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Population ageing and CO_2 emission: Empirical evidence from high income OECD countries

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Abstract

This article attempts to examine the effects of population ageing on CO_2 emission in 25 high income OECD countries in the framework of Environmental Kuznets Curve (EKC). Using a relatively new cointegration technique and fully modified ordinary least square in a panel data over 1980-2009 the empirical results find evidence of inverted-U shaped EKC in these OECD countries. Specifically, empirical results demonstrate that per capita CO_2 emission increases initially with economic growth; however, after reaching a per capita income level of US$ 24,657 it starts falling. With regard to ageing, the cointegrating vector indicates that a one percent increase in the share of aged population will reduce per capita CO_2 emission by 1.55 percentin the long run.

Keywords: Population ageing, Kuznets curve, Panel cointegration, CO2 emission, Fully modified least square

JEL classifications: Q56; C33; O10

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1. Introduction

Currently, population ageing and global warming are two serious issues in the forefront of policy agenda around the globe. These problems are even acute in high income countries compare to their developing counterparts. CO_2 emission has been one of the major driving forces behind the global warming and the resulting changes in weather patterns caused serious disruptions on the balance of natural system that supply the necessities of life over the last two decades. The US Energy Information Administration (EIA) states that high income OECD countries accounted for nearly 40 percent of total CO_2 emission in the world in 2009(EIA, 2011).At the same time, globally the proportion of people aged 60 and over is growing faster than any other age groupand that poses serious challenges for government policy making in the coming years.One OECD (Organization for Economic Cooperation and Development, 2005) study shows that the population over age 65 represents 20% to 30% of the population aged 20-64 in G7 countries. At current trends, this dependency ratio will reach 35% to over 50% by 2030, and 40% to more than 70% by 2050. This unprecedented demographic change will have serious impact onlabour participation rate and fiscal balance of these economies.Poterba (2001 & 2004) and Takáts (2010) demonstrate the effects of population ageing on financial market as well.Given that these two issues pose serious challenges to the humanity it is surprising that there is hardly any systematic study linking these issues together. By linking together these two drivers this article aims to investigate the effects of population ageing on CO_2 emission in 25 high income OECD countries in the framework of environmental Kuznets curve.

Although demographic trends, such as population growth or population density, are considered to be important factors driving greenhouse gas emission (O'Neill *et al*. 2001), the role of any particular age cohort, specially aged cohort (65 years and above), in greenhouse gas emissionremains virtually an unexplored area of research. The age structure can affect emission directly or indirectly. The direct link between ageing and CO_2 emission stems from the consumption pattern of the elderly people.A shift in the composition of population by age structure produces shift in the aggregate mix of goods and services demanded (O'Neill *et al.*,2010). Consumption needs of elderly people differ from those of economically active or young cohort, which affect energy requirement embodied in different consumer goods

(Schipper, 1996; Bin and Dowlatabadi, 2005). Dietz and Roza (1994) argued that higher portion of working age population consume more energy and resources and thus produce more emission. Following this logic it can be argued that as consumption level of the elderly people is generally lower than the working age cohort, they consume less energy and resources and produce less emission. In fact research shows that consumption drops significantly after retirement (Bateman *et al.,* 2001; Statistics New Zealand, 2004). For example from US Consumer Expenditure Survey (CES) Dalton *et al.* (2008) conclude that absolute levels of fuel use by older households are substantially smaller than young households. This implies that an older person uses less private transport, resulting in lower car and resource usage, which reduces pollution (McDonald *et al.,* 2006).Consumption pattern and nature of needs during the old age is such that provision of basic needs, good health, healthy social relations, security, which are less energy intensive, become more important than reckless consumption or consumption of goods and services for short-term satisfaction (McDonald *et al.,* 2006).

Indirect effect of demographic structure on CO_2 emission works through the labour market dynamics. Ageing population is associated with lower labour participation rate, which slows down economic growth and slower economic growth in turn, reduces emission (O'Neill *et al.,* 2010).However, the other view is that many of the conveniences that address age-related changes such as automobiles, elevators, air-conditioning, etc. are highly dependent on energy which implies that the growth of elderly people increase CO_2 emission. On balance, CO_2 could go either way due to population ageing. However, the indirect and direct effect of ageing population taken together may reduce CO_2 emission in the high income countries.

The contribution of this study is manyfold. First, to our knowledge, this is the first study that examines the effect of population ageing on CO_2 emission in a panel setting. Second, in this study we consider the cross-sectional dependence and use unit root test suitable for cross-sectional dependent variables. Third, this is the first study that examines short-run and long-run dynamics of EKC with panel cointegration and panel error correction methods. Finally, this paper finds evidence of inverted-U shape EKC which is a significant contribution to the existing empirical literature, where 'the evidencein favour of a reasonable inverted-U EKC relationship for carbon dioxide is mixed' (Galeotti *et al.,* 2006: 155).

The rest of the paper proceeds as follows.Analytical framework to examine the effect of ageing population on CO_2 emission is discussed in Section 2, followed by a description of data sources, estimation methods and analysis of results in Section 3. The paper concludes in Section 4.

2. Analytical Framework

The much used framework to analyse the environmental pollution-development nexus is Environmental Kuznets Curve (EKC), which postulates an inverted U-shaped relationship between the level of economic development and pollution. The EKC originated from Kuznets Curve that posits an inverted U-shaped relationship between economic development and income inequality (Kuznets, 1955).It is popularized in the analysis of pollutant-income relation in the works of Grossman and Krueger (1991 & 1995), Shafik and Bandopadyay (1992), and Selden and Song (1994). However, long before the introduction of EKC in pollutant-income analysis, Ehrlich and Holden (1971) introduced a different approach to analyse the impact of economic development on environmental pollution. The approach is known as IPAT. O'Neill and Chen (2002) describe IPAT as the approach to assess the environmental impact (I) of human activities as the product of three factors: population size (P), affluence (A) and technology (T).

This IPAT approach has been criticised for its inability to take into account many other factors that indirectly affect the environment (Shaw, 1989; Harrison, 1994). O'Neill and Chen (2002) note that this limitation of IPAT approach makes it ill-suited to micro-level analyses. Accordingly the results obtained are also not trustworthy. On the contrary EKC has been used to evaluate the impact of a wide range of factors, such as population density (Selden and Song, 1994; Grossman and Krueger, 1995; Lim, 1997; Suri and Chapman, 1998; Wu, 1998; Rupsingha*et al.,* 2004; Culas, 2007); urbanization (Torras and Boyce,1998; income inequality (Torras and Boyce, 1998; Ravallion*et al.*, 2000) trade openness (Suri and Chapman, 1998; Harbaugh*et al* 2002); literacy (Torras and Boyce, 1998; Cole, 2003). This is why Carson (2010) notes that IPAT model is a restricted version of EKC.

Despite mixed findings on the empirical robustness of EKC, this paper adopts this approach as the analytical framework to examine the effect of ageing on CO_2 emission. This is because the inconclusive findingsare attributed to the improper treatment of the time series used in various studies. Wagner (2008) indicates that while per capita income and CO_2 are typically non-stationary variables, this issue has not been sufficiently addressed by previous EKC literature. Wagner also notes that in a non-stationary panel, ignoring cross-section dependence, which most of the previous panel EKC studies did, has dramatic impact on the finding.Accordingly, this study uses all available techniques to accurately identify the data generation process so that robust finding on the estimated EKC relation is obtained. First, the basic EKC in quadratic form is specified as follows:

$$\ln pcco2_{it} = \beta_0 + \beta_1 \ln pcgdp_{it} + \beta_2 \ln pcgdp_{it}^2 + \mu_{it} \qquad (1)$$
$$\beta_1 > 0;\ \beta_2 < 0;$$

where*lnpcco2* is log of per capita carbon dioxide emission, and*lnpcgdp* is log of per capita gross domestic product (GDP). This quadratic form of EKC implies that initially economic growth is harmful for environment as it is associated with environmental degradation. However, after a certain point the relationship turns to be environment friendly, that is, economic growth reduces emission and improves environmental quality.

Next the basic EKC is augmented with demographic variable, namely share of population aged 65 years and above in total population (*odep*) as follows:

$$\ln pcco2_{it} = \beta_0 + \beta_1 \ln pcgdp_{it} + \beta_2 \ln pcgdp_{it}^2 + \beta_3 odep_{it} + \mu_{it}$$
$$\beta_1 > 0;\ \beta_2 < 0; \beta_3 < 0 \qquad (2)$$

Here the hypothesized negative sign of β_3 implies that as the economy heads towards an ageing society, CO_2 emission is reduced through the direct and indirect influences of aged population on emission.

3. Data Sources, Estimation Methods and Analysis of Results

Data from a panel of 25 OECD countries over the period 1980 – 2009 are used in this paper.[1]The two main sources of data are: World Development Indicator-2011 (WDI 2011) and The US Energy Information Administration (EIA). Data on per capita GDP and population aged 65 years and above are collected from WDI-2011, while Carbon Dioxide (CO_2) emission data are collected from EIA.

The analyses start with visual inspection of underlying data series in order to identify whether there is any abnormal movement in the variables. Figures A1, A2 and A3 in Appendix A, produce time series plots of the variables. It is apparent from these plots that none of the series experiences any such movements either in trend or level. Next we proceed to see if there is any cross-section dependence among the variables. Widely used panel unit root tests, such as Im, Pesaran and Shin (2003), Levin, Lin and Chu (2002) and Maddala and Wu (1999) are not robust if cross-section dependency exists among the variables. To identify cross-section dependence, if any, the general diagnostic test for cross-section dependence in panels proposed by Pesaran (2004) is employed and the results are reported in Table-1

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[1] Country list is given in Appendix B.

Table-1: Pesaran's (2004) cross-section dependence test

Variables	Test statistics	*p*-value	Correlation
lnpcco2	21.67	0.000	0.572
lnpcgdp	89.73	0.000	0.946
ageing	63.81	0.000	0.758

The results indicate that there is high degree of dependence among the cross-section units. In all three cases the null of cross-section independence is rejected at a very high significance level as indicated by the *p*-values. As the traditional panel unit root tests does not accommodate this dependence, panel unit root test proposed by Pesaran (2007) is employed which designed to handle this cross-section dependency and the results are presented in Table-2.

Table-2: Pesaran's (2007) panel unit root test

Series	Test statistic at level		Test statistic at first difference	
	Without trend	With trend	Without trend	With trend
lnpcco2	-3.180	-0.430	-10.870	-9.270
	(0.001)	(0.334)	(0.000)	(0.000)
lnpcgdp	1.422	5.584	-6.938	-6.690
	(0.923)	(1.000)	(000)	(0.000)
ageing	-0.620	5.253	-9.050	-4.248
	(0.268)	(1.000)	(0.000)	(0.000)

Note: Figures in the parentheses are *p*-values.

Unit root test results in Table-2 indicate that the variables are I(1). When variables are found non-stationary, the natural route of analysis is to look for long-run cointegrating relationship among the variables. Cointegration technique proposed by Pedroni (2004) is widely used for this purpose. However, one limitation of this method is that it only identifies if there is cointegrating relation among variables, it cannot estimate the speed of adjustment or error correction in the short run. Recently Westerlund (2007) proposes a cointegration technique that can also be used to calculate the error correction parameter. Unlike residual-based cointegration tests, this test is free from common factor restriction. Common factor restriction is referred to the requirement that the long-run cointegrating vector for the variables in their levels being equal to the short-run adjustment process for the variables in their first differences (Kremers *et al*, 1992). This common factor restriction is forwarded as a plausible explanation for the failure of null hypothesis in many studies when cointegration is strongly suggested in theory, such as Ho (2002). Another advantage of this new cointegration test is that it handles the problem of cross-sectional dependence by bootstrapping the critical values of the test statistics.

In this new cointegration test, four test statistics are proposed; two are designed to test the alternative that the panel is cointegrated as a whole, while the other two are designed to test the alternative that variables in at least one cross-section unit are cointegrated. The former two statistics are referred to as *group statistics*, while the latter two are referred to as *panel statistics*. *The* data generating process in this test is assumed to be as follows:

$$y_{it} = \phi_{1i} + \phi_{2i}t + z_{it} \tag{3}$$

$$x_{it} = x_{it-1} + v_{it} \tag{4}$$

where t and i represent time and space dimensions of data, respectively. In this formulation, the vector x_{it} is modelled as a pure random walk and y_{it} is modelled as the sum of the deterministic term $\phi_{1i} + \phi_{2i}t$ and a stochastic term z_{it}. This term is modelled as follows:

$$\alpha_i(L)\Delta z_{it} = \alpha_i\left(z_{it-1} - \beta_i' x_{it-1}\right) + \gamma_i(L)' v_{it} + e_{it} \tag{5}$$

where, $\alpha_i(L) = 1 - \sum_{j=1}^{p_i} \alpha_{ij} L^j$ and $\gamma_i(L) = \sum_{j=0}^{p_i} \gamma_{ij} L^j$

Now substituting Equation (2) into Equation (4) gives the following error correction model for y_{it}

$$\alpha_i(L)\Delta y_{it} = \delta_{1i} + \delta_{2i}t + \alpha_i\left(y_{it-1} - \beta_i' x_{it-1}\right) + \gamma_i(L)' v_{it} + e_{it} \tag{6}$$

where, $\delta_{1i} = \alpha_i(1)\phi_{2i} - \alpha_i\phi_{1i} + \alpha_i\phi_{2i}$ and $\delta_{2i} = -\alpha_i\phi_{2i}$

In Equation (6) above, the vector β_i defines a long run equilibrium or cointegrating relationship between the variables *x* and *y*. However, in the short run there might be disequilibrium, which is corrected by a proportion $-2 < \alpha_i \leq 0$ each period. Here, α_i is called error correction parameter. If $\alpha_i < 0$, then there is error correction and the variables are cointegrated and if $\alpha_i = 0$, then there is no error correction and the variables are not cointegrated. Group test statistics are given by[2]

$$G_\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \tag{7.a}$$

$$G_\alpha = \frac{1}{N}\sum_{i=1}^{N}\frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)} \tag{7.b}$$

and panel statistics are:

$$P_\tau = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \tag{8.a}$$

$$P_\alpha = T\hat{\alpha} \tag{8.b}$$

One distinguishing feature of this test is thatfrom panel statistic (8.b), it is possible to estimate the magnitude of adjustment of short-run deviation from long-run equilibrium relation, that is, the magnitude of error correction is $\hat{\alpha} = P_\alpha / T$. Westerlund (2007) cointegration test results are reported in Table-3. As there is cross-section dependence among the variables, robust *p*-values are also reported through bootstrap procedure.

Table-3: Westerlund (2007) panel cointegration

Statistic	Value	*p*-value	Robust *p*-value
G_τ	-3.277	0.000	0.000
G_α	-5.997	0.927	0.172
P_τ	-13.233	0.000	0.000
P_α	-5.526	0.160	0.012

Robust *p*-values in Table-3 indicate that three, out of four, test statistics are highly significant implying long-run cointegrating relation between the dependent and independent variables as specified in equation (2). The short-run error correction magnitude of this long-run relation is estimated as $-5.526/30 = -0.1842$. The magnitude appears to be small;any deviation from long-run equilibrium value takes more than five years to be corrected. This may be due to the fact that change in demographic trend is a slow moving process, so the deviation is delayed to be eliminated.

[2] For derivation of these statistics, please see Westerlund (2007).

Cointegration test gives us information only about the existence of a long-run equilibrium relation among the variables under consideration; however, it does not provide with the exact information as to the direction of influences of the independent variables on the dependent variables. To be more specific, cointegration analysis does not tell anything about the hypothesized signs and magnitudes of the coefficients in equation (2).Fully Modified Ordinary Least Square (FMOLS)proposed by Pedroni (2000)is used to get these estimates. First we estimate cubic form of the long-run basic EKC[3](without the demographic variable). While estimating the FMOLS a common time dummy is included. The result is reported in Table-4. The result of cubic form equation implies an inverted-N shape EKC, which is not consistent with the theoretical as well as empirical link between CO2 emission and economic growth. We therefore look for an inverted-U shape EKC and estimate the quadratic form of the equation. The result reported in Table-4 clearly supports the existence of an inverted-U shape EKC in the panel of 25 high income OECD countries. The turning point of this inverted-U shape EKC is estimated to be US$ 24,657 (constant 2000$).[4] The finding of inverted-U shape EKC is consistent with those ofprevious panel studies on OECD countries, such as,Dijkgraaf and Vollebergh (2001) and Galeotti *et al.* (2006). However, the turning points in these two studies (US$15,704 and US$ 15,657 respectively) are much lower than our estimate of US$ 24,657. This difference may be due to difference in base year for constant dollar (1990 vs 2000). Besides, the sample countries in those studies are not the same as the present study. As the prime objective of this study is to assess the impact of population ageing on CO_2 emission, we do not delve into this turning point issue any further. However, it is sufficient to say that if proper econometric procedures are followed, a statistically significant inverted-U shaped relationship between pollutant (CO_2 in this case) and economic growth (per capita GDP) can be identified in the long run.

[3] Although the cubic form of per capita GDP is not included in the cointegration test, this cubic form EKC is estimated to see if the N-shaped EKC exists for the sample of high income countries.
[4] Table B2 lists the countries that are below and above this turning point as of 2009.

Table-4: FMOLS estimate of cointegrating vector

Independent variables	Basic EKC (cubic form)		Basic EKC (quadratic form)		Basic EKC (quadratic form) with *odep*	
	Coef.	*t*-stat	Coef.	*t*-stat	Coef.	*t*-stat
ln *pcgdp*	-12.6076	-1.7821	10.9333	6.0902	10.4605	3.8079
ln $pcgdp^2$	3.6762	2.0463	-1.2447	-5.7721	-1.1476	-3.5525
ln $pcgdp^3$	-0.3323	-2.2934				
odep					-0.0155	-4.1131

In order to assess the impact of ageing population, the basic quadratic form EKC is augmented with the ageing variable *odep*. The results are reported in Table – 4. This Table reveals thatall coefficients are highly significant with anticipated signs (*t*- Statistics, in Table 4). In addition to an inverted-U shaped EKC, the results show that ageing population has negative influence on CO_2 emission. A 1 percent increase in the share of elderly people (65 years and above) reduces per capita CO_2 emission by 1.55 percent in the long run.

4. Conclusion

This articleaims to examine the effect of population ageing on CO_2 emission in 25 OECD countries in the framework of Environmental Kuznets Curve (EKC). Using a panel data over 1980 – 2009 and employing the state of the art econometric procedures, the empiricalresults show that population ageingreduces CO_2 emission in the long run. To be specific,the result shows that log of per capita income, income square and share of the population aged 65 years and above, is cointegrated in the long run. The error correction parameter shows that the speed of short-run adjustment is -0.1842, meaning that it takes more than five years to return to the long-run path from short-run disequilibrium. The cointegrating vector indicates that per capita CO_2 emission increases initially with economic growth; however, after reaching a per capita income level of US$ 24,657 it starts falling. With regard to ageing, the cointegrating vector indicates that, in the long run, a 1 percent increase in the share of aged population will reduce per capita CO_2 emission by 1.55 percent.

Findings of this study have significant policy implications. Evidence of inverted-U shaped EKC implies that the harmful effect of environmental degradation on economic growth is a self-limiting phenomenon. As per the finding of this study, 15 countries in the sample are already in the downward sloping region of the EKC and the remaining 10 countries are in the upward sloping region. So, CO_2 emission is in decreasing trend in the former group of countries. The emission will start falling once the latter group of countries reach the turning point. However, population ageing reduces CO_2 emission in all countries. Therefore, in the decades to come the combined effect of growth and ageing will reduce CO_2 emission in these countries without requiring any deliberate policy intervention.

The present study opens up a couple of future research avenues. It is assumed that the indirect effect of population ageing comes at the cost of economic growth. A further research may be carried out to estimate the magnitude of this indirect effect. One more possibility of further research is to examine the effect of ageing on other types of pollutant, such as SO_2(Sulphur dioxide) or water quality and so on.

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Appendix-A

Figure-A1: Time series plots of log of per capita CO_2 emission

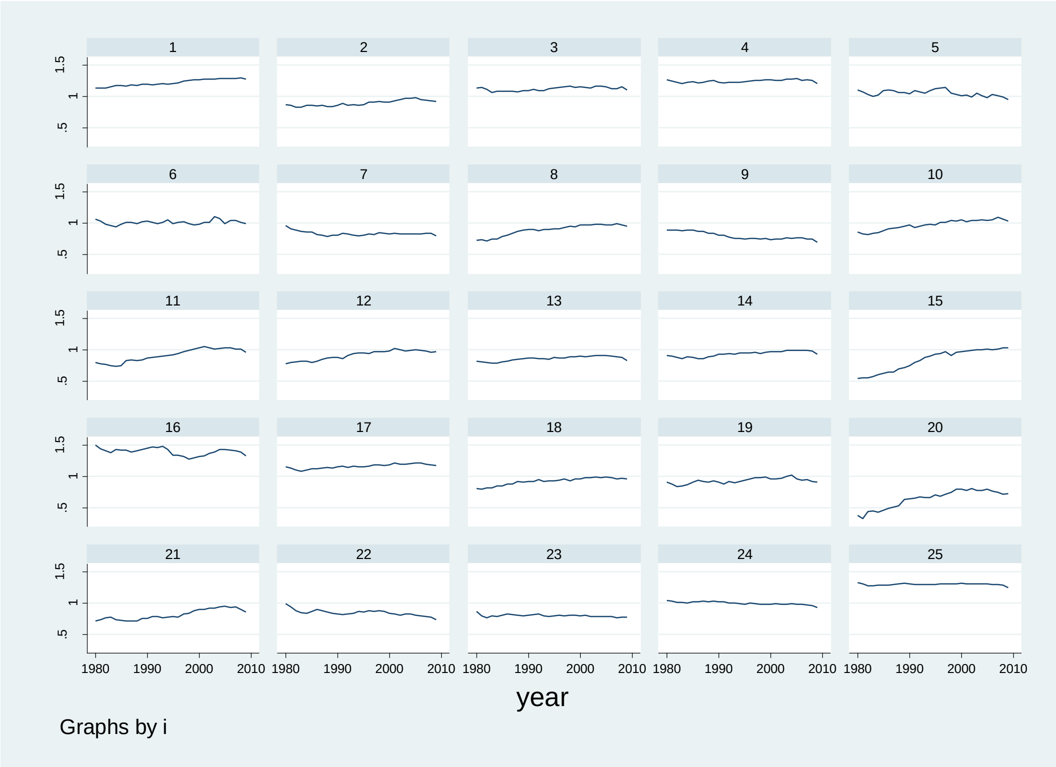


Figure-A2: Time series plots of log of per capita GDP

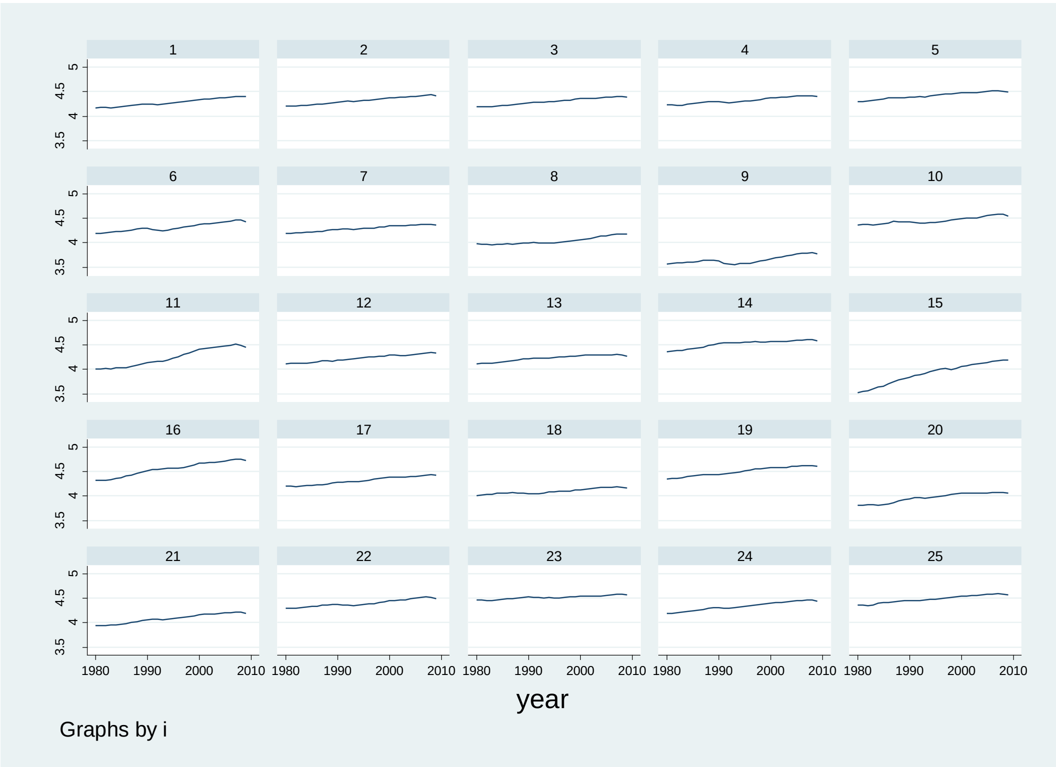
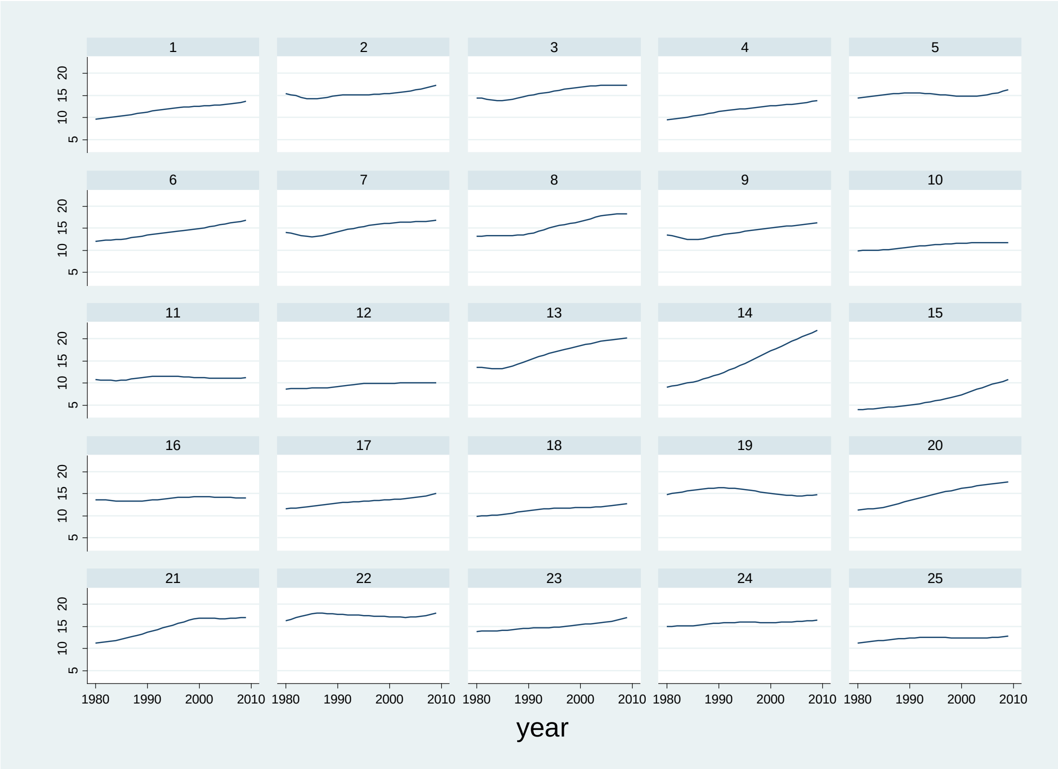


Figure-A3: Time series plots of share of old dependents (65+)



Appendix-B

Table B1: List of countries

Australia	Finland	Ireland	Luxembourg	Spain
Austria	France	Israel	Netherlands	Sweden
Belgium	Greece	Italy	New Zealand	Switzerland
Canada	Hungary	Japan	Norway	United Kingdom
Denmark	Iceland	Korea, South	Portugal	United States

Table-B2: List of countries above & below the turning point US$ 24,657

Countries above the turning point		Countries below the turning point	
Countries	Per capita income in 2009 (US$)	Countries	Per capita income in 2009 (US$)
Australia	25056.13	Belgium	24176.36
Austria	26106.16	France	22820.07
Canada	25099.03	Greece	14843.69
Denmark	30547.87	Hungary	5833.457
Finland	26495.92	Israel	21806.05
Iceland	35183.82	Italy	18479.19
Ireland	28502.44	Korea, South	15443.62
Japan	38177.37	New Zealand	14711.74
Luxembourg	52388.14	Portugal	11588.07
Netherlands	26093.96	Spain	15533.77
Norway	40935.96		
Sweden	30899.25		
Switzerland	37032.33		
United Kingdom	27259.19		
United States	37016.04		