logmeatprod	Log of meat production per capita in kgs	3.86	0.81	1.54	5.69
pricemeat	The price of meat to non meat items	1.88	0.36	0.94	2.58
gini	The Gini coefficient	37.8	5.11	19	58
hindu	The % of Hindus	2.58	13.02	0	85
pdi	Power distance	42.29	12.16	28	95
idv	Individualism	73.23	23.79	6	91
mas	Masculinity	62.78	7.92	37	68
uai	Uncertainty avoidance	38.75	19.9	13	101
lto	Long term orientation	27.43	6.86	25	65
protectenv	Concern for the environment	0.58	0.05	0.28	0.66

Table 3. Differenced OLS regression results: main model

	Coef.	**Robust Std. Err.**	**t**	**P>|t|**
d_loggdp	-1.56	0.403***	-3.86	0
d_loggdp_sq	0.09	0.024***	3.77	0
d_edlevel2	0.01	0.002***	3.67	0
d_logmeatprod	-0.08	0.055	-1.42	0.16
Constant	-0.01	0.007	-1.68	0.10
Observations	97			
F (4, 92)	7.67			
Prob>F	0			
R-squared	0.62			
Root MSE	0.07			

Table 4. Differenced OLS regression using exports per capita

	Coef.	**Robust Std. Err.**	**t**	**P>|t|**
d_loggdp	0.30	0.074***	4	0.000
d_loggdp_sq	-0.01	0.004***	-3.59	0.001
d_edlevel2	0	0**	2.12	0.037
d_logXpercap	-0.02	0.003***	-7.2	0.000
Constant	0	0.001	2.74	0.008
Observations	81			
F (4, 76)	15.58			
Prob>F	0			
R-squared	0.77			
Root MSE	0.01			

Table 5. Differenced OLS regression results for split samples

Below Median GDP				
	Coef.	**Robust Std. Err.**	**t**	**P>|t|**
d_loggdp	-1.86	0.354***	-5.25	0
d_loggdp_sq	0.11	0.021***	5.04	0
d_edlevel2	0.01	0.002***	4.99	0
d_logmeatp~d	-0.09	0.047*	-1.85	0.07
Constant	-0.01	0.012	-1.11	0.27
Observations	41			
F (4, 36)	15.23			
Prob>F	0			
R-squared	0.77			
Root MSE	0.08			
Above Median GDP				
	Coef.	**Robust Std. Err.**	**t**	**P>|t|**
d_loggdp	0.02	0.105	0.23	0.82
d_loggdp_sq	0	0.005	-0.22	0.82
d_edlevel2	0	0	-0.09	0.93
d_logmeatp~d	-0.01	0.006	-0.87	0.39
Constant	0	0.001	2.47	0.02
Observations	56			
F (4, 49)	0.26			
Prob>F	0.90			
R-squared	0.01			
Root MSE	0			

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Appendix

Data

Household expenditure surveys provide a detailed account of all of the expenditures incurred by a large sample of individual households over a specified time period. Household expenditure surveys have a similar structure across countries. Often, these datasets also provide information on household income and other socio-economic variables. Most of the datasets used in this paper are from the Living Standard Measurement Studies (LSMS), which are available from the World Bank website (World Bank, 2009c). We used these data to estimate levels of vegetarianism in Albania, Azerbaijan, Brazil, Bulgaria, East Timor, Guatemala, India, Ivory Coast, Kyrgyzstan, Peru, South Africa, Tajikistan and Tanzania. The remaining data were obtained from statistical offices in individual countries. Data for the U.S.A (U.S. Department of Labor, 2009), Russia (Carolina Population Centre, 2009), Nepal (Central Bureau of Statistics, 2009), Ireland (Central Statistics Office Ireland, 2009), Vietnam (General Statistics Office of Vietnam, 2009), France (Institut National de la Statistique et des Études Économiques, 2009), the UK (Office for National Statistics, 2009a and 2009b) and Jamaica (Statistical Institute of Jamaica, 2009) were obtained in this manner.

Where available, we used data on all meat consumed in the household, be it from purchases, home production, gifts or in-kind payments. For other countries, only data on meat expenditures were available. Table A1 indicates which measure was used in each case. Where possible we used household disposable income. However, on some occasions net or gross income had to be used. Where available, the value of income received in kind was included in the income variable. For some countries, income was not available or was inconsistent with reported levels of expenditure. In such instances, total household expenditure was used as a proxy for income. Table A1 specifies which income measure was used. In almost all cases the total household food consumption variable was composed of all food bought for home consumption by the household. Food purchases which occurred while eating out, in cafes and restaurants for example, were excluded because we were not able to determine what proportion of this consumption related to meat products. Purchases of alcohol, cigarettes and tobacco were also excluded but non-alcoholic beverages were included.

Infrequency of purchase

Expenditures are normally recorded in a diary for a specified period. For surveys with a short diary period, individual households' responses may not always reflect their "normal" purchasing patterns with respect to individual goods or categories of goods. We filter the data to exclude observations where infrequency of purchase is likely to have led to an unrepresentative expenditure pattern in the period surveyed. That is, we exclude from the analysis all those households that appeared to have not purchased enough food, relative to income and household size in the defined period. We do this by estimating food share *F,* which is the share of food consumption (or expenditure) as a percentage of income (or total expenditure) for every household in the sample:

$$(1)\quad F_j = \frac{C_j \big/ N_j^d}{Y_j^q}$$

where C denotes total food consumption of household j; N number of people in household j (raised to the power d); and Y income of household j (raised to the power q). We thus control for the number of people in the household as well as for economies of scale in household consumption through the equivalization factor d. Income is also equivalized using the elasticity q. The income elasticity for food varies between 0.2 and 0.4 for the countries in the sample; small changes in q have little impact on results. So, we set q = 0.3. We then find the mean and the standard deviation of food share F for each income decile in each country. Any household whose food share is less than the average minus the standard deviation for the relevant income decile is omitted from the analysis.

There is another adjustment required for United States data. The Consumer Expenditure Survey (CES), which is the microdata we use for the USA, is carried out on an annual basis and asks respondents to list all food items purchased over a weekly period. The majority of households stay in the sample for two weeks. We found that the number of zero observations on food expenditures was much higher in the CES than was the case for other countries. We use 18 years of cross sectional data and this pattern appeared throughout. As a result, we applied another measure to identify those households that did not shop frequently enough for us to include them in the analysis. One of the CES data files had already amalgamated food products into different categories. We further reduced the number of categories to leave nine food groups in total. These are cereal and bakery products, meat products, fish products, eggs, milk

and dairy products, processed fruit and vegetables, fresh fruit and vegetables, sweets, non-alcoholic beverages and miscellaneous food and oils. If households reported zero expenditures in six or more of these food groups we omitted them. We also omitted those households that reported expenditures for one week only. The remaining samples for the USA consisted of 5,122 households per annum on average.

Mixed households

Where there are two or more residents and the household reports some level of meat consumption, we estimate the probabilities that there are different numbers of vegetarians in that household. We refer to these as mixed households because they can contain both vegetarians and meat eaters. Since the expenditure data we are using is recorded on a household rather than on an individual basis, we derive expected meat and non-meat consumption based on equivalised income and number of members for all possible combinations of vegetarians and non-vegetarians in the household. The predicted share of meat in total food consumption, conditional on the household structure, is then compared to the observed meat share. We then sequentially test the hypotheses that there are 0, 1, 2, … vegetarians; and impute the lowest number that is not rejected.

Divide total food expenditure C_i for person i into three components: consumption of non-meat items if the person is a vegetarian C^{vv}, consumption of non-meat items if the person is a meat-eater C^{vm}, and consumption of meat items if the person eats meat C^{mm}:

$$C_i \equiv C_i^{vv} + C_i^{vm} + C_i^{mm} \tag{2}$$

Segment the population into two types, vegetarian (v_i=1) and non-vegetarian (v_i=0).

Now assume that all persons of a given type (vegetarian or non-vegetarian) have homogeneous demand for each component of food. Food demand is a fixed sum per person scaled by the level of household income per capita, using an equivalisation factor that accounts for economies of scale in household consumption. This specifies the following:

$$C_i^{vv} = W_i \left(\frac{Y_j}{N_j^d} \right)^q \; i \in j \tag{3a}$$

$$C_i^{vm} = V_i \left(\frac{Y_j}{N_j^d} \right)^r \; i \in j \tag{3b}$$

(3c) $$C_i^{mm} = M_i \left(\frac{Y_j}{N_j^d} \right)^s \; i \in j$$

where Y is household disposable income of household j and q, r and s are the elasticities of demand with respect to equivalised income for the relevant food types. N is the number of persons in the household and $0<d\leq 1$ is the equivalisation factor. W, V and M are per capita expenditures on the relevant food types by those who consume them.

By restricting the sample of households examined, we can obtain regression equations that allow us to recover the values of the structural parameters d, q, r, s, W, X and Y.

First consider single-person vegetarian households, which would allow one to estimate W and q:

(4a) $$C_i^T = W_i Y_j^q \quad \forall \; v_i = 1, \; N_j = 1$$

Taking logs of both sides yields an equation that can be estimated with OLS regression:

(4b) $$\ln C_i^T = \ln W_i + q \ln Y_j \quad \forall \; v_i = 1, \; N_j = 1$$

One can get more general results of these parameters (plus an estimate of d) using data on vegetarian households of all sizes:

(5a) $$C_i^T = N_j^d W_i \left(\frac{Y_j}{N_j^d} \right)^q \Leftrightarrow \ln C_i^T = \ln W_i + q \ln Y_j + d\left(1-q\right) \ln N_j \; \forall \; v_i = 1, \; N_j \geq 1$$

Equation (5a) is estimated as

(5b) $$\ln C_i^T = a + q \ln Y_j + b \ln N_j \Rightarrow \ln W_i = \hat{a}; \hat{d} = \frac{\hat{b}}{1-\hat{q}}$$

The standard deviation of d is estimated by developing the first order Taylor approximation around the estimated parameter

(6) $$d = \frac{b}{1-q} \approx \frac{\hat{b}}{1-\hat{q}} + \frac{1}{1-\hat{q}}\left(b-\hat{b}\right) + \frac{\hat{b}}{\left(1-\hat{q}\right)^2}\left(q-\hat{q}\right)$$

and computing the variance of that

(7) $$\begin{aligned} \sigma_d^2 &\approx \iint_{b,q} \left[\frac{\hat{b}}{1-\hat{q}} + \frac{1}{1-\hat{q}}\left(b-\hat{b}\right) + \frac{\hat{b}}{\left(1-\hat{q}\right)^2}\left(q-\hat{q}\right) - \frac{\hat{b}}{1-\hat{q}} \right]^2 f(b,q)\mathrm{d}b\mathrm{d}q \\ &= \frac{1}{\left(1-\hat{q}\right)^2}\sigma_b^2 + \frac{\hat{b}^2}{\left(1-\hat{q}\right)^4}\sigma_q^2 + \frac{2\hat{b}}{\left(1-\hat{q}\right)^3}\sigma_{bq} \end{aligned}$$

The estimates of r, s, V and M are based on data on single person meat-eating households:

$$(8) \qquad C_i^{vm} = V_i Y_j^r \;\Leftrightarrow \ln C_i^{vm} = \ln V_i + r \ln Y_j \;\; \forall \; v_i = 0,\; N_j = 1$$

$$(9) \qquad C_i^{mm} = M_i Y_j^s \Leftrightarrow \ln C_i^{mm} = \ln M_i + s \ln Y_j \;\; \forall \; v_i = 0,\; N_j = 1$$

Our goal is to estimate the number of vegetarians in a given household. For households that do not buy meat, we declare all members to be vegetarian: $v_i = 1$. For single-person household, there is therefore no uncertainty. For multi-person households, we proceed as follows. We predict the expected share of meat in total food consumption S, conditional on the hypothesized number of vegetarians in the household:

$$(10a) \quad \mathrm{E}\left[S_j \mid N_j^V \right] = \frac{N_j^M \hat{C}_i^{mm}}{N_j^M \left(\hat{C}_i^{mm} + \hat{C}_i^{vm} \right) + N_j^V \hat{C}_i^{vv}}$$

with

$$(10b) \quad N_j^V := \sum_{i \in j} v_i ; N_j^M := N_j - N_j^V$$

Using the standard errors of the regressions (4), (8) and (9) and a second-order Taylor approximation of (10), we find that

$$(11) \quad \begin{aligned} \mathrm{Var}\left[S_j \mid N_j^V \right] = & \frac{N_j^M \hat{C}_i^{vm} + N_j^V \hat{C}_i^{vv} - N_j^M \hat{C}_i^{mm}}{\left(N_j^M \left(\hat{C}_i^{mm} + \hat{C}_i^{vm} \right) + N_j^M \hat{C}_i^{vv} \right)^3} N_j^{M\,2} \sigma_{mm}^2 + \\ & \frac{N_j^{M\,2} \hat{C}_i^{mm}}{\left(N_j^M \left(\hat{C}_i^{mm} + \hat{C}_i^{vm} \right) + N_j^V \hat{C}_i^{vv} \right)^4} \left(N_j^{M\,2} \left(\sigma_{mm}^2 + \sigma_{vm}^2 \right) + N_j^{V\,2} \sigma_{vv}^2 \right) \end{aligned}$$

Assuming a lognormal distribution, we compute the relative probabilities of the hypotheses N^V=0, 1, …, N_j-1. We then impute the number of vegetarians $\tilde{N}$ as the smallest $\tilde{N}$ for which $p(\tilde{N}^V > N^V) \geq 0.95$.

Aggregation

The number of households in the sample that report no meat consumption or purchase is readily estimated. Sample weights are used where available to estimate the fraction of all-vegetarian households. We estimate the total number of vegetarians in a country as the number of vegetarians in each household in our sample, again applying a weight for representativeness where appropriate. For households that report no meat

consumption, the number of vegetarians is equal to the number of household members.

Table A1. Data by year and country

Year	Country	Households	Number of people	Household income measure	Consumption measure
2005	Albania	3275	13734	Net income	expenditure
1995	Azerbaijan	1864	9281	Total declared income	consumption
1997	Brazil	2838	11917	Net income	expenditure
2001	Bulgaria	2359	6618	Total expenditure	consumption
2003	Bulgaria	3012	8152	Total declared income	consumption
2001	East Timor	1596	7699	Total expenditure	consumption
1979	France	9406	28413	Total expenditure	expenditure
1985	France	9814	32251	Gross income	expenditure
1995	France	9099	23462	Total expenditure	consumption
2001	France	8956	22265	Gross income	expenditure
2005	France	8970	21891	Net income	expenditure
2000	Guatemala	6078	31155	Gross income	expenditure
1998	India	1527	9903	Total declared income	consumption
1987	Ireland	6909	24161	Disposable income	consumption
1994	Ireland	6958	22311	Disposable income	consumption
1999	Ireland	6700	20918	Disposable income	consumption
2004	Ireland	5266	15934	Disposable income	consumption
1985	Ivory Coast	1522	12124	Total declared income	consumption
1986	Ivory Coast	1546	11803	Total declared income	consumption
1987	Ivory Coast	1560	10666	Total declared income	consumption
1988	Ivory Coast	1523	9266	Total declared income	consumption
1988	Jamaica	1648	6225	Total expenditure	consumption
1989	Jamaica	1256	5381	Total expenditure	consumption
1990	Jamaica	703	2468	Total expenditure	consumption
1991	Jamaica	1576	5813	Total expenditure	consumption
1992	Jamaica	3843	13679	Total expenditure	consumption
1993	Jamaica	1710	6058	Total expenditure	consumption
1994	Jamaica	1708	5815	Total expenditure	consumption
1995	Jamaica	1715	6191	Total expenditure	consumption
1996	Jamaica	1608	5867	Total expenditure	consumption
1997	Jamaica	1743	6086	Total expenditure	consumption
1998	Jamaica	6461	22409	Total expenditure	consumption
1999	Jamaica	1633	5480	Total expenditure	consumption
2000	Jamaica	1570	5447	Total expenditure	consumption
2001	Jamaica	1436	4727	Total expenditure	consumption
2002	Jamaica	6165	20847	Total expenditure	consumption
2003	Jamaica	1781	5930	Total expenditure	expenditure

Year	Country	Households	Number of people	Household income measure	Consumption measure
2004	Jamaica	1755	6020	Total expenditure	expenditure
2005	Jamaica	1698	5679	Total expenditure	expenditure
1993	Kyrgyzstan	1894	9338	Total declared income	consumption
1996	Nepal	3014	17095	Total expenditure	consumption
2004	Nepal	3431	18174	Total expenditure	expenditure
1985	Peru	4615	23470	Total expenditure	consumption
1992	Russia	5946	15985	Gross income	expenditure
1993	Russia	5388	14260	Gross income	expenditure
1994	Russia	2843	9526	Gross income	expenditure
2000	Russia	2950	10504	Gross income	expenditure
2001	Russia	2962	10908	Gross income	expenditure
2002	Russia	5224	13422	Gross income	expenditure
1993	South Africa	4776	20517	Net income	consumption
1999	Tajikistan	1818	12265	Total declared income	expenditure
2003	Tajikistan	3620	21915	Total declared income	consumption
1993	Tanzania	4844	26705	Total declared income	consumption
1961	UK	3057	9027	Total expenditure	expenditure
1962	UK	3114	9040	Total expenditure	expenditure
1963	UK	2972	8710	Total expenditure	expenditure
1968	UK	6408	18746	Net income	expenditure
1969	UK	5995	17019	Net income	expenditure
1970	UK	5731	16642	Net income	expenditure
1971	UK	6328	18109	Net income	expenditure
1972	UK	6231	18034	Net income	expenditure
1973	UK	6320	17806	Net income	expenditure
1974	UK	5935	16827	Net income	expenditure
1975	UK	6373	17936	Net income	expenditure
1976	UK	6205	16909	Net income	expenditure
1977	UK	6428	17890	Net income	expenditure
1978	UK	6182	16886	Net income	expenditure
1979	UK	6068	16494	Net income	expenditure
1980	UK	6141	16706	Net income	expenditure
1981	UK	6680	18172	Net income	expenditure
1982	UK	6491	17435	Disposable income	expenditure
1983	UK	6171	16414	Disposable income	expenditure
1984	UK	6294	16385	Disposable income	expenditure
1985	UK	6155	15853	Disposable income	expenditure
1986	UK	6399	16348	Disposable income	expenditure

Year	Country	Households	Number of people	Household income measure	Consumption measure
1987	UK	6463	16420	Disposable income	expenditure
1988	UK	6331	15897	Disposable income	expenditure
1989	UK	6583	16399	Disposable income	expenditure
1990	UK	6167	15226	Disposable income	expenditure
1991	UK	6237	15041	Disposable income	expenditure
1992	UK	6569	15916	Disposable income	expenditure
1993	UK	6143	15180	Disposable income	expenditure
1994	UK	5811	13881	Disposable income	expenditure
1995	UK	6018	14529	Disposable income	expenditure
1996	UK	5973	14560	Disposable income	expenditure
1997	UK	5537	13515	Disposable income	expenditure
1998	UK	5315	12461	Disposable income	expenditure
1999	UK	5469	12888	Disposable income	expenditure
2000	UK	6225	14589	Disposable income	expenditure
2001	UK	5537	12868	Disposable income	expenditure
2002	UK	6037	14293	Disposable income	expenditure
2003	UK	6152	14628	Disposable income	expenditure
2004	UK	5759	13518	Disposable income	expenditure
2005	UK	5889	13859	Disposable income	expenditure
1980	USA	4002	12428	Gross income	expenditure
1981	USA	3794	11687	Gross income	expenditure
1990	USA	4830	14159	Net income	expenditure
1991	USA	5112	14969	Net income	expenditure
1992	USA	4745	13814	Net income	expenditure
1993	USA	4764	13738	Net income	expenditure
1994	USA	4251	12374	Net income	expenditure
1995	USA	3875	11260	Net income	expenditure
1996	USA	4061	11764	Net income	expenditure
1997	USA	4100	11952	Net income	expenditure
1998	USA	4155	11994	Net income	expenditure
1999	USA	5260	15193	Net income	expenditure
2000	USA	5357	15608	Net income	expenditure
2001	USA	5496	15942	Net income	expenditure
2002	USA	5424	15678	Net income	expenditure
2003	USA	4152	11762	Net income	expenditure
2004	USA	5941	17043	Net income	expenditure
2005	USA	6151	17758	Net income	expenditure
1992	Vietnam	4331	20503	Total expenditure	consumption

Year	Country	Households	Number of people	Household income measure	Consumption measure
1998	Vietnam	4989	24192	Total expenditure	consumption
2002	Vietnam	26589	113557	Total expenditure	consumption
2004	Vietnam	8268	32180	Total expenditure	consumption

Figure A1. Relative price of meat to non meat items and vegetarianism

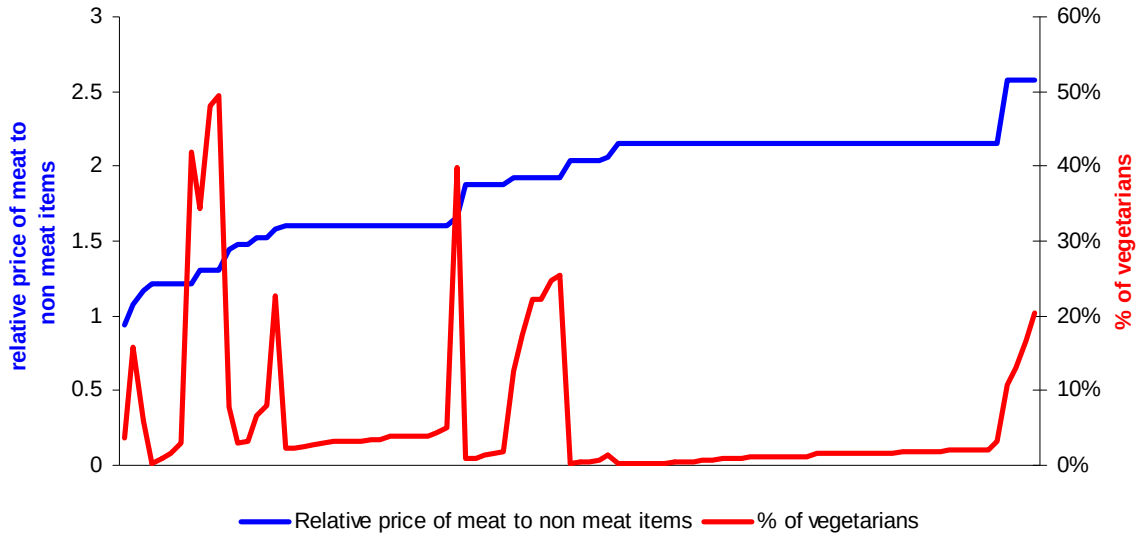


Figure A2. Hinduism and vegetarianism

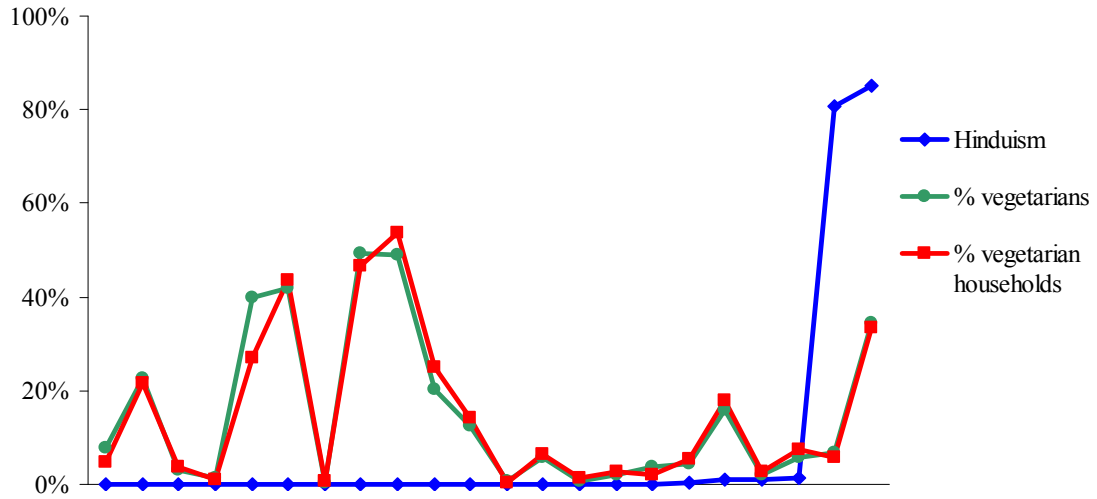


Figure A3. The gini coefficient and vegetarianism

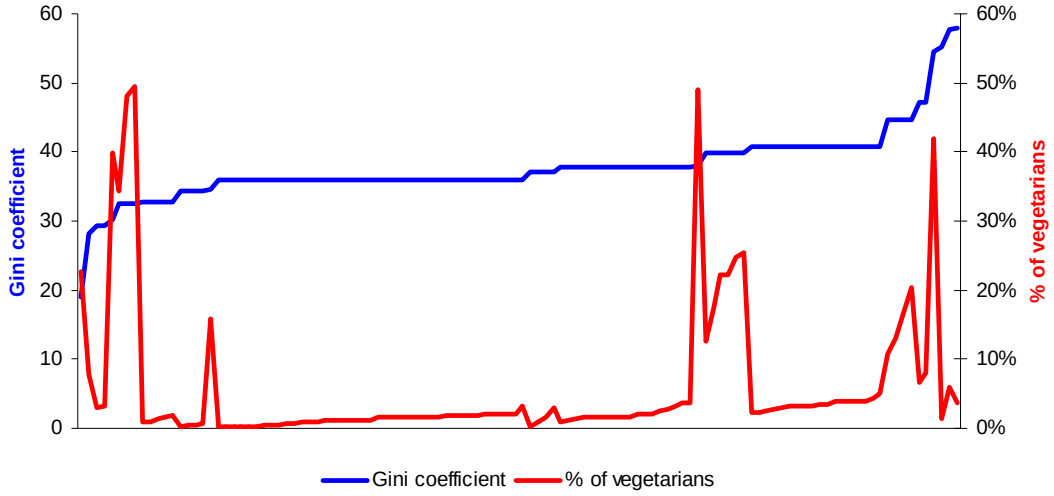
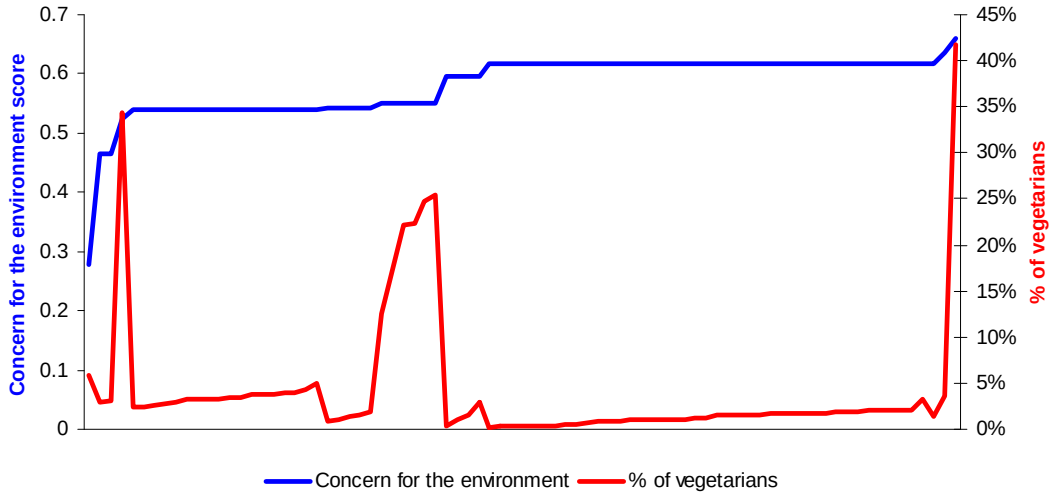


Figure A4. Concern for the environment and vegetarianism



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Philip J. O'Connell and *Delma Byrne*

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Adele Bergin, Thomas Conefrey, John FitzGerald and
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Maurizio Pisati, *Christopher T. Whelan*, Mario Lucchini and *Bertrand Maître*

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Richard S.J. Tol

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Thomas Legge and *Sue Scott*

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Pete Lunn and *Elish Kelly*

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Luke M. Brander, Katrin Rehdanz, *Richard S.J. Tol*, and Pieter J.H. van Beukering

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Giulia Macagno, Maria Loureiro, Paulo A.L.D. Nunes and *Richard S.J. Tol*

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Seán Diffney, Seán Lyons and *Laura Malaguzzi Valeri*

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Jean Goggin and *Iulia Siedschlag*

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David Anthoff

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Eimear Leahy and *Seán Lyons*

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David Anthoff, Richard S.J. Tol and Gary W. Yohe

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Alan Barrett and Anna Rust

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Daiju Narita*, Richard S.J. Tol, David Anthoff*

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2008

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Anne Nolan

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Nicola Commins and *Anne Nolan*

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Frances Ruane

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Seamus McGuinness, Elish Kelly and *Philip O'Connell*

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Christopher T. Whelan and *Bertrand Maître*

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Karen Mayor, Seán Lyons, David Duffy and *Richard S.J. Tol*

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Christopher T. Whelan and *Bertrand Maître*

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Sue Scott, Seán Lyons, Claire Keane, Donal McCarthy and *Richard S.J. Tol*

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David Duffy and *Pete Lunn*

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Tord Kjellstrom, R Sari Kovats, Simon J. Lloyd, Tom Holt, *Richard S.J. Tol*

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Daiju Narita, *Richard S. J. Tol* and *David Anthoff*

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Aleksander Kucel, *Delma Byrne*

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Richard S.J. Tol, Terje K. Berntsen, Brian C. O'Neill, Jan S. Fuglestvedt, Keith P. Shine, Yves Balkanski and Laszlo Makra

256 Intra-Union Flexibility of Non-ETS Emission Reduction Obligations in the European Union
Richard S.J. Tol

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Richard S.J. Tol

254 Measuring International Inequity Aversion
Richard S.J. Tol

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Alan Barrett and *Elish Kelly*

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David Anthoff, Richard S.J. Tol and Gary W. Yohe

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Thomas Conefrey, John D. Fitz Gerald, Laura Malaguzzi Valeri and *Richard S.J. Tol*

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Tim Callan, Sean Lyons, Susan Scott, Richard S.J. Tol and Stefano Verde

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Onno Kuik, Luke Brander and *Richard S.J. Tol*

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Richard S.J. Tol and *Seán Lyons*

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Richard S.J. Tol, Tim Callan, Thomas Conefrey, John D. Fitz Gerald, Seán Lyons, Laura Malaguzzi Valeri and *Susan Scott*

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Tim Callan and *Claire Keane*

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Alan Barrett and Yvonne McCarthy

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Jacqueline O'Reilly and *Miriam M. Wiley*

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Alan Barrett, *Seamus McGuinness* and *Martin O'Brien*

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Charlie Karlsson, Gunther Maier, Michaela Trippl, *Iulia Siedschlag,* Robert Owen and *Gavin Murphy*

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Seamus McGuinness, *Frances McGinnity, Philip O'Connell*

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Richard S.J. Tol

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The International Study Group on Exports and Productivity

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Joe O'Doherty, *Seán Lyons* and *Richard S.J. Tol*

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Merike Darmody, Selina McCoy, Emer Smyth

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