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The Link Between Economic Growth and Environmental Quality: Does Population Ageing Matter?

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Abstract

The social preference for environmental care is a critical factor explaining the Environmental Kuznets Curve (EKC), the purported inverted U-curve relationship between per capita income and pollution. However, little is known about the potential impact of population ageing on the social preference for environmental protection. This is alarming as micro based surveys reveal that demographic factors could affect social preferences for environmental quality (Hersch and Viscusi; 2005). This study explores if and how population ageing contributes to an explanation of the EKC via willingness to pay. The main results can be summarized as follows. In a few instances of EKC specifications for air pollutants, we find that the estimated coefficients for *population ageing* are statistically different from zero and positively impact on pollution emission. Using Baldwin (1995) decomposition of *actual pollution emissions* we propose alternative explanations for this result. In particular, population ageing may impact upon *incipient* pollution via various channels, e.g. the changing consumption patterns of older individuals. Also, there may a negative impact of ageing on abatement expenditure either via individual preferences or via a tighter government budget constraint that channels expenditure away from environmental protection. We find some evidence in support of this last mechanism.

JEL classification codes: J11, E62, H41

1. Introduction

In OECD countries, population ageing is having a significant impact both on the age profile of the population and the composition of the labour force**.** Public policy challenges have already arisen in countries where the proportion of the population over the age of 65 has rapidly increased since the 1970s (see Table 1). While the adverse macroeconomic effects of population ageing are well explored in the literature (e.g., Bloom, Canning and Sevilla 2001) the potential consequences of this demographic transition for the social preference for environmental care have been almost completely ignored. This is undoubtedly a matter of concern because the social preference for environmental care is a critical factor explaining the Environmental Kuznets Curve (EKC), the argument according to which economic growth is ultimately beneficial for the environment as high levels of GDP per capita induce increased demand for environmental quality (Dinda 2004). Although wide micro surveys show that population ageing may substantially impact upon the willingness to pay for environmental protection (Hersch and Viscusi 2005), our current state of knowledge does not account for the profound impact population ageing may have on environmental quality.

Our central research question focuses on how population ageing contributes to an explanation of the Environmental Kuznets Curve via willingness to pay. By testing the hypothesis that the demographic transition impacts upon the specification of an empirical EKC, we may advance our understanding of the observed paradoxical situation where increasing awareness of the need for environmental care coexists with alarmingly stable public expenditure for environmental protection.

2. The link between economic growth and environmental quality. The first generation studies

Essentially, the Environmental Kuznets Curve is the purported inverted-U shaped relationship between per capita emissions and per capita GDP. Low levels of per capita GDP are initially associated with a clean, agrarian economy and correspondingly low pollution emission levels. As GDP per capita increases, emissions first increase with the evolution of a polluting industrial economy, then finally decrease as a cleaner, service based economy develops (Dinda 2004). The EKC derives its name from the work of Kuznets (1955) who posited a similar relationship between income inequality and economic growth. Conceptually, it is hypothesised that several factors may shape the EKC. Certainly, the income elasticity of demand for environmental quality is an important determining factor in the emergence of the EKC. As income increases, the income elasticity of demand for environmental quality may exceed unity, thereby contributing to the downward sloping segment of the EKC.

The empirical basis of the EKC has been the subject of extensive research. Most of the data employed to econometrically test the EKC is drawn from cross-sections of countries, cross-sectional panel data and pooled data. A reduced form model is used to examine the various relationships between per capita emissions and per capita GDP:

$$y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x_{it}^{\ 2} + \beta_3 x_{it}^{\ 3} + \beta_4 z_{it} + \varepsilon_{it} \qquad (1)$$

where y is per capita emissions in country i at time t, x is per capita income, z relates to other variables of influence on environmental care, α is a constant term, and β_k is the coefficient of the k explanatory variables. Broadly, an inverted U-shaped relationship between emissions and per capita GDP has been observed for air pollutants which have a direct impact on human health, whereas there is no firm empirical evidence supporting the emergence of an EKC in water quality indicators, nor regarding other environmental indicators such as urban sanitation and municipal wastes (Dinda 2004). In their path-breaking paper, Grossman and Krueger (1991) investigated the environmental impacts of the North American Free Trade Agreement on sulphur dioxide emissions and smoke emissions and found that a cubic polynomial of per capita GDP was the preferred functional form.

In a later paper, Grossman and Krueger (1995) used panel data available from Summers and Heston (1991) and GEMS for the years 1979 to 1990 to investigate the presence of an EKC relationship for four environmental indicators: urban air pollution, oxygen quality in river basins, contamination of river basins by faecal matter, and heavy metal contamination of river basins. The sample size varies depending on the particular emission under investigation. In this analysis, the reduced form empirical specification included a cubic for real GDP per capita.[1] Additional location specific characteristics were included to improve the precision of the estimation by reducing the variance of the residuals in the relationship between pollution emissions and GDP per capita. Using random effects estimation, this analysis provided evidence of an EKC relationship for each of the four environmental indicators.

There exists empirical support for the emergence of an EKC for atmospheric pollutants. For example, Stern and Common (2001) investigate the presence of an EKC for emissions of sulphur using a panel of 73 countries between the years 1960 and 1990. Their results provide evidence of a global inverted-U shaped EKC. For the OECD sub-sample, random effects estimation produces consistent results[2] and again reveals an inverted-U shaped EKC. The EKC for the non-OECD sub-sample is monotonic. Interestingly, when estimating the fixed time effects for the World sample, Stern and Common find a decline in emissions, *ceteris paribus*. The average rate of this decline is 1.5 percent per year. Selden and Song (1994) use cross-national panel data to investigate the EKC for four air pollutants. Using the same data used by Grossman and Krueger (1991 and 1995), Selden and Song find evidence of the emergence of an EKC for suspended particulate matter, sulphur dioxide, nitrous oxide and carbon monoxide using pooled cross section, fixed effects and random effects estimation.

A limited number of empirical studies provide support for the emergence of the EKC relationship with respect to land degradation. For example, Cropper and Griffiths (1994) find evidence of an inverted-U shaped relationship for the rate of deforestation in Latin America and Africa, while Antle and Heidebrink (1995) found that an EKC emerged for park and forest amenities. Interestingly, Kaufmann, Davidsdottir, Garnham and Pauly (1998) found a U-shaped relationship between per capita income and atmospheric concentration of sulphur dioxide.

The ecological transition implied by the EKC necessitates that the turning point of the U-shaped curve is crucial, particularly for policy analysis. For many pollution indicators, the estimated turning point lies in the income range US$3000-10 000 per capita (1985 dollars). Grossman and Krueger (1995) found a turning point of US$4053 (1985 dollars) for sulphur dioxide emissions, while Selden and Song (1994) found a turning point of approximately $11 000-$12 000 for the same variable. Kaufmann et al. (1998) found peak atmospheric concentration of sulphur dioxide occurring at $12,500 (1985 dollars). The turning point for nitrous oxides has been estimated at between US$17,600 and US$22,000 (Cole 2004; Selden and Song 1994). Cole (2004) found a turning point of US$24,700 for carbon oxides, US$8650 for particulate matter, and US$42,200 for volatile organic compounds (all 1995 dollars).

2.1 Second generation studies

Various researchers, such as Hill and Magnani (2002), evidence that the hypothesised inverted-U relationship between per capita GDP and pollution emission levels lacks firm conceptual and empirical foundations. The authors provide evidence of a clear omitted variable problem in the empirical specification of the EKC, showing that the relationship is highly sensitive to the choice of pollutant, sample of countries and time period. Further, they establish that two important omitted variables are education and income inequality. Stern (2004) contends that much of the EKC literature is econometrically weak, with few studies considering omitted variable bias and adequate empirical specification. Similarly, Stern, Common and Barbier (1996) refute the existence of an econometrically robust EKC. The authors conduct simulations combining EKC estimates from various studies and World Bank forecasts for economic growth, and then aggregate these measures to determine a global pollution impact. Global sulphur dioxide emissions were shown to monotonically increase over the forecast period, which ranged to 2025. Empirical work by de Bruyn, van de Bergh and Opschoor (1998) also casts doubt on the efficacy of the EKC hypothesis. The authors illustrate that the inverted-U relationship between per capita income and environmental degradation may not hold for specific countries over time.

Related to the decomposition between actual emissions, incipient pollution and abatement is the issue of willingness to pay for environmental protection. Particularly controversial in the EKC hypothesis is the notion that there exists a necessary stage-based link or development path between pollution emissions and economic growth, with environmental improvement eventually occurring without the need for policy intervention (Roberts and Grimes

[1] A cubic for average per capita GDP over the previous three years was also included as a proxy for permanent income, however due to the high correlation between GDP per capita and lagged GDP per capita, the inclusion of the latter did not make a quantitative difference to the regression results.
[2] Established via the Hausman Test

1997). Magnani's (2000 and 2001) analyses highlight the existence of an omitted variable problem which strongly questions the purported automatic link between improvement in environmental quality and economic growth. These studies contend that measures of the income distribution function other than the mean may be important determining factors in the relationship between environmental quality and economic growth. Specifically, Magnani (2001) focuses on the willingness to pay as opposed to the ability to pay for environmental protection. This analysis is located within a political economy framework in which income inequality is a determinant of the willingness to pay for environmental protection, and therefore an explanatory variable in a pollution abatement regression. It is this political economy framework that may provide a valid instrument to better understand how population ageing impacts on individual willingness to pay and government pollution abatement.

2.2 Willingness to pay for environmental protection: the impact of population ageing

While numerous scholars have examined public support for environmental protection from the perspective of theoretical environmental sociology,[3] empirical research investigating the relationship between age and willingness to pay for environmental protection is characterised by its paucity. An important exception to this is recent research by Hersch and Viscusi (2005), which utilises a 1999 Eurobarometer survey of European citizens containing observations on more than 16 000 respondents from fifteen countries. The authors empirically establish a steady decline with age in willingness to pay for environmental protection. Specifically, it is evident that the degree to which individuals are willing to incur higher petrol prices if such prices reflect a greater degree of environmental protection declines with age. Hersch and Viscusi control for socioeconomic characteristics and age-related differences concerning the source and breadth of information regarding the environment, perceived health implications stemming from climate change, and degree of concern regarding climate change. Indeed, the empirical work by Hersch and Viscusi (2005) provides foundations to the hypothesis that population ageing may be a significant determining factor in an EKC specification and more specifically in a willingness to pay analysis of government environmental protection. By empirically testing the hypothesis that the demographic transition impacts upon the EKC specification, we may begin to understand the apparently paradoxical situation where mounting awareness of the need for environmental care exists in tandem with stable public expenditure for environmental protection.

3. The link between economic growth and environmental quality. Does population ageing matter?

A number of important motivations and research results drive our hypothesis that population ageing may negatively impact upon environmental quality. Indeed, there are firm indications that population ageing may be a significant determining factor in the willingness to pay for environmental protection (Hersch and Viscusi 2005). Additionally, we view as defensible the notion that an increased proportion of individuals over the age of 65 will likely drastically increase the dependency ratio and subsequently contribute to a binding government budget constraint. This fiscal pressure may divert financial resources away from abatement expenditure towards care for the elderly perhaps most significantly in the form increased public expenditure on health care. Another potential explanation for the negative correlation between the demographic shift and environmental quality is the idea that relative to the younger population, older individuals may demonstrate changing consumption patterns which increase pollution emissions, an example of which is heightened energy demands during periods of extreme weather conditions.

Finance studies indicate that population ageing may affect portfolio allocations between risky and safer assets. First, empirical studies support the argument that age is an important determinant of the individual rate of time preference, implying that as agents grow older, they desire a shorter time span of investment returns. Second, Bellante and Green (2004) find that the relative risk aversion of the elderly modestly decreases with age. Similarly, Georgarakos (2004) empirically establishes decreasing absolute risk aversion preferences among the elderly. Third, Senesi (2003) observes that the proportion of income saved declines with age. In addition, Kennickell and Lusardi (2004) find that the precautionary savings motive is particularly important for the elderly.

In the macroeconomic literature, portfolio allocation decisions are not directly related to the demand for environmental protection. However, this literature points out that the individual rate of time preference, the relative risk aversion of the elderly, and the share of income accruing to the elderly may impact upon the portfolio allocations between risky and safer assets, and may therefore be important factors in the willingness to pay for environmental

[3] See, for example Brechin and Kempton (1994); Buttel (1987); Martínez-Alier (1995); Van Lierer and Dunlap (1980).

protection for three reasons. First, the individual rate of time preference and decreasing absolute risk aversion preferences of the elderly may together imply increased investment in 'safer' assets with a shorter time horizon of returns, rather than more long term and 'risky' environmentally friendly technologies. Second, lower aggregate and increased precautionary savings may lead to reduced aggregate investment, including reduced investment in environmentally friendly technologies. Third, the elderly may offer political support to policies that promise immediate economic growth rather than longer term policies which provide for environmental protection, owing to a shorter remaining lifespan. Similar reasoning supports the notion that that population ageing may negatively impact upon the preference for environmentally friendly market goods.

This empirical analysis aims to shed light on how the demographic shift contributes to an explanation of the Environmental Kuznets Curve. In order to test this hypothesis, our empirical investigation focuses on determining whether the demographic shift contributes to explaining the EKC and government R&D investment in pollution abatement.

4. An empirical investigation. Data and methodology

We use a panel data set specifically constructed for this research project. The sample consists of the thirty OECD member countries (Appendix 1 provides a full list of OECD member countries). The time periods covered in the sample are: 1970, 1975, and all years between 1980 and 2002. Data is drawn from the OECD Statistical Division, World Bank, and the International Monetary Fund, and therefore satisfy the criteria of reliability and international comparability.

Emission data is drawn from the OECD Environmental Data Compendium series (hereafter 'the Compendium'). Nitrogen oxide is a traditional anthropogenic air pollutant which exerts direct pressure on human health and environmental quality, and is primarily emitted from the burning of fossil fuels at high temperatures. Nitrogen oxide is an important determinant of photochemical oxidants and smog and contributes to acid rain. Data for the years 1970 and 1975 is drawn from the 1993 Compendium; data between the years 1981 and 1984 is from the 1995 Compendium; data for 1980 and the period 1985 to 1989 is from the 1999 Compendium; and all data between 1990 and 2002 is drawn from the 2004 Compendium. We measure total nitrogen oxide emissions in a given year (NO_2). Emissions of greenhouse gases may lead to increases in the Earth's surface temperature and have corresponding deleterious effects on world climate patterns, increases in sea level and global warming potential. Emissions of carbon dioxide represent the largest single contribution to global warming. Data on carbon dioxide emissions for the years 1970 and 1975 is drawn from the 1993 Compendium; data between the years 1981 and 1984 is from the 1995 Compendium; data for the period 1986 to 1989 is from the 1999 Compendium; and data for the years 1980 and 1985, and all data between 1990 and 2002 is drawn from the 2004 Compendium. Carbon dioxide emissions refer to total emissions in a given year. Data on greenhouse gas emissions for the years 1990 to 2002 is from the 2004 Compendium. Greenhouse gas emissions measure total anthropogenic emissions of the six major greenhouse gases and translate this measure into a carbon dioxide equivalent. Aggregate emissions data was converted to per capita emissions using population data from OECD (2006).

The independent variables used to empirically investigate the relevance of population ageing as an explanatory variable in the EKC specification are: GDP per capita, population ageing, value added in industry[4], trade in goods and services and population density. Real per capita GDP was constructed using total GDP and population data from OECD (2006). Nominal GDP figures, in US dollars at purchasing power parity were converted to 2000 prices using the US GDP deflator. *Population ageing*, the proportion of a country's population over the age of 65, is our explanatory variable of interest. Table 1 illustrates that although OECD countries display a common trend towards population ageing, the data contains adequate dispersion for the purposes of our statistical analysis. If our hypothesis that population ageing negatively affects pollution emissions is supported by the empirical evidence, the coefficient on age will be positive. The variables *population ageing* and *value added in industry* are drawn from the 2006 OECD Factbook. As articulated by scholars such as Panayotou (2000) and Copeland and Taylor (2004), the industrial composition of output is an important control variable in the EKC specification, since pollution emissions are likely to increase when a nation's overall output mix tends towards pollution intensive industries and products.

[4] *Value added in industry* accounts for the industrial composition of output in a particular country and is expressed as a percentage of total value added. Industry is defined as mining and quarrying, manufacturing, construction, and production and distribution of electricity, gas and water.

Consequently, the expected coefficient on *value added in industry* is positive. *Trade in goods and services* is expressed as a percentage of GDP and accounts for a country's openness to international trade. Numerous authors including Copeland and Taylor (1995), Chichilnisky (1994), Cole (2004), and Nahman and Antrobus (2005) illustrate that volume of international trade is an important inclusion in the EKC specification due to the clear and significant effects international trade has on pollution emissions according to the pollution haven hypothesis. As such, the expected coefficient on *trade in goods and services* is negative.

Table 1. Population Ageing in OECD Countries: proportion of the population over the age of 65.

	1970	1980	1990	2000
Canada	7.9	9.4	11.2	12.6
Mexico	4.3	3.8	4.0	4.8
United States	9.8	11.3	12.5	12.4
Japan	7.1	9.1	12.1	17.4
Korea	3.1	3.9	5.1	7.2
Australia	8.3	9.6	11.1	12.4
New Zealand	8.5	9.9	11.1	11.7
Austria	14.1	15.4	15.0	15.4
Belgium	13.4	14.3	15.0	16.8
Czech Republic	12.1	13.5	12.5	13.8
Denmark	12.3	14.4	15.6	14.8
Finland	9.1	12.0	13.4	14.9
France	12.9	13.9	14.0	16.1
Germany	13.7	15.6	14.9	16.4
Greece	11.1	13.1	13.7	16.6
Hungary	11.5	13.4	13.3	15.1
Iceland	8.8	9.9	10.6	11.6
Ireland	11.1	10.7	11.4	11.2
Italy	10.9	13.1	14.9	18.3
Luxembourg	11.9	13.6	13.4	14.1
Netherlands	10.2	11.5	12.8	13.6
Norway	12.9	14.8	16.3	15.2
Poland	8.4	10.1	10.1	12.2
Portugal	9.4	11.3	13.4	16.2
Slovak Republic	9.1	10.5	10.3	11.4
Spain	9.7	11.2	13.6	16.8
Sweden	13.7	16.3	17.8	17.3
Switzerland	11.3	13.8	14.6	15.3
Turkey	4.3	4.6	4.2	5.5
United Kingdom	12.9	15.0	15.7	15.8

This data is sourced from the 2005 National Accounts of OECD Countries. *Population density* refers to the number of inhabitants per kilometre squared in a particular country. Selden and Song (1994) illustrate that population density is an important explanatory variable in the empirical EKC. The explanation for this result centres on the notion that more densely populated countries display an increasing demand for reduced per capita emissions at every income level than sparsely populated countries (Selden and Song 1994). Consequently, *population density* enters the EKC regression with an expected negative coefficient. The data for *population density* for the years 1970 and 1975 is from the 1993 OECD Environmental Data Compendium; data for 1981 to 1984 is from the 1995 Compendium; data for 1986 to 1989 is from the 1999 Compendium, and data for the years 1980, 1985, and 1990 to 2002 is drawn from the 2004 Compendium.

Data on environmental policy are rare (Shafik 1994). To our knowledge the OECD Environmental Program is the only source of information on environmental measures that satisfies the criteria of reliability and international comparability. Information on public R&D expenditure intended to protect the physical environmental from degradation is collected for OECD countries between 1980 and 2002. Environmental protection includes all research relating to pollution: study of origins and causes, diffusion and transformation and the effects on human beings and the environment, but excludes research on changes in the production process that result in the generation of less pollution. As such this indicator can be interpreted as related to a broad set of policies for environmental protection aimed to increase environmental quality. The data is in US Dollars at 2000 price levels. Data for 1981, 1985, 1990, 1995 and the years between 2000 and 2003 are drawn from the 2004 Compendium. Data for 1991 to 1994 are from the 1997 Compendium, while data for 1980 and the years between 1996 and 1998 are from the 1999 Compendium. Finally, the variable *budget* captures the level of tightness of the government budget constraint. This variable is measured by government budget surplus (deficit) as a percentage of GDP. The variable *budget* was constructed using data on total government budget surplus (deficit) from the World Bank (2005) and GDP data from the International Monetary Fund (2006). Table 2 contains some summary statistics.

Table 2. EKC specification for nitrogen oxide emissions, carbon dioxide emissions and greenhouse gas emissions: Summary statistics

Variable	Number of observations	Mean	Standard deviation	Min	Max
Per capita emissions of nitrogen oxides[a]	584	0.0000409	0.0000235	0.00000815	0.000133
Per capita emissions of carbon dioxide[b]	728	0.00000949	0.00000505	0.0000011	0.0000441
Per capita emissions of greenhouse gasses[c]	222	0.0134279	0.0053653	0.0059113	0.0349844
Per capita public R&D expenditure for environmental protection[d]	301	3.450	2.363	0	11.035
Real GDP per capita[e]	907	18566	7103.788	2934.728	50419.76
Population ageing[f]	210	11.954	3.372	3.075	18.271
Value added in industry[g]	878	25.581	4.714	10.827	39.638
Trade in goods and services[h]	909	33.13	20.326	5.097	144.371
Population density[i]	730	122.358	113.404	1.7	480
Budget[j]	838	-3.023	3.925	-20.786	10.049

[a] Per capita emissions of nitrogen oxides is given as quantities of NO2 (tonnes).
[b] Per capita emissions of carbon dioxide (tonnes).
[c] Per capita emissions of greenhouse gases is given as a carbon dioxide equivalent (tonnes).
[d] Per capita public expenditure for environmental protection.
[e] Real GDP per capita is denominated at 2000 US prices using PPP.
[f] Population ageing refers to the proportion of a country's population over the age of 65.
[g] Value added in industry is expressed as a percentage of total value added.
[h] Trade in goods and services is expressed as a percentage of total GDP.
[i] Density refers to the number of inhabitants per kilometre squared.
[j] Budget refers to government budget surplus (deficit)-GDP ratio.

4.1 Econometric Specification

We now turn to the EKC regression equation:

$$e_{it} = \alpha + \beta_0 x_{it} + \beta_1 (x_{it})^2 + \beta_2 (x_{it})^3 + \rho_1 D_{it} + \delta_k z_{kt} + \mu_{it} \qquad (2)$$

where we specify the error term as $\mu_{it} = \varepsilon_{it} + \mu_i$ which is decomposed into a white-noise component ε_{it}, and a country effect, μ_i which captures unobservable country-specific factors. In Eq. (2) e_{it} is per capita pollution emissions in country i at time t; x_{it} is per capita GDP; α is the constant term; β_k is the coefficient of the k explanatory variables; ρ_{it} represents *population ageing*, and z_{kt} relates to control variables that influence environmental care: *value added in industry, trade in goods and services, and population density*. As such, the parameters $\alpha, \beta, \rho, \delta$ are the estimated coefficients, and x, D and z are the independent variables. As previously discussed, a number of theoretical and empirical EKC studies find that the preferred functional form for per capita GDP in the specification of an empirical EKC is a cubic polynomial.

This empirical analysis aims to shed light on how the demographic shift contributes to an explanation of the Environmental Kuznets Curve. Fundamental to the relationship between pollution emission and GDP is the role of individual preferences for environmental protection as articulated by Baldwin (1995), who provides a decomposition of pollution emissions in the EKC. The dependent variable in the EKC specification - actual pollution e, is decomposed into two quantities: incipient pollution I and abatement G, where $e=I-G$. As such, per capita actual emissions e depends positively on incipient pollution I, defined as the level of pollution in a particular country given the current level and composition of output with zero environmental costs; and negatively on pollution abatement G, which is the difference between incipient pollution and actual pollution at a point in time for a particular country. Crucially, pollution abatement G is a policy-induced variable. Further, incipient pollution and pollution abatement are functions of economic growth, or $I=I(Y)$ and $G=G(Y)$. Assuming homogenous agents, per capita GDP provides an average measure of economic well-being. The evolution of pollution emission levels in the EKC relationship relies on the impact of growth in GDP per capita upon both incipient pollution and pollution abatement. In the EKC, economic growth impacts upon the evolution of incipient pollution via both the scale and composition effects. As the scale of economic activity increases, there is a corresponding increase in incipient pollution. This impact may be partially mitigated by the industrial composition of output tending towards less pollution intensive industries. However, the scale effect will likely dominate the composition effect. As a consequence, economic growth ultimately increases incipient pollution, $I'(.) > 0$. The downward sloping segment of the EKC will emerge if growth in GDP per capita increases the intensity of abatement activities such that incipient pollution is offset (Baldwin 1995).In order to test the hypothesis that the positive impact of population ageing is due to a shift in preferences against environmental protection, we estimate an abatement investment regression including a measure for a binding government budget constraint as one of the explanatory variables.

5. The Empirical Results

Table 3 illustrates estimation results for emissions of nitrogen oxides, carbon dioxide and greenhouse gases respectively. Both random effects (RE) and fixed effects (FE) estimation results are reported.

For each emission, the coefficients for per capita GDP have the expected signs and are highly significant. The emergence of a cubic polynomial form for the estimated EKC is indicated by the positive coefficient of *per capita GDP*, negative coefficient for *per capita GDP squared* and positive coefficient for *per capita GDP cubed*. This relationship for emissions of nitrogen oxides, carbon dioxide and greenhouse gases is illustrated in Figures 1, 2 and 3 respectively. The findings related to the turning points in both RE and FE specifications of the EKC are consistent with numerous studies.[5] Interestingly, the estimated turning points for all three emissions are equal for both RE and FE estimation. This may indicate that the country effects component of the error term, μ_i is not correlated with the explanatory variables. As such RE estimation is consistent and efficient and yields similar results to FE estimation.

Empirical results across each of the three tested emission variables are highly consistent. To elaborate, for emissions of nitrogen oxides, carbon dioxide and greenhouse gases, each additional explanatory variable exhibits the expected sign and in most cases is highly significant. The explanatory variable *trade in goods and services* is negatively correlated with per capita emissions of nitrogen oxides. The somewhat contentious explanation for this result is consistent with the pollution haven hypothesis (Cole 2004). Further, the explanatory variable *value added in industry* is positively correlated with emissions of nitrogen oxides. This relationship is highly intuitive and well illustrated in the literature (Copeland and Taylor 2004).

[5] For example, the peak per capita emissions of nitrogen oxides occur at a per capita income level of $24 725, while the second turning point, beyond which emissions increase, is found at $39 963. This finding is consistent with numerous studies which empirically investigate an EKC for nitrogen oxides, where the level of GDP per capita at which the first turning point occurs has been estimated at between US$17,600 and US$22,000 (Cole 2004; Selden & Song 1994). For emissions of carbon dioxide, the first turning point is found at $20 855 per capita, while the second turning point occurs at $53 431. This is consistent with Galeotti, Lanza and Pauli (2006), where the initial turning point for carbon dioxide emissions was found to occur at an income level of $20 514 (in 2000 US dollars) for OECD countries. Finally, the first turning point in the EKC for greenhouse gas emissions occurs at a per capita income level of $30 355, while the second turning point is found at $66 053. This result is unique insofar as empirical studies which establish an EKC for carbon dioxide using a cubic in GDP per capita are scarce.

Population density has the expected negative coefficient. The explanation for this lies in the notion that more sparsely populated countries will likely express less urgency to reduce per capita pollution emissions at every income level than more densely populated countries (Selden and Song 1994). In general, the inclusion of population ageing as an explanatory variable improves the goodness of fit in the specification of the empirical EKC.

The empirical result which demands the most attention is that the estimated coefficients for *population ageing* are statistically different from zero at the 5% level for emissions of nitrogen oxides and carbon dioxides for both FE and RE estimation. In the EKC specification for greenhouse gases, the estimated coefficient on population ageing is statistically significant at the 5% level only for RE estimation. In addition, as expected the correlation between per capita pollution emissions and the proportion of individuals over the age of 65 is positive for each of the emission variables. Specifically, a 1 percentage point increase in the proportion of the population aged over 65 years will cause an increase of 0.0013 tonnes of per capita nitrogen oxides emissions, 0.456 tonnes of carbon dioxide emissions per capita, and 0.3258 tonnes of greenhouse gas emissions per capita. Indeed, this result supports our hypothesis that population ageing may negatively impact upon environmental quality. The positive correlation between population ageing and pollution emissions may be due to various factors. First, population ageing may impact upon incipient pollution via mechanisms such as portfolio allocation decisions between risky and safer assets, reduction in aggregate savings, and the changing consumption patterns of older individuals. Second, this relationship may be driven by the negative impact of the demographic shift on abatement expenditure as older individuals display diminished preferences for environmental care and population ageing diverts government expenditure away from environmental protection. It is with these possible explanations in mind that we turn to testing the impact of population ageing on government R&D investment for pollution abatement.

5.1 Does population ageing affect country specific abatement expenditure?

Table 4 illustrates the empirical results obtained by estimating a country specific and time-varying measure of government R&D investment in pollution abatement. Besides the share of the population aged 65 and above, explanatory variables are a quadratic in per capita GDP, and two alternative measures that proxy the tightness of the government budget constraint, namely government surplus over GDP ratio (*budget)* and a dummy variable (*fiscally troubled*) that takes value one if a country is fiscally troubled, zero otherwise. As per the Maastricht Treaty, we determined that a country be considered fiscally troubled if *average* annual government net borrowing for the period 1990 to 2002 exceeded 3 percent of GDP (OECD 2005*b*). The top panel of Table 4 shows the regression results for per capita government R&D investments in pollution abatement when the government fiscal position is measured by a continuous variable measuring the budget surplus (deficit)-GDP ratio. In the bottom panel we use an alternative measure which is the time invariant country-specific dummy variable *fiscally troubled*=0, 1.

Table 4 reports by column alternative specifications, with the last one encompassing the previous two. The main results can be summarized as follows. Public investment in pollution abatement has a non-linear relationship with GDP per capita, with per capita GDP first increasing and then decreasing the dependent variable. Such a result is robust to alternative specifications as well as to alternative measures of the fiscal position of the government. The quadratic polynomial in the share of the population aged 65 and plus shows that population ageing fails to reach statistical significance, a finding that is robust to the inclusion among the dependent variables of the government budget position (*budget* and its squared term). The estimated relationship between the variable *budget* and the government expenditure in pollution abatement R&D is somehow counterintuitive. With its negative impact on the dependent variable it suggests that fiscally troubled countries may spend more for the environment. Such a result suggests strongly that there may be *reverse causation,* with environmental protection impacting negatively on the government fiscal position. To test somehow that the government fiscal position affects environmental protection, rather than the other way round, the bottom panel of Table 4 illustrates the empirical results obtained with country-specific, time-invariant dummy variables such as *fiscally troubled.* It clearly shows two set of findings. First, age is consistently non-statistically significant. Secondly *fiscally troubled* is robustly statistically significant and with the expected *negative* sign, which suggests that indeed the tendency for a country to run a significant deficit negatively impacts upon its allocation of public funds in favour of pollution abatement.

6. Conclusions

The social preference for environmental care is a critical factor explaining the Environmental Kuznets Curve (EKC), the purported inverted U-curve relationship between per capita income and pollution. However, little is known about the potential impact of population ageing on the social preference for environmental protection. This is alarming as micro based surveys reveal that demographic factors could affect social preferences for environmental quality (Hersch and Viscusi, 2005). This study has explored if and how population ageing contributes to an explanation of the EKC via willingness to pay. The main results can be summarized as follows. We find that *population ageing* positively contributed to pollution emissions. The results obtained using a decomposition of *actual pollution emission* in incipient pollution and abatement highlight that changing consumption patterns of older individuals may increase incipient pollution. Instead, we find little evidence that the share of the population aged 65 and older is directly impacting upon government expenditure for pollution abatement *via preferences*, although we find some evidence that it may indirectly reduce environmental protection by negatively affecting the government budget position.

APPENDIX 1: OECD Member Countries

Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

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Table 3
Environmental Kuznets Curve for emissions of nitrogen oxide, carbon dioxide and greenhouse gases

	EKC Specification for nitrogen oxide emissions[a]		EKC specification for carbon dioxide emissions[b]		EKC specification for greenhouse gas emissions[c]	
Explanatory variable	RE[c]	FE	RE[c]	FE	RE[c]	FE
Per capita GDP	7.06e-06*** (1.40e-06)	7.06e-06*** (1.62e-06)	0.00117*** (0.00034)	0.00117*** (0.00038)	0.00240*** (0.00063)	0.00240** (0.00109)
(Per capita GDP)^2	-2.31e-10*** (4.96e-11)	-2.31e-10*** (5.73e-11)	-3.90e-8*** (1.24e-8)	-3.90e-8*** (1.40e-8)	-5.77e-8*** (2.06e-8)	-5.77e-8 (3.54e-8)
(Per capita GDP)^3	2.38e-15*** (5.70e-16)	2.38e-15*** (6.59e-16)	3.50e-13** (1.48e-13)	3.50e-13** (1.66e-13)	3.99e-13* (2.18e-13)	3.99e-13 (3.75e-13)
Population ageing	0.00132** (0.00055)	0.00132** (0.00063)	0.45640*** (0.13117)	0.45640* (0.14728)	0.32581** (0.15037)	0.32581 (0.25803)
Value added in industry	0.00066*** (0.00019)	0.00066*** (0.00021)	0.29351*** (0.04254)	0.29351 (0.04776)	0.24140*** (0.06582)	0.24140 (0.11296)
Trade in goods and services	-0.00036*** (8.45e-05)	-0.00036*** (9.77e-05)	-0.06017*** (0.02113)	-0.06017 (0.02372)	-0.10468*** (0.02168)	-0.10468** (0.03720)
Population density	-0.00028*** (8.61e-05)	-0.00028*** (9.95e-05)	-0.03942 (0.01882)	-0.03942 (0.02113)	-0.09305*** (0.03303)	-0.09305 (0.05668)
Constant	-0.03025 (0.00917)	-0.00832 (0.01338)	-0.00682*** (0.00258)	-6.32356** (2.55370)	-10.27098* (6.18998)	-8.27871 (7.34409)
R-squared	-	0.2631	-	0.0070	-	0.0536
Log-likelihood ratio	-571.71	-	-317.14	-	-54.20	-
Number of observations	*N* = 147	*N* = 147	*N* = 179	*N* = 179	*N* = 53	*N* = 53
Turning Points	\$24 725; \$39 963	\$24 725; \$39 963	\$20 855; \$53 431	\$20 855; \$53 431	\$30 355; \$66 053	\$30 355; \$66 053

[a] The dependent variable is per capita emissions of nitrogen oxides, given as quantities of NO_2 (tonnes).
[b] The dependent variable is per capita emissions of carbon dioxide (tonnes).
[c] The dependent variable is per capita emissions of greenhouse gases, given as a carbon dioxide equivalent (tonnes).
[d] Estimation procedure: maximum likelihood estimator.
***,**,* Indicate statistical significance at the 1, 5 and 10% levels, respectively. Standard errors are in parentheses.

Table 4
Public R&D expenditure for environmental protection[a]

Explanatory variable	RE[b] Specification I	RE[b] Specification II	RE[b] Specification III
Per capita GDP	0.00038*** (0.0000939)	0.00062*** (0.00005)	0.0005179*** (0.000103)
(Per capita GDP)^2	-6.62e-09*** (1.87e-09)	-1.06e-08*** (1.12e-09)	-8.59e-09*** (2.05e-09)
Population ageing	0.47436 (0.37049)	-	0.13370 (0.37843)
(Population ageing)^2	-0.00928 (0.01267)	-	0.00267 (0.01313)
Budget	-	-0.02933** (0.01340)	-0.04975* (0.02878)
(Budget)^2	-	0.00176* (0.00101)	0.00191 (0.00251)
Constant	-7.93086*** (2.56232)	-7.28945*** (0.68906)	-7.74032*** (2.53837)
Log-likelihood ratio	-55.82	-136.25	-45.98
Number of observations	101	265	91

Explanatory variable	RE[b] Specification I	RE[b] Specification II	RE[b] Specification III
Per capita GDP	0.00038*** (0.0000939)	0.00053*** (0.00005)	0.00038*** (0.00009)
(Per capita GDP)^2	-6.62e-09*** (1.87e-09)	-9.34e-09*** (1.05e-09)	-6.62e-09*** (1.87e-09)
Population ageing	0.47436 (0.37049)	-	0.47436 (0.37049)
(Population ageing)^2	-0.00928 (0.01267)	-	-0.00928 (0.01267)
Fiscally troubled	-	-1.80851*** (0.17428)	-2.56354*** (0.35929)
Constant	-7.93086*** (2.56232)	-5.92929*** (0.63412)	-7.93086*** (2.56232)
Log-likelihood ratio	-55.82	-167.48	-55.82
Number of observations	101	300	101

[a] The dependent variable is the natural logarithm of per capita public expenditure for environmental protection.
[b] Estimation procedure: maximum likelihood estimator.
***, **, * indicate statistical significance at the 1,5 and 10% levels, respectively. Standard errors are in parentheses.

Figure 1: Environmental Kuznets Curve for Nitrogen Oxides

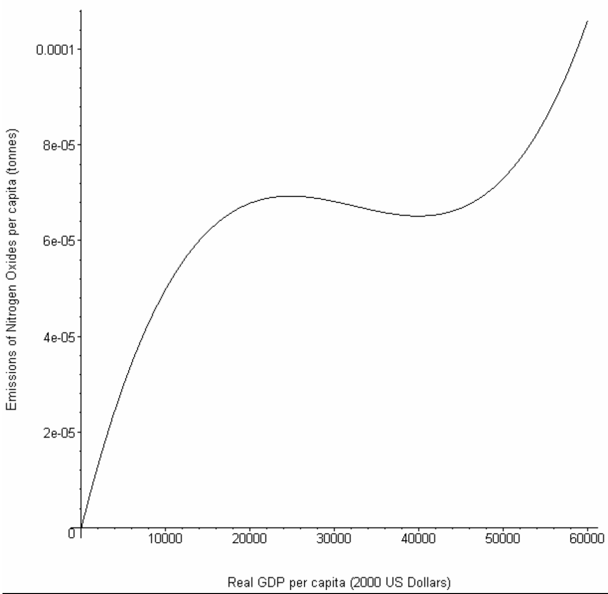

Figure 2: Environmental Kuznets Curve for Carbon Dioxide

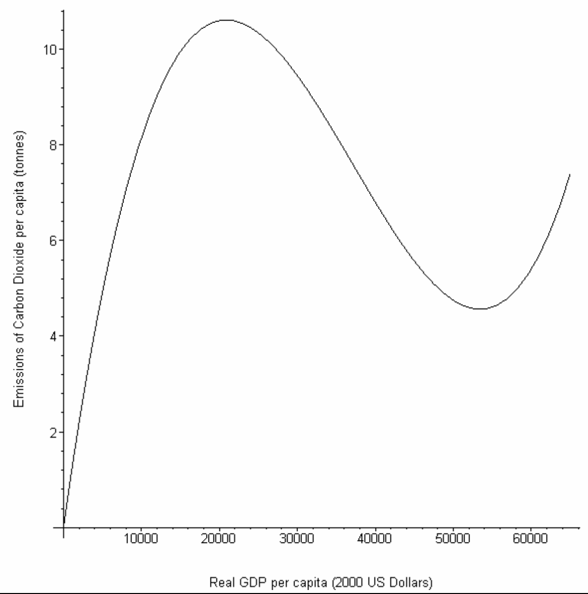

Figure 3: Environmental Kuznets Curve for Greenhouse Gases