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Age Dynamics and Economic Growth: Revisiting the Nexus in a Nonparametric Setting*

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ABSTRACT

This paper explores the relationship between the growth rates of per capita income and age-structured population in a non-parametric setting. Analysis in this framework provides us with new insights about the interaction structure: significant non-linear relation between the two and interesting 'direct' and 'feedback' effects on growth. Nonlinearity is found to be a major source of growth fluctuations in OECD and non-OECD countries.

JEL Classification codes: C23, J10, O47.
Key words: Age dynamics, Economic growth, Non-parametric panel.

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1 Introduction

The contribution of demographic fluctuations to economic growth is now an established phenomenon.[1] in this context, there is mounting evidence that aggregate population growth, *per se*, cannot provide adequate insight into economic growth variations as rigorous empirical research over the last four decades have not delivered a conclusive answer to whether aggregate population growth would exert positive, negative or no impact on growth rate of per capita income. A sizable body of empirical (Kelley and Schmidt, 1995, 2001; Crenshaw et al., 1997; Birdsal et al., 2001; Mishra, 2004) and very recently the theoretical (Boucekkine et al., 2002) literature have shown that a clear and meaningful relation between economic growth and population can be understood when the latter is disaggregated into various components, viz., population of different age groups (0-14: young age; 15-64: Working age; 65+: retired cohorts) so that the contribution of each group can be studied and the net impact can be wieghed. The empirical scrutiny has, so far been restricted to the parametric domain in attempting to elucidate the theoretical arguments (e.g., convergence-patterns model as in Kelley and Schmidt, 1995, 2001). An evident outcome of parametric specification is that the relation between economic-growth and age-structured population is linear, relegating a complex feedback mechanism which can turn the relation highly non-linear. While non-linearity can have substantial implications for economic growth and policy, the empirical literature has thus far did not pay attention while trying to illustrate the empirical relevance of many growth theoretic models. In an attempt to delineate a clear relational structure between the two, we revist the problem in a non-parametric setting, where the flexibility of the non-parametric framework allows to examine the non-linear structure of the relationship.

Kelley and Schmidt (1995, 2001), Crenshaw et al. (1997) use parametric model to explain how younger age, working age and retired age population growth impact economic growth in a panel of developed and developing countries. The relationship between age-structured population and economic growth were assumed to be linear although there could be high possibility of the existence of a non-linear relation between the two. While parametric specification of a growth model, viz., convergence pattern approach have been extensively used in the empirical literature, its pitfalls against 'letting the data speak as it is' makes it less realistic to modeling demography-economic growth relationship. There are ample evidence that population growth by itself can be non-linear however linearity along with increasing returns to scale can generate per capita income growth in the economy (Jones, 2003). One may question then: Does the age-structured population and economic growth share linear relation? Can non-linear age-structure cause growth variations in developing and developed economies?

It is known that 'linearity' is a restrictive case of non-linear structure and in that sense it is more realistic to assume that age-specific population will have varied impact on economic growth due to the their 'resource-using' and 'resource-creating' abilities in the economy. Based on a linear parametric panel regression framework, many important empirical studies have found that while younger age-population decelerate economic growth via excess resource consumption, the working age population speeds up the growth due to their ability to contribute to resource creation. Retired age population is also assumed to be resource-users. Therefore, the *a priori* assumption of linear relation between population age-structure and economic growth disregards the inherent dynamics arising out of their interactions which could have enormous policy implications. To our opinion, the relation between age-structured population and economic growth is more complicated than it appears to be. Our purpose herewith is to explain the dynamics of population in a non-parametric setting. Unless we have strong reasons to believe a linear

[1] Malmberg and Lindh (2005) explains that about 30 percent of world output growth is attributed to demographic variations.

or non-linear functional form of certain degrees could explain the demography-economic growth linkage, it is necessary that we model the relationship without pre-specified assumption about their functional relation. Moreover, since the exact specification of the function has important implications for growth and policy, it seems realistic to investigate the linkage in a more general setting. In this paper we attempt to answer to these concerns via non-parametric modeling of our panel data on age-specific population and per capita income of about 110 countries spanning over 40 years.

Specifically we study (i) if some intuitive and definitive conclusions can be drawn about the age-structured population growth and economic growth in this setting. The analysis is purported for a set of OECD and non-OECD countries since the economic structure and population dynamics of these countries are vastly different and therefore a distinctive analysis based on non-parametric method is purported to provide useful policy recommendations for transforming the demographic resources into better economic opportunities. (ii) We would also like to shed light on the idea whether non-linear demographic age structure can be a source of growth variations in OECD and non-OECD countries.

2 Data and econometric specification

2.1 Data

The variables under investigation in this paper are per capita income growth, aggregate population growth and population growth of different ages, viz., 0-14, 15-64, and 65+. Per capita income data have been collected from Penn World Table 6.1 and is defined as GDP per capita with purchasing power parity (PPP) which is based on 1996 international US dollars. Population data are from the World Bank Development Indicators. We have a panel data of 110 countries (total of OECD - 24 and non-OECD - 86) spanning over four decades : 1960-2000. The growth rates of (age-specific and total) population and per capita income are based on logarithmic differences of period t and $t-1$. The 'lag' or 'feedback' effect of age-dynamics on economic growth, i.e., how population growth at period $t-1$ on income growth at period t is also explained as a part of the model specification of our data, where we generate a first difference of the data. Table 1 provides the descriptive statistics of the variables considered in our investigation for OECD and non-OECD countries. Notice that, as expected OECD countries mean per capita growth rate (0.028) is higher than non-OECD countries (0.015), while the latter have higher total population mean growth (0.023) than OECD countries (0.009). The common feature of both set of countries is that the mean growth rate of retired age people (population 65+) is higher than the work force (population 15-64), though the work force is seen to grow faster than the young age population (population 0-14). However, work force grows at a faster rate (two times higher) in non-OECD countries (0.025) than OECD (0.011), which is a recent empirical trend.

Table 1: Descriptive Statistics

Variable	OECD (1000 Obs.)				Non-OECD (3400 Obs.)			
	Mean	Std. Dev	Min.	Max.	Mean	Std. Dev	Min.	Max.
Per Capita GDP growth	0.028	0.031	-0.095	0.135	0.015	0.072	-0.543	0.575
Population growth 0-14	-0.001	0.014	-0.042	0.035	0.020	0.015	-0.049	0.080
Population growth 15-64	0.011	0.008	-0.004	0.036	0.025	0.010	-0.059	0.079
Population growth 65+	0.020	0.017	-0.020	0.288	0.028	0.021	-0.201	0.201
Total population growth	0.009	0.007	-0.005	0.032	0.023	0.010	-0.059	0.078

2.2 Econometric specification

Our econometric specification consists of a generalized additive model (GAM) for panel data.[2] Additive models are widely used in both theoretical economics and econometrics. Deaton and Muellbauer (1980) provides examples in which a separable structure is well designed for analysis and important for interpretability. From econometric viewpoint, this specification has the advantage of avoiding the 'curse of dimensionality' which appears in non-parametric regressions when many explanatory variables are accounted for. It also allows to capture non-linearities and heterogeneity in the effect of explanatory variables on the response variable. Moreover, the statistical properties (optimal rate of convergence and asymptotic distribution) of the regression function estimator is well known (see e.g., Stone, 1980). The structure of the model is given by

$$y_{it} = \sum_{j=1}^{p} f_j(\mathbf{x}_{it}^j) + \mu_i + \varepsilon_{it}, \qquad i = 1, \cdots, N; \quad t = 1, \cdots, T, \tag{1}$$

where y_{it} denotes the response variable, $\mathbf{x}_{it}^j$ are j explanatory variables for $j = 1, \cdots, p$, the f_j are unknown univariate functions to be estimated; μ_i is unobserved individual specific effects for which we allow arbitrary correlation with $\mathbf{x}_{it}^j$. Thus, we make no assumption on $\mathbb{E}(\mu_i|\mathbf{x}_{it}^j)$ for any set of dates $t = 1, \cdots, T$. For the idiosyncratic error ε_{it}, we assume independent and identical distribution, but no restriction is placed on the temporal variance structure. The unobserved effect μ_i can be eliminated by differencing or by computing the within transformation. Lagging the model (1) one period and subtracting gives

$$y_{it} - y_{i,t-1} = \sum_{j=1}^{p} f_j(\mathbf{x}_{it}^j) - \sum_{j=1}^{p} f_j(\mathbf{x}_{i,t-1}^j) + \eta_{it}, \tag{2}$$

where $\eta_{it} = \varepsilon_{it} - \varepsilon_{i,t-1}$, and we assume (*first difference* assumption, FDA) that $\mathbb{E}(\eta_{it}|\mathbf{x}_{it}^j, \mathbf{x}_{i,t-1}^j) = 0$, for $i = 1, \cdots, N$ and $t = 2, \cdots, T$. It should be noticed that the latter assumption is weaker than that of strict exogeneity which drives the within estimator (see, e.g. Wooldridge, 2002).[3] The FDA assumption identifies the functions

$$\mathbb{E}\left[y_{it} - y_{i,t-1}|\mathbf{x}_{it}^j, \mathbf{x}_{i,t-1}^j\right] = \sum_{j=1}^{p} f_j(\mathbf{x}_{it}^j) - \sum_{j=1}^{p} f_j(\mathbf{x}_{i,t-1}^j), \tag{3}$$

with the norming condition $\mathbb{E}[f_j(.)] = 0$, since otherwise there will be free constants in each of the functions. In practice, we base our estimation on the "backfitting algorithm" (see, Hastie and Tibshirani, 1990).

3 Results

Figures 1 and 2 present the results of GAM estimation of the non-parametric panel data of our demography-economic growth relationship for OECD and non-OECD countries. Each figure consists of eight subsets of graphs which include the impacts of population growth aged 0-14, 15-64, 65+, and total population, each with their 'lagged' or feedback effects on economic growth. The results are interpreted from two perspectives. First, analysis of the relational structure, which emphasizes on the 'curvature' of the demography-economic growth relation, i.e., whether they are linear or non-linear. By studying this feature we seek to answer to the following concern: Is the relation between age-structured population and

[2] See e.g. Hastie and Tibshirani (1990) and Stone (1985) for further details on GAM.

[3] In our situation, strict exogeneity precludes any feedback from the current value of GDP per capita growth rate on future values of population growth rate, which is not a realistic assumption.

economic growth linear? Second, we explain the effects of age-structured population growth in terms of 'direct effect' and 'feedback effect' on economic growth.

Insert Figure 1

[Caption: GAM estimation of 'age-dynamics' effects on economic growth: OECD countries. The solid curves are the non-parametric fits $\hat{f}_j(.)$. Dashed curves are the 95% bootstrap pointwise confidence intervals. The straight solid lines represent the zero line.]

Insert Figure 2

[Caption: GAM estimation of 'age-dynamics' effects on economic growth: Non-OECD countries. The solid curves are the non-parametric fits $\hat{f}_j(.)$. Dashed curves are the 95% bootstrap pointwise confidence intervals. The straight solid lines represent the zero line.]

With respect to the relational structure, a study of these figures gives the first hand impression that age-specfic as well as total population growth's effect on per capita income growth of both OECD and non-OECD countries are highly non-linear. To test for the significance of nonlinearity in our model, we use the 'gain' statistic (see, Hastie and Tibshirani, 1990 for details).[4] The 'gain' is computed as $184.479 > \chi^2(71.058) = 91.736$ and $336.230 > \chi^2(136.030) = 164.2492$ respectively for OECD and non-OECD countries data. As a result, there is a strong evidence of nonlinearity.

This finding provides a new evidence, in contrast to the linearity assumption of the wide array of empirical models of the demogrpahy-economic growth relation built on parametric framework. The non-linear curvature of the population components suggests that the relation between economic growth and age-structured population involves far more complex mechanism than is usually assumed with a linear structure. In the linear case, stochastic demographic shocks may eventually wither away with little or no long-run effect on economic growth, whereas nonlinearity can induce the shocks to work in an intricate way so that the response of the economy to such shocks could stretch beyond 'mean reversion' in the long-run. Indeed, nonlinear demographic structure can thus be a potential source of growth fluctuations in OECD and non-OECD countries.

The effects of age dynamics on economic growth can be interpreted as follows. A comparison of the two figures (Figures 1 and 2) evinces that a clear distinction emerge for (dynamic) effects of population for OECD and non-OECD countries. For instance, while the growth of younger age population (0-14) will continue to have positive influence on economic growth of OECD countries and would continue to do so, a downward trend is observed for non-OECD countries although the effect is still positive. This is an important finding as non-OECD countries economic policies are generally targeted towards population 'control'. Here we find that the young age population will improve economic performance for non-OECD countries which is already apparent in case of OECD countries.

Interestingly, the contribution of working age population (15-64) for OECD countries to their economic growth will steadily rise while for non-OECD countries, the contribution will decline although

[4] Intuitively, the 'gain' is the difference in normalized deviance between the GAM and the linear model. A large 'gain' indicates a lot of nonlinearity, at least as regards statistical significance. The distribution of this statistic can be approximated by a chi-square $\chi^2\,(df = df_g - df_l)$, where df_g denotes the degree of freedom of the GAM. It is computed as the trace of $2\mathbf{S} - \mathbf{S}\mathbf{S}'$ where $\mathbf{S}$ is the smoothing matrix; and df_l is the degree of freedom of the linear model (here we use the first difference linear model estimated by ordinary least squares). In the latter case, we have $\mathbf{S} = \mathbf{X}\left(\mathbf{X}'\mathbf{X}\right)^{-1}\mathbf{X}'$, where $\mathbf{X}$ is the matrix of regressors.

there is a possibility of reversal and have positive effect. Moreover, the 'negative' trend is not significant while looking at their confidence band and concentration of observations above the 'zero line'. There could be exceptions for some non-OECD countries where work-force accumulation could still have negative direct effect on growth possibly due to high accumulation of young age-population in the past, so that the net effect could be negative. Moreover, the growth of retired cohorts (65+) in OECD countries is observed to exert negative effects on economic growth. The same may not be true for non-OECD country blocks as a 'hump-shape' is observed for the growth impact of retired cohorts on their economic growth although the effect would be mostly negligible or slightly negative for those countries. As opposed to the conventional wisdom, aggregate population growth will have positive effect on economic growth of non-OECD countries, while the effect is observed to be negative for OECD country blocks.

Interesting implications for growth emerge when we compare the 'feedback-effect' of population on economic growth for both set of countries. Consider the case of young age population. It appears from Figures 1 and 2 that the feedback effect of this population component shares a similar structure in both OECD and non-OECD countries. However, the effects can be discerned by studying their magnitudes: the stock of young age population at period $t-1$ will continue to have exert growth-enhancing effect in both OECD and non-OECD countries, the effect of which will be higher for non-OECD and lower for OECD countries (compare the magnitude above the zero line). As expected accumulation of work force will have positive externalities on growth, i.e., the economy will grow more due to the stock of 'human capital' and all synergetic effects of work force, e.g., higher knowledge creation, etc. Interestingly, non-OECD countries are likely to enjoy more growth opportunities from the accumulation of working age population than OECD countries hinting at the relative stagnation of the latter economies with respect to high addition of work force where it induces instant and rapid growth synergies in OECD countries and slower but steady in OECD countries.

4 Conclusion

In this paper we provided an alternative approach to study the effects of age-dynamics on economic growth. Though there are many economic theoretic and statistical grounds to choose between parametric and non-parametric specification of growth model, the *a priori* assumption of a particular functional form in the parametric panel growth regression so far provided somewhat unrealistic ground to study demography-economic growth relation. A true picture of the structure of demography-economic growth relation can occur when no a priori constraint on the data is imposed so that meaninglful policy implications can be derived. The non-parametric specification in this paper threw light on this aspect of the problem and found that a highly non-linear demographic structure characterizes age-structured population and economic growth and that the non-linearity can be a potential source of growth fluctuations in OECD and non-OECD countries.

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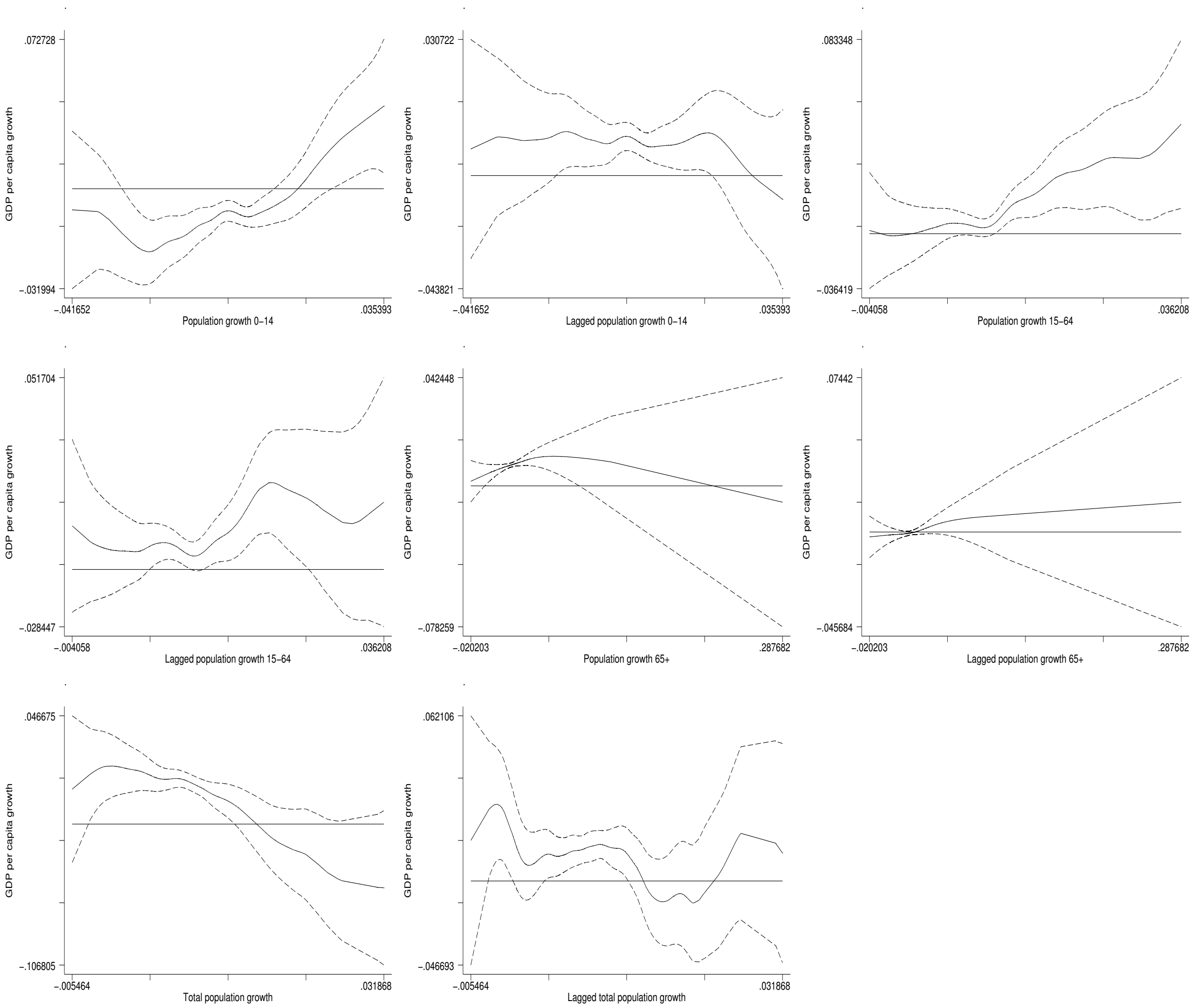

Figure 1: GAM estimation of 'age-dynamics' effects on economic growth: OECD countries. The solid curves are the non-parametric fits $\hat{f}_j(.)$. Dashed curves are the 95% bootstrap pointwise confidence intervals. The straight solid lines represent the zero line.

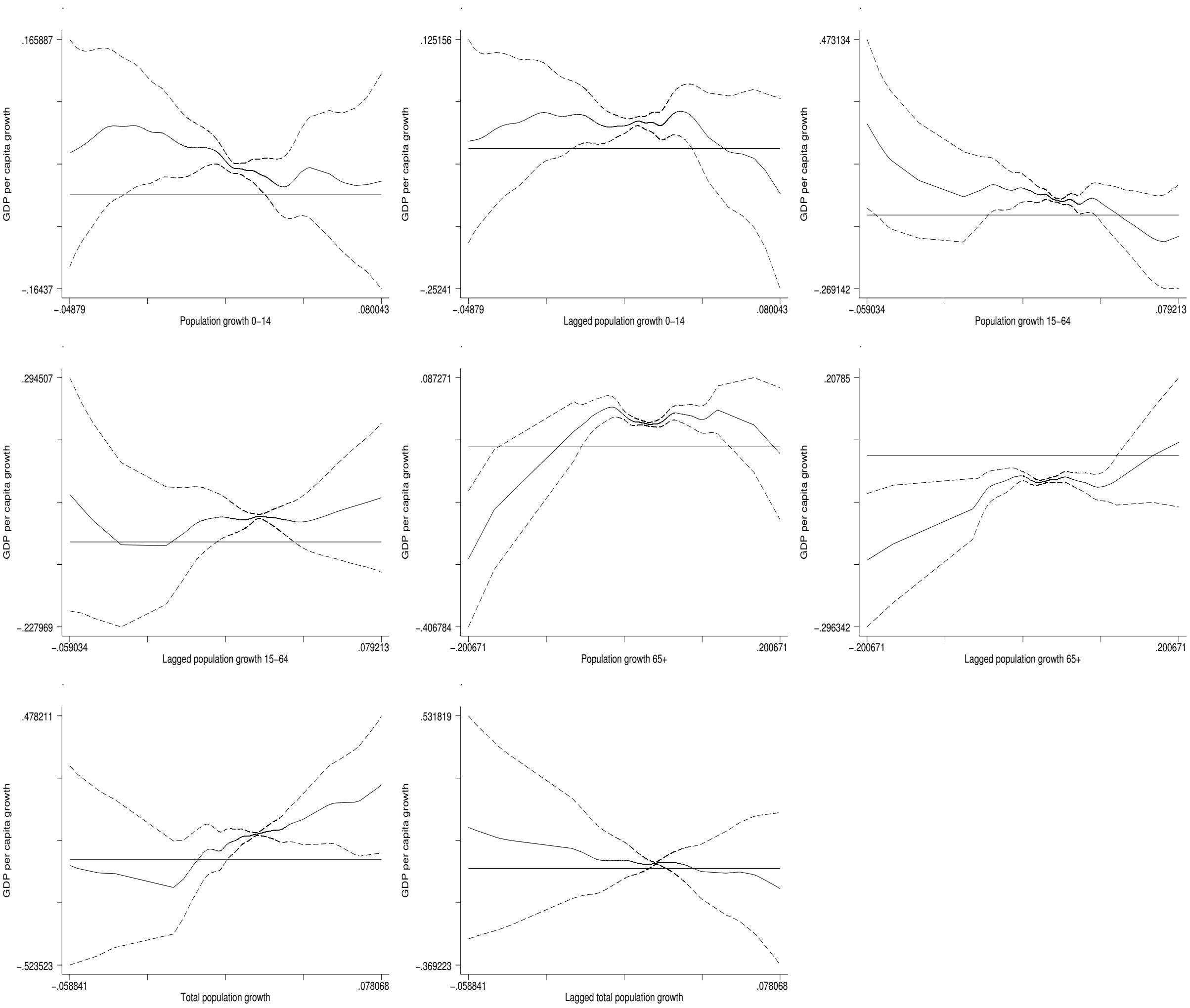

Figure 2: GAM estimation of 'age-dynamics' effects on economic growth: Non-OECD countries. The solid curves are the non-parametric fits $\hat{f}_j(.)$. Dashed curves are the 95% bootstrap pointwise confidence intervals. The straight solid lines represent the zero line.

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