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UMR 7522

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Auteur

Tapas K. MISHRA

Document de travail n° 2006–**17**

Juin 2006

Faculté des sciences économiques et de gestion
Pôle européen de gestion et d'économie (PEGE)
61 avenue de la Forêt Noire
F-67085 Strasbourg Cedex

Secrétariat du BETA
Christine Demange
Tél. : (33) 03 90 24 20 69
Fax : (33) 03 90 24 20 70
demange@cournot.u-strasbg.fr
http://cournot.u-strasbg.fr/beta

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

UNIVERSITÉ LOUIS PASTEUR STRASBOURG

A Further Look into the Demography-based GDP Forecasting Method*

Tapas K. Mishra
BETA, Lousi-Pasteur University
Strasbourg 1, France
and IRES, Department of Economics,
Université Catholique de Louvain, Belgium.
e-mail: mishra@ires.ucl.ac.be

June 27, 2006

Abstract

Demography-based income forecasting has recently gained enormous popularity. Malmberg and Lindh (ML, 2005) in an important contribution forecast global income by incorporating demographic age information where the variables were assumed to be stationary. Drawing on the insights from recent theoretical and empirical advances, in this paper we re-examine the stationary assumption and argue in favour of a more flexible framework where 'stationarity' is a limiting condition of the stochastic demographic behavior. Based on Mishra and Urbain (2005) where we showed that the age-specific population display varied long-term and short-term dynamics, we invest this idea in the present paper for long-term projections of per capita income (till 2050) of a set of developed and developing countries and the World income. We find that GDP forecast that corroborates demographic information have higher forecasts than without demographic information - a result consistent with ML, but we find that embedding 'memory' features of demographic variables lead to higher forecast that ML. The relevance of stochastic shocks in GDP forecasting is drawn in this paper and implications of these forecast in the presence of fluctuating age-shares in those countries are discussed.

JEL Classification: C13, E32, E43, E63 J11 C33 O47.
Key words: Global income forecasting, Long memory, Demographic components, Economic growth

*I sincerely thank David de la Croix and F. Shadman Mehta for their comments which improved the content of the paper. I also thank James Davidson for providing numerous suggestions in course of estimation of the paper and Théophile Azomahou and Claude Diebolt for their comments. Financial support from the Belgian Federal Government, Grant PAI P5/10,"Equilibrium theory and optimization for public policy and industry regulation', is gratefully acknowledged. The usual disclaimer applies.

1 Introduction

An overwhelming spurt of research in the last two decades both in theory (e.g., Boucekkine et al. 2002) and empirics (e.g., Kelley and Schmidt 1995; Malmberg and Lindh, 2005) emphasize that population growth, specifically the changes in the demographic components (viz., age structure, life expectancy rate, fertility and mortality rates, etc.,) exert substantial influence on economic growth and development. As Malmberg and Lindh (hereafter, ML, 2005) state, three arguments underline the importance of age structure for per capita income. First, the savings argument, which states that countries with high child-dependency rates will be low and this may lead to low productivity (Coale and Hoover, 1958). Second, a high dependency rate implies a low worker per capita ratio which directly leads to low per capita income due to pure accounting effect (Krueger, 1968 and Janowitz, 1973). Third, as demonstrated by Lindh and Malmberg (1999), age structure within the working-age population is also of enormous importance. These arguments have important implications for long-term per capita income forecasting. Historically, such forecasts have been based primarily on assumptions about the rate of technological change.

In the empirical growth literature it has been suggested that a stable statistical relation exist between age structure and per capita income. Therefore, conventional population projections can be used to forecast future trends in income growth. An apparent outcome of this perceived advantage is a paradigmatic shift in economic growth forecasts - from the conventional *technology-based* forecasting to the recent *demography-based* forecasting. Malmberg and Lindh (2005) in an important research have provided the underpinning and usefulness of demography-based income forecasting method. In this paper, we evaluate the key assumptions of the demography-based income forecasts and suggest modifications in the forecasting model by accounting for the 'dynamics' of demographic changes and possible presence and persistence of shocks while forecasting per capita income. We are motivated by the fact that embedding historical information in a model actually enriched its explanatory power of a future event. Demographic shocks of any magnitude - smaller or bigger - while being embedded in the income forecasting model is expected to take into account the (hidden) demographic shocks exogenous or endogenous.

The conventional methodological underpinning of the demography-based income forecasting method rests on the critical assumption that (components) of population remain 'stationary' (or stable over time) implying that a shock to the population growth series would not bring about remarkable changes in the future growth trajectory. In other words, demographic components are assumed to possess 'short memory' ability to remember past shocks. This typical feature of demographic variables provided the forecasters the necessary platform to increasingly employ them in long-run economic forecasting. Interestingly, a recent theoretical development - which demonstrates that due to its endogenous nature[1] population growth and its

[1] In the sense that past population growth affects the economy so that it is endogenously determined as part of an interacting system.

components may imply unstable (or chaotic) pattern - seems to have been overlooked in the forecasting literature. Following this theorization, a shock to the population series in the remote past can significantly affect its future growth trajectory and in turn, economic growth. Therefore, the future growth path of these variables can become very sensitive to their initial distributions (Prskawetz and Feichtinger 1995). Moreover, the population series may even experience many shifts due to endogenous cycles (or phase switch) caused by frequent demographic changes and changes in the demo-economic policy (Day, 1993). Thus, endogenous nature of population growth combined with endogenous phase switching can give rise to chaotic or unstable pattern in demographic variables. Recent empirical findings (e.g., Gil-Alana 2003; Mishra and Urbain, 2005) also provide credence to this claim.

In view of these developments, it appears to us that the stationary assumption underlying the growth of population and its components is far too narrow as it downplays the role of possible shocks in the series which could have more than mere short-run impacts on long-term projections. In fact, the 'strength and length of memory' of demographic variables to remember past shocks governs their future growth path and shapes the pattern of interaction with the economic system. Taking this as the starting point, this paper aims to provide a new dimension to the population and thus, the demography-based forecasting methods by extending the domain of demographic variables from stationarity (i.e., no possibility of stochastic shocks) to nonstationarity (i.e., possibility of stochastic shocks which are characterized by long memory).

This point was taken in Mishra and Urbain (2005), where components of population change are shown to be characterized by non-stationary processes. Building on this research, in this paper we employ long memory data characteristics of population growth and its components to forecast per capita income of selected developed and developing countries. By doing so we in fact embed historical information about the stochastic behavior of demographic variables in the forecasting model - a fact which was so far sidelined in the empirical demographic research. Though time series methods are receiving immense popularity in demographic forecasting processes (for instance Lee and Tuljapurkar, 1994), the propounded methods still lack flexibility and does not appropriately account for the different demographic dynamics, precisely, the length of demographic shocks and its corresponding impact on long-run growth of the economy. The central aim of this paper is to propose modifications in the conventional demographic forecasting methods by suggesting a long-memory process for the evolution of the demographic variables and consequently incorporate these dynamics in the forecast of per capita income of some developed and developing countries.

2 Problems in Income Forecasting

Income forecasting is a challenging task. The conventional technology-based forecast suggests that future trajectory of income growth principally depends on technological change. However, empirical specification of the parameter of technology change is endowed with many problems, important of them is the extent of uncertainty inherent in technological change and the specification of other growth related variables such as inflation, money supply growth etc. Interestingly, recent research seems to have overcome some of the inherent difficulties in the technology-based forecasting method by suggesting an alternative, viz., demography-based forecasting of economic growth. Lindh and Malmberg (1999) show that variations in age-specific population growth account for a significant variations in some of the key macroeconomic fundamentals, like inflation, savings, etc. Therefore, demographic variables, like age shares are highly recommended as instrument for forecasting income growth. Nevertheless, this apparent appeal of demographic variables as instruments for economic growth forecasts may not be taken too easily as the implementation of the approach still remains a wide academic debate.

A recommended way to perform demography-based income forecast is to regress GDP on demographic variables and make forecast for some future date. It may be noted that, demographic projections are uncertain in nature. To a first order approximation this is a question of the assumptions made on fertility, migration and mortality in demographic projections (ML, 2005). Moreover, probabilistic demographic forecasts can also be included into the model to deal with this issue in an explicit way (e.g., Prskawetz et al. 2004). Drawing on the effect of age structure on economic growth, the authors derive the uncertainty of predicted economic growth rates using probabilistic demographic forecasts in case of India, where they combine the effect of social infrastructure alongside demographic variable (i.e., age structure) for forecasting economic growth. Though probabilistic methods provide certain range of values with confidence interval for forecast, its biggest limitation as being probabilistic has called for alternative methods. The regression approach *a la* ML (2005) assumes significance in this context.

Following Lindh and Malmberg (1999), the age-structure information can be used in the growth regression in panel data and forecast economic growth based on the demographic information. However, a common worry in panel data is the problem of heterogeneity both across countries and over time. Thus the question is whether it is legitimate to assume a homogeneous model for such a variety of countries, different in size, location, history, institutions and natural resources. In fact, in some sense, every country is a unique economic system related to its neighbors by a multitude of different relations (ML, 2005). The authors posit that:

> 'Using a panel estimation approach confers substantial advantages. Not only does the number of observations increase substantially, but it also allows us to control for unobservable that are constant over the estimation period as well as common time-specific effects. The price to be paid for this is that we need to assume that a more or less general model applies to all countries in the sample. It is, however, neither inconceivable nor impossible to account for some country differences within the model'.

Among many possible problems in panel regression analysis (for instance, the presence of structural break), ML (2005) note the importance of regression of non-stationary time series which result in spurious outcomes. Phillips and Moon (1999) demonstrate that this problem can be substantially ameliorated in a panel context by the cross-section information. However, the extent of non-stationarity can still induce problem in panel regression. Bai and Ng (2003) and others suggest the use of stochastic common factor model to take account of the possible non-stationary feature of regressors in the panel data observing that in recent years panel data for many demographic and macroeconomic variables are available for large time and cross-section dimension. If non-stionarity is is a serious concern in individual time series, it can infest the same problem when considered in a panel data. Therefore, substantial amelioration of spurious outcome may not eliminate the problem completely. Care needs to be taken to treat the non-stationary nature of variables in the panel in order that one attempts to achieve a good forecast. A panel forecast method of GDP in line with ML but taking non-stationary demography features needs further theoretical and empirical development, which is not the focus of this paper although we have preserved it for future research. In this paper, we take note of the non-stationary problem of demographic variables and induct their characteristics in the GDP forecast for each individual country.

Finally, there is a problem of assuming a common data generating process (DGP) for all countries in the panel and perform income forecast for a set of countries in the global level. The standard way is to assume that cross-country observations are drawn from a DGP that is at least partly common to all countries, viz., the demographic transition and the concurrent industrialization and aging of the population. ML (2005) reiterate that while their observations from more developed countries provide some information to forecast the evolution of the less developed countries, their sample contains little information regarding the aging society and how it will adapt to a rising dependency burden. Recent work on non-stationary panel seems to offer a solution to this problem by identifying the set of countries in terms of the common stochastic shocks they share and then it is possible to forecast for the those blocks of countries. While this could be an interesting direction of research, complying with the scope of this paper we would only focus on univariate income forecast by incorporating stochastic demographic information in the model.

3 Model

This section outlines the usefulness of long-memory methodology for demography-based income forecasting. ML's (2005) forecasting technique is described first before we elaborate on the long-memory framework in the income-forecasting framework. ML start with a model for a panel regression in levels of the logarithm of per capita GDP, y, on the logarithm of age shares, x, and a trend function $V(t)$, t being the time period:

$$log(y_{it}) = V(t) + \sum_{k=0-14}^{65+} \gamma_k X_{kit} + \zeta_i + \epsilon_{it} \tag{1}$$

ζ_i is the country-specific intercept, $k = 0-14, 15-29, 30-49, 50-64, 65+$. In this equation, GDP per capita is assumed to be described by Cobb-Douglas index of age-shares, and $V(t)$ is intended to capture technological change. This is a standard production function specification with the exception that population age shares have been substituted for production factor intensities. To incorporate the effects of life expectancy and heterogeneity, ML proposed the following model:

$$log(y_{it}) = \alpha log(e_{0it}) + \sum_{k=0-14}^{65+} (\beta_k + \theta_k log(e_{0it}))\gamma_k X_{kit} + \zeta_i + \nu_t + \epsilon_{it}, \tag{2}$$

where $log(e_{0it})$ is the log of life expectancy at birth. Theoretically, the model allows for changing age share coefficients contingent on how far the demographic transition has progressed. To account for time-specific effects, ν_t has been added to the equation. ML (2005) thus describes *simple model* (Eq.1) and *interaction model* (Eq.2) to analyse the effect of demographic variables on per capita income. Based on their previous work (Lindh and Malmberg, 1999), ML suggests that an aggregation of the age groups (viz., children 0-14, young adults 15-29, mature adults 30-49, middle aged 50-64, and old age 65+) works well in growth equations without running into the collinearity problems. The limits for these functional groups are not exact. However they vary both with time and culture, as well as the institutions that transmit and govern the economic effects of the age group. ML assumes that this specification is a pragmatic approximation for estimating growth effects from the continuous age distribution. The age distribution in turn proxies for the actual functional changes over the life cycle which are the real causes for the income effects.

Equations 1 and 2 assume that demographic variables, viz., age-specific population and life expectancy, are stationary. Non-stationary nature of these variables in the panel data would cause spurious regression as mentioned above. However, as some research (Mishra and Urbain, 2005) show that age-specific population may contain long-memory component and therefore shocks are persistent in these series. This observation might create additional problem in the panel regression. Bai and Ng (2002, 2003), and Im, Pesaran and Shin (2003), among others provide formulation to deal with nonstationarity in panel data that enables testing of unit root in a panel framework. A natural question that may arise is: what if one or all of the demographic variables (in Eq.1 or 2) are non-stationary? How do we forecast if demographic variables are characterized by a long-memory process? It is closer to reality to assume that demographic variables might be affected by some shocks, endogenous or exogenous, which can stay with the series for some period of time in the future. Apparently, ML's specification rules out the possibility of such shocks and if at all some exist, the authors argue, are ameliorated by panel structure.

Granger and Joyeux (1980) showed that long-memory in a time series can arise due to aggregation of individual series. Even though the extent of memory of shocks are ameliorated in the panel, the effects are not completely neutralized. Moreover, individual countries demographic dynamics can substantially affect forecasting performance. To address these concerns let's consider the DGP of y_{it} in a long-memory framework. The income growth equations are described with and without demographic variables, similarly as ML's (2005) *simple* and *interaction* model. We re-write ML's equations in a long memory framework with one notable exception. The formalization of our model concerns with univariate long-memory framework, as there is virtually little literature on the study of long-memory characteristics in a panel data set up. Two variants of the model are considered, viz., model with and without demographic structure. In case of the former, we first introduce population growth, and then induct age-shares information. Aggregate population growth is assumed to suppress dynamic information in the model, as aggregation greys out dynamic behavior of individual components of population. This problem can be ameliorated by introducing age-shares, which exhibit wide variability and are dynamically linked to GDP fluctuations. For a discussion on this refer to Lindh and Malmberg (1999). The following equations describe our model.

$$Model1 : (1-L)^d \Phi(L)(y_{it} - \mu^1_{it}) = \mu^2_{it} + \Theta(L)\epsilon_{it} \tag{3}$$

$$Model2 : (1-L)^d \Phi(L)(y_{it} - \mu^1_{it}) = \mu^2_{it} + \gamma n_{it} + \Theta(L)\epsilon_{it} \tag{4}$$

$$Model3 : (1-L)^d \Phi(L)(y_{it} - \mu^1_{it}) = \mu^2_{it} + \sum_{k=0-14}^{65+} \beta_k x_{kit} + \Theta(L)\epsilon_{it} \tag{5}$$

L is the lag operator, $\Phi(L)$ and $\Theta(L)$ are autoregressive (AR) and moving average (MA) polynomials. $i = (1, ..., N)$ refers to countries, and $t = (1, ..., T)$ denotes time. ϵ_{it} is assumed to be normally distributed. n_{it} is the aggregate population growth rate. μ^1 and μ^2 are (Type 1 and Type 2) intercepts. Type 1 intercept accounts for structure and changes in the dependent variable, i.e., whether an independent and/autonomous factor govern the growth of the dependent variable. Type 2 intercept enters as an explanatory variable, which in the absence of other regressors, account for some independent exogenous changes occurring in the system. x_{kit} are population age shares. $(1-L)^d$ describes the fractional differencing operator which is given by

$$(1-L)^d = \sum_{j=0}^{\infty} h_j L^j \tag{6}$$

where $h_0 = 1$ and

$$h_j = \frac{-d\Gamma(j-d)}{\Gamma(1-d)\Gamma(j+1)} = \frac{j-d-1}{j} h_{j-1}, j \geq 1. \tag{7}$$

Note that Type 2 intercept is induced in the model as an exogenous drift. The contribution to the process takes the form $(1-L)^{-d}\mu_{it}^2$, which since the pre-sample terms are truncated, gives a sequence of the form

$$\mu_{it}^2 \sum_{s=1}^{t} h_s = O(t^d), \tag{8}$$

when $h_t = O(t^{d-1})$, by a standard result on summation series. This implies that the process is non-stationary, with infinite mean and variance in the limit, for $d > 0$. For fractional process without drift, the model is stationary for $0 < d < 0.5$.

Equation 5 is the univariate long memory representation of ML's (2005) *simple model* which incorporates only population age shares. *Interactive* model as in ML (2005) with life-expectancy at birth can be introduced; however we feel that it is not required at this stage given the objective of the paper. Since the thrust of the paper lies in introducing fractional feature of demographic variables in GDP forecasting, long-memory dynamics in age-specific population can to some extent account for inclusion of life-expectancy in the forecast, although with no absolute certainty. Our idea is to keep the model simple and study the effects of long-memory on GDP forecast. Therefore, the interaction variables as in ML can be introduced in future research.

The DGP described by Eq.3 states that y_{it} is governed by the structure of memory, the autoregressive and by moving average polynomial representation of *iid* shocks. Eq.4 has broader encompassing as it accounts for the effect of aggregate population growth. Eq.5 is still broader as it segregates the total population into age shares and plugs them into the model. The peculiarity of these equations is that we allow for the possibility of demographic dynamics in the growth equation, where shocks can have more than mere short-run impacts on the historical trajectory of y_{it}. In fact, depending on the non-integer values and sign of d, short, long, or intermediate memory properties can arise. For instance when $d < 1/2$, the series has finite variance, but for $d = 1/2$, the series has infinite variance. The y_t is stationary and invertible when $-1/2 < d < 1/2$. For $d = 1/2$, standard Box-Jenkins techniques will indicate that differencing is required and provided that $d < 1$, differencing will produce a series whose spectrum is zero at zero frequency. This heavily-used model is a special case of an autoregressive fractionally integrated moving average ($ARFIMA(p, d, q)$) process.

A detailed description of the properties can be found in the survey of Baillie and Bollerslev (1994). In the demographic context see (Mishra and Urbain, 2005) for a comprehensive analysis. Ding, Granger and Engle (1993) suggests that ARFIMA models estimated using a variety of standard estimation procedures yield "approximations" to the true unknown underlying DGPs that sometimes provide significantly better out-of-sample predictions than AR, MA, ARMA, GARCH, simple regime switching, and related models, with very few models being "better" than ARFIMA models, based on analysis of point mean square forecast errors (MSFEs).

- **Estimation strategy**

ML (2005) employ a panel data framework to forecast global income. In this paper, we resort to univariate forecast of world income as well as the income of a sample of developed and developing countries with and without consideration of demographic age structure. Our strategy is as follows. First, employing ARFIMA methodology we forecast total and age-specific population of different countries till 2050. The population age-structure in our case comprise of three categories, viz., young 0-14, working age 15-64, and retired cohorts 65+. Thus, we perform long-memory forecast of total population and each age group and based on the forecasts, we calculate population growth rate, $n_t = [ln(TotalPop_t) - ln(TotalPop_{t-1})]$ for each country. The age shares are calculated as: $x_{(0-14)it} = (\frac{PopulationAge(0-14)}{TotalPopulation})_{it}$, $x_{(15-64)it} = (\frac{PopulationAge(15-64)}{TotalPopulation})_{it}$, and $x_{(65+)it} = (\frac{PopulationAge(65+)}{TotalPopulation})_{it}$ for $t = (1960, ..., 2050)$.

Second, we perform ARFIMA regression of y_{it} using the regressors as in Models 2 and 3 taking into account the demographic information and availability of GDP data till current period (in our case it is 2000), and then use the parameter estimates to forecast GDP till 2050 given our forecast population growth and age shares till 2050. ML (2005) use medium variant population projection till 2050 to forecast GDP. Contrarily, we have used our time series forecast of age-specific population which takes into account the demographic variations and persistence of possible shocks in the economic and demographic system. For notational convenience, we will refer to forecast from Eq.3 as Raw model, and from Eq. 4 and 5 as Demographic model.

4 Data and Empirical Results

4.1 Data

In this section we discuss the forecasting results based on raw and demographic models of GDP. The results are compared with ML (2005) and implications are drawn from the analysis. We have used data for real GDP per capita (collected from Penn World Table version 6.1) at purchasing power parity in 1996 US dollar. Information on age-specific population has been collected from the World Bank Development Indicators. For real GDP, the sample is from 1960-2000 and for age-specific population the sample extends till 2003. We have selected a set of developed and developing countries to compare our results with ML (2005). The selected countries are Belgium, Sweden, USA and Japan among developed countries and India and China, among developing countries. We have also performed forecasting for the World real GDP data to study the pattern of global variation of income till 2050. The results are discussed in two steps. First, we analyse the pattern of age-specific population till 2050 for different countries. Specifically, we will concentrate on providing intuition on how population of different vintages would act upon economy's resources. Second, based on the calculation of age-shares and population growth rate, the forecasting results are discussed. In course of comparison, reference is made to the forecast from the raw model as it would provide an idea about how the allowance of demographic information in the model changes forecast pattern.

4.2 Empirical results

4.2.1 Variations in age shares

In this sub-section, we analyze the variations in age shares till 2050 for the selected developed and developing countries. The analysis is purported to give an idea of the effect of different age shares on economy's resources. Rising younger age population (i.e., 0-14) mounts pressure on the economy by consuming resources that could have otherwise been used for capital formation. Working age population (i.e., 15-64) contributes to economy's growth by creating resources. The retired age population (i.e., 65+) also exerts pressure on the economy, because like younger cohorts they also force government to plan a chunk of economy's resource for consumption, pension, and retirement benefits. An economy therefore, needs to plan beforehand for the inter-generational distribution of resources considering at how different age-shares would look like, say five decades from now. A meticulous economic planning is therefore proves handy for efficient management and mobilization of resources. More so, the dynamics of age-share movement is important for explaining long-term growth of income. To have an idea about how various age shares in some developing and developed countries behave, refer to Figure 1 below.

Population age shares till 2050 have been calculated based on the time series projections of age-specific and total population of different countries till 2050. Unlike ML (2050), who relied on the medium variant UN projections, we have performed an ARFIMA forecast for total and age-specific population. Figures for total population forecasts have been adopted from our earlier estimates[2]. A striking common feature among all the developed and developing countries (in Figure 1) is that young age population share (0-14) will continue to fall in the coming decades, at a faster rate for developed countries (viz., Belgium, Japan, Sweden, and USA) and slower for the world and the developing ones (viz., China and India). This is not surprising given the recent trend of population growth in developing and developed economies. For the former, population growth of young cohorts will decline slowly as the current high rate will guide its future trajectory. Similar logic applies for developed countries where the current lower rate of young population growth would further lower the rate in the coming decades. The pattern is a clear indication of an autoregressive structure, where past high(low) growth of population results in current high(low) growth[3].

[2]Please refer to the Paper 3 of the thesis.

[3]Note that, demographic process evolves in a slower pace than other economic processes, as

Some striking features emerge from Fig.1: Number of worker (i.e., population 15-64) will experience a steady global rise. Similar trend is observed among developing countries, viz., India and China, which will continue to dominate the economic power in the coming decades. Though the share of younger cohorts will continue to fall for these two most populous countries, China is likely to experience a rise in retired cohorts, which is more than India's in 2050. Due to the smaller and declining share of retired age population, India is likely to be in a better position in terms of economic growth, as she would divert lesser resources for consumption end.

A typical situation is observed for the European countries, viz., Belgium and Sweden, where till the recent period, young and retired people age share are almost at par, however the share of the latter is deemed to gradually exceed the young age share till 2050. Similar structure is also observed for working age share, therefore these countries will experience a similar trend in GDP growth in the next decades. Among developed countries, USA's working age people share will remain constant throughout the coming decades though a steady decline will be observed for young and retired age shares. Given these dynamic demographic information, in the next subsection we examine the pattern of income forecast for these countries and compare our results with ML (2050).

4.2.2 Real GDP per capita and age-specific population forecast

Table 2 presents the results obtained by estimating the model in eq. 2, in the first column without the interaction terms. The second and third column report the interaction regression, direct age effects in the second column, and coefficients for the interaction with *log e0* in the third column. The estimates show that life expectancy is positively correlated with per capita income. The estimates of interaction effects also indicate that the basic hypothesis is valid; life expectancy modifies the correlation with demographic structure by shifting life phases. Of course, these estimates also imply that a substantial impact of life expectancy is through the interaction with the age share variables.

Table 1 summarizes the ARFIMA forecasting models, which are selected on the basis of Schwarz criteria and highest likelihood of the estimated models. We have estimated $ARFIMA(p, d, q)$ model with a maximum order of p and q set equal 2. The chosen model for each country has been used for forecasting. Forecasting results with and without demographic information are presented in Table 3. All estimations have been performed in *Time Series Modelling (TSM)* package version 4.10 of James Davidson (2005).

From Table 3 it can be observed that younger age population is likely to fall in all developed and developing countries. For instance, among the European countries, Belgium will experience a fall from about 1690.4 thousand in 2010 to 1485.5 thousands in 2050. Whereas for Sweden it is 1499.7 thousands in 2010 and 1383.1 thousands in 2050. Given the current trend this would mean, Sweden will

multitude of factors act and interact with demographic process to ensure faster and slower evolution.

Figure 1: Plot of Age-specific population age shares: 1960-2050

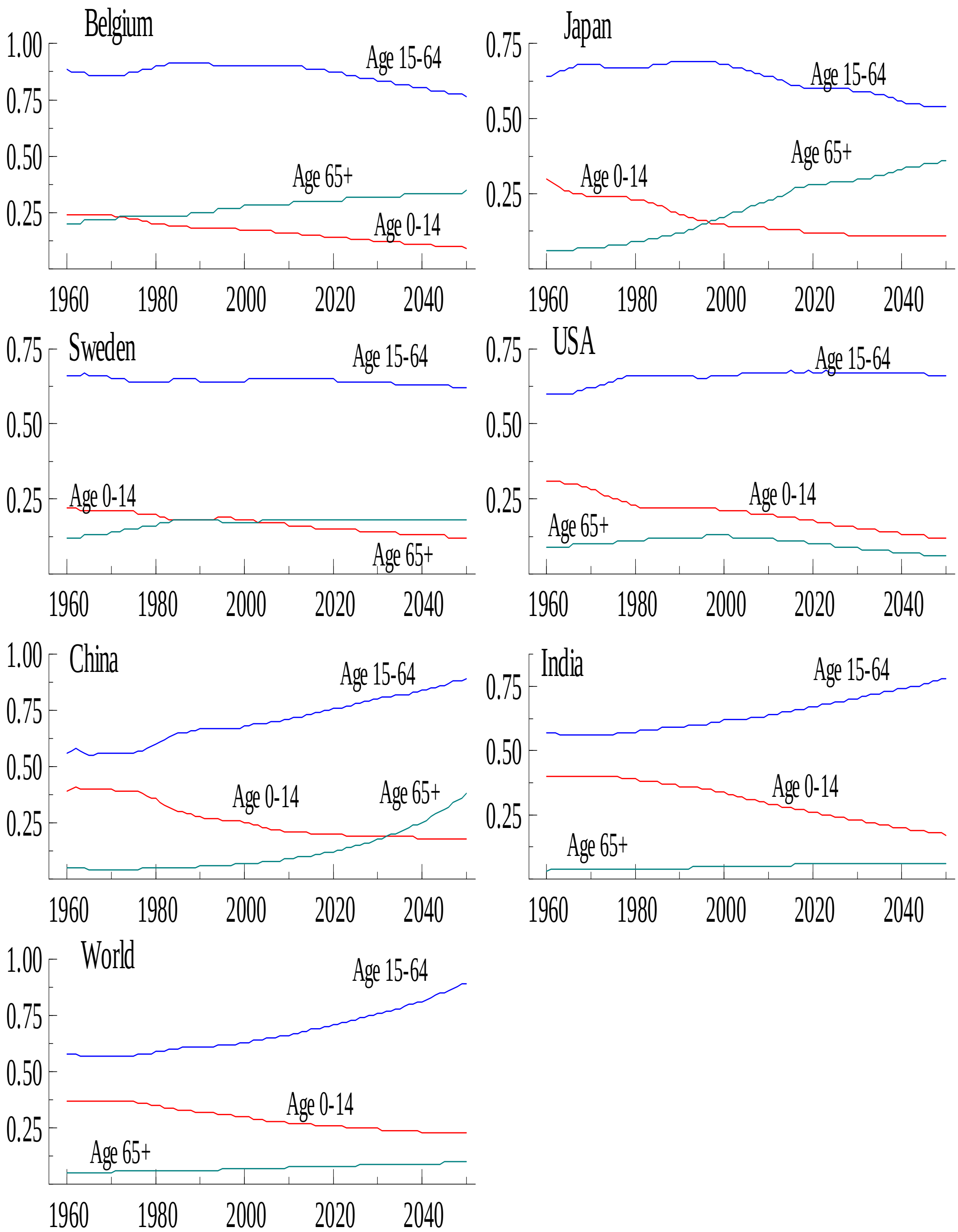

Table 1: Selected ARFIMA(p,d,q) Models for Forecasting

Countries	Age 0-14	Age 15-64	Age 65+	Real GDP (Pop Growth)	Real GDP (Age Shares)
Belgium	(1,1+d,2)	(2,1+d,2)	(1,1+d,0)	(2,d,0)	(1,d,0)
Sweden	(1,1+d,0)	(1,1+d,0)	(1,1+d,0)	(1,d,0)	(1,d,2)
Japan	(1,1+d,0)	(1,1+d,1)	(1,1+d,0)	(1,d,1)	(1,d,0)
USA	(1,1+d,0)	(1,1+d,0)	(1,1+d,0)	(2,d,1)	(1,d,2)
China	(1,1+d,0)	(1,1+d,2)	(1,1+d,0)	(0,d,0)	(0,d,2)
India	(1,1+d,0)	(2,1+d,0)	(1,1+d,0)	(2,d,0)	(2,d,0)
World	(1,1+d,0)	(1,1+d,0)	(1,1+d,0)	(1,d,0)	(1,d,1)

Note: Model selection based on Schwarz criteria

experience about 10.3 percent decline and Belgium with a 15.5 percent decline in the younger population. At the same time, these countries would see an increase in the number of working age people, viz., Sweden about 18 percent and Belgium about 8.37 percent. Given the number of retired age people in 2005 (viz., 1754.6 and 1587.6 thousands for Belgium and Sweden respectively), there won't be substantial change in these age groups in 2050. The effect of these age-structure changes can be calculated for GDP in 2050.

Examining the case of Sweden for instance, we find that the per capita GDP would stand at about 45752.4 dollars in 2050 without demographic variations in the forecasting model (Model 1). However, once stochastic aggregate population dynamics is embedded in the model a significant rise in the per capita GDP forecast is observed (which is 53156.7 dollars in 2050). Further improvement in the forecast is warranted once stochasticities in the population components (Model 3) are taken into account. The results are indicative of the fact that (1) a demography-based GDP forecast puts an optimistic figure for future, (2) Comparing the estimate (which is 59754.5 dollars) with ML (2005) estimate for Sweden for the year 2050 (54000 dollars in the interaction model), we find a slightly higher forecast for GDP per capita, possibly due to our consideration of long-memory features of demographic shocks. Notice that although inducting demographic information in the forecasting model delivers higher prediction than the raw model (where no demographic information is included), it is difficult to judge whether consideration of demographic dynamics alone can exude better and higher forecast. We have not so far considered any competing model (like a forecast model with other non-demographic variables) to lend a comparison. However, our assessment is based on a priori finding of some researchers like ML (2005) that demography-based income forecasting models are as good as other competing framework. In general our results comply with ML's conclusion about the relevance of demographic dynamics in income forecasting.

In ML(2005) a hump around 2010 for Sweden is observed, where after reaching an estimated income level of about 48000 dollar, the amount declines to about 36000 dollar in four decades. Our forecast does not predict such humps,rather it shows a steady increase over time. The possible reason may be in the assumption of the data generating process (DGP). Long-memory DGP assumes certain degree of smoothness, where the forecast is made simultaneously considering the effect of shocks (the memory parameter), the endogenous system (the autoregressive parameter) and some possible external shocks (the moving average parameter), besides the built in demographic information for the forecast. ML's DGP follows a panel structure, and it is possible that due to the differences in DGPs, the smoothness of the forecast may follow in one and disappear in the other.

ML (2005) showed that due to recent baby boom around 1990, Sweden would have very fast growth over the next two decades while the US would stagnate earlier and Japan already stagnated. The interaction model which loads increased longevity has a much more positive path but still stagnating in the long run. Similarly, considering some examples of less developed economies, the authors showed that the 'difference between forecasts between India and China have a similar pattern as for the USA although at lower levels and the simple model stagnates later in China and later still in India'.

Table 2: Parameter estimates of ARFIMA regression between GDP and age-structured Population relation. Sample (1960-2000)

Country	Belgium	Sweden	Japan	USA
Intercept	12.873 (2.497)	9.335 (0.04)	6.626 (2.310)	11.553 (0.34)
Age 0-14	-2.969 (1.198)	-1.364 (1.816)	-1.052 (0.858)	-0.795 (1.291)
Age 15-64	3.101 (1.169)	1.503 (2.236)	1.571 (1.019)	8.939 (2.460)
Age 65+	4.596 (1.173)	-0.308 (1.231)	-1.752 (1.081)	-0.231 (3.578)
d	-0.067 (0.040)	0.653 (0.221)	0.029 (0.004)	0.241 (0.220)
AR1	0.561 (0.055)	-0.153 (0.181)	0.492 (0.050)	
AR2				
MA1		-0.987 (0.170)		-0.128 (0.125)
MA2		-0.289 (0.130)		-0.015 (0.022)
R2	0.99	0.99		0.99

	China	India	World
Intercept	8.936 (0.915)	6.526 (0.168)	9.651 (0.661)
Age 0-14	-8.132 (0.970)	-1.567 (0.529)	-0.753 (0.268)
Age 15-64	1.389 (1.309)	1.101 (0.411)	0.034 (0.150)
Age 65+	-0.835 (6.094)	2.813 (1.460)	1.258 (0.922)
d	-0.022 (0.008)	0.334 (0.145)	0.086 (0.036)
AR1	0.438 (0.265)	0.438 (0.265)	0.291 (0.313)
AR2	-0.089 (0.140)	-0.089 (0.140)	0.494 (0.289)
MA1	-1.064 (0.072)		-0.567 (0.238)
MA2	-1.040 (0.072)		
R2	0.98	0.99	0.99

Note: Standard errors are in parentheses.

Table 2 reports the parameter estimates of ARFIMA regression between real GDP per capita and share of age-structured population for a set of developed and developing countries. In general age-specific population are observed to exert expected impacts on the countries income per capita, viz., theoretical caveat is that age 0-14 have negative, age 15-64 exert positive and age 65+ have negative effect on the resources of an economy. While theoretical prediction about the sign of effects stand true under the most general circumstance, say under linearity assumption of the model, it verily depends upon the economy's strength in the form of 'how quickly the feedback-effect' takes place from the accumulation of these groups of population. From table 2 we observe that Sweden, Japan, USA, and China exhibit the expected effects for the specific age-groups while for Belgium and the world GDP's response to retired age population (age 65+) is still positive. Although negative impact of this age group is expected, the finding of positive sign may not be perturbing given that the model does not take into account all the non-linear structure arising out of the interactions among each age-group and the GDP. Notice also that significant stochastic demographic shocks (the estimates of d) is observed for Sweden, Japan, USA, India and the world. Therefore, non-inclusion of such shocks in the forecasting model (as done in ML for instance) may not reveal much about the trajectory and impact of demographic shocks in delivering a better forecast. Positive and larger d in the model indicates long-memory population shocks, which in our estimates are mostly mean-convergent; larger demographic shocks can induce high non-linear interaction between the demography and economic growth system.

Table 3: ARFIMA(p,d,q) Forecast of Global Income and Population Age

	Years	Age 0-14	Age 15-64	Age 65+	RGDP	RGDP(Pop)	RGDP(Age)
	(in '000)	(in '000)	(in '000)	(US dollar)	(US dollar)	(US dollar)	(US dollar)
Belgium	2010	1690.4	6996.0	1790.1	25616.7	26849.4	26769.0
	2020	1621.3	7176.7	1812.7	27173.6	30424.4	31445.1
	2040	1528.1	7392.3	1802.4	29941.5	36461.1	42916.0
	2050	1485.5	7461.4	1792.9	31101.1	38330.5	49662.2
Sweden	2010	1499.7	5984.9	1641.7	27419.2	27364.4	27419.2
	2020	1453.9	6242.3	1749.2	31319.6	32663.1	33189.9
	2040	1404.7	6794.0	1954.5	40578.8	45297.2	49069.8
	2050	1383.1	7089.7	2077.0	45752.4	53156.7	59754.5
Japan	2010	16903.9	83033.5	29173.0	28652.6	32209.0	33657.8
	2020	15610.5	76496.5	40741.4	32273.4	37835.4	41647.6
	2040	13492.6	57988.5	81145.6	39458.3	48242.7	62630.0
	2050	12499.0	47382.1	114119.3	44002.4	53050.5	75886.9
USA	2010	61944.9	210238.9	36351.8	34787.0	34821.8	44311.5
	2020	62317.7	237755.9	36098.3	36827.5	39104.8	54176.3
	2040	61389.9	304979.5	32048.3	39695.8	45889.9	63196.2
	2050	61759.3	343863.5	29378.0	41233.2	49217.3	66303.6
China	2010	279847.5	989544.5	119252.7	4226.0	5312.9	7054.4
	2020	252710.5	1143952.6	166208.8	5406.7	7244.5	12562.9
	2040	207939.0	1510573.6	325787.3	8326.5	11864.4	17518.3
	2050	187587.4	1734101.5	456343.0	10024.6	14401.7	17094.3
India	2010	349759.1	766814.3	65447.3	3320.9	3449.6	3521.4
	2020	347666.9	938464.2	87640.6	4427.5	4571.5	4634.1
	2040	317426.0	1405635.4	157156.9	7704.0	7797.0	8656.8
	2050	294195.6	1715131.0	210449.3	10328.9	10532.3	12200.1
World	2010	1856122.1	4497354.9	508387.8	6517.2	6478.2	6666.2
	2020	1920315.3	5261885.6	606221.0	6840.4	6985.6	7318.8
	2040	2028891.2	7060313.4	805324.0	7416.0	7728.0	8239.5
	2050	2078173.6	8244031.1	914378.6	7615.2	7956.1	8453.2

Note: RGDP: Real GDP forecast without demographic information, RGDP (POP) is with population growth and RGDP(Age) is with age share information

Table 4: Malmberg and Lindh (2005) Forecasts (in dollars)

Countries	Simple model	Interaction model
China	9000	13500
India	7200	10200
Japan	40000	75000
USA	44000	62000
Sweden	42000	54000

Note: Figures are calculated from Malmberg and Lindh (2005) for the year 2050. Actual figures are not available, hence these are closer approximations

Comparing our long memory GDP forecasts[4] with ML's it can be observed that India's annual per capita GDP will grow to about 12000 dollar in 2050 using Model 3, i.e., with age shares. In case of China, the same model forecasts 17094 dollars in 2050. These estimates are higher than ML's interaction model (Table 4). Note that the raw model does not predict substantial difference in the forecast between India and China. However, as we induct demographic information in the model, viz., model 2 and 3, the differences become prominent. For instance, accounting for population growth in the model, China would have per capita GDP of 14401 dollars in 2050, while India will have 10532 dollars during the same time. For India the increase is very little, which is about 200 dollars more than the raw model. For China, Model 2 improves forecast about 4000 dollar more than the raw model (model 1 without demographic information). The forecast further widens when we accommodate age-shares in the model. For India, there is a significant change of forecast values from 10532.3 dollars with Model 2 to 12200.1 dollars in 2050. For China, although the figure is much higher than India's, looking at the growth (from 2010 till 2050), it can be easily seen that, India's income growth is faster than that of China. The possible reason could be due to the specific pattern of age-share variation (as explained in the preceding subsection). The 95% confidence band for these estimates are provided in Table 5.

Among developed countries, Japan's per capita GDP is estimated to be higher than other countries (both developed and developing). The raw model forecasts 44002.4 dollars in 2050, which increases to 53050.5 dollars when we introduce population growth in the model. However, a hopping 75886.9 dollars is reached when we incorporate age-share dynamics in the forecasting model.[5] ML's interaction model

[4]Note that our forecasts are basically point forecasts sequentially performed over long period of time. Although these forecasts do not reveal much about parameter uncertainty in comparison to interval forecasts, a study of the estimated confidence interval for the point forecast provides some idea about the range of values the forecast would fall. Moreover, all the forecast plots accompany density forecast figures to help explain the amount of uncertainty. Standard practice in time series based forecasts is to take account of point forecasts, at the least while estimating an ARFIMA type of model.

[5]Even though Japan's population shows in general a declining trend except an expected continuous rise of retired population till 2050, a declining population does not necessarily entail negative economic growth. Productivity growth can still boost GDP per capita, and if large enough, even

forecasts about 75000 dollars, although the simple model (without life-expectancy rate) projects GDP about 40000 dollars for Japan in 2050. For USA, the demographic model with population growth projects GDP per capita at 49217.3 dollars with the lower limit of the 95% confidence band calculated at 45615.4 dollars and upper limit at 51948.1 dollars (Table 4). While for age-share model, the forecast is still higher (65186.0 dollars) which is also more than ML's estimates from simple and interaction models. The lower and upper 95% confidence band for our age-share model are 59994.0 dollars and 70122.6 dollars respectively. Generally tighter confidence bands are indicatoin of lower amount of uncertainty where the forecast value would range between 5 percent confidence interval. Looking at the forecast values and their confidence band we observe narrow confidence band for our forecasts which is a rough measure of predictive uncertainty. Predictions from a model with lower uncertainty are the ones which are more reliable. However, to examine if our forecasts are 'accurate', we need to find an alternative measure.

Note that accuracy of forecast is related to reliability in the following way: Accuracy = precision + reliability. For our purpose it is necessary to comment upon the precision of our forecasts. Standard convention to check for forecast accuracy is either to examine the *ex post* error terms or to simulate the *ex ante* errors. Concerning the first possibility, a rough measure of forecast accuracy is therefore to compare the mean-square error of the models although a study of the simulated ex-ante error terms can throw light on the predictive accuracy. To compare between 'raw and demographic' models we may take note of the AIC (Akaike Information Criterion) values; a model with higher AIC is generally a better model and more informative. Comparison of the mean square error across models would reveal which of them have better predictive accuracy. Table 6 reports results of the mean square errors from the estimation of forecast models with and without demographic information (Model 3 here). It is evident that the mean square error is smaller for the demographic model for all countries and therefore our stochastic demography-based income forecast model can be said to provide better prediction than the raw model.

For USA the younger population will remain more or less constant over the decades, while work force would increase and the number of retired people will also experience concurrent decrease. This seems to have an income effect which would mean that the less number of retired people would continue to contribute to the income growth along with the then current work force. Given the constant growth of younger cohorts, USA is likely to be in the advantage and might experience accelerating growth in income in the coming decades. However, Japan's income growth will far exceed USA in 2050 and would be the richest nation on the earth. Also it may be noted that World income will continue to grow along with each

overcome the effect of population decline. The coefficients of stochastic shocks, d is higher for USA and lower for Japan. Greater magnitude of long-memory demographic shocks would reduce predicted values while interacting with different population components. Although the concomitant rise in retired population and a fall in the work-force, Japan is accompanied by systemic social changes including the employment system, the social security system and the financial system where this high-per capita income appears plausible and sustainable.

age-specific population group. In 2050, the per capita GDP for the world will be 8453.2 (with Model 2) which is a growth of about 36 percent in 5 decades. Inclusion of demographic variations increase forecast from 7615.2 dollars to 7956.1 dollars (using population growth) and 8453.2 dollars (with age shares). A general trend thus may be noted from 3 - that inclusion of demographic information improves forecast. Raw model does not incorporate demographic variations, and therefore, GDP forecasts can be assumed to be governed mainly by exogenous shocks in the form of moving average parameters, or some endogenous shocks (reflected in the form of autoregressive structure). However, corroboration of demographic information enriches the forecasting model so that variations in income can be accounted for by demographic variations.

Table 5: Confidence Band for Real GDP per capita Forecast (in US dollars)

Country/Variables	Lower 95% CI	Upper 95% CI
BELGIUM		
1. Pop Growth	32016.3	45752.4
2. Age Shares	47429.5	52052.1
CHINA		
1. Pop Growth	2070.4	74906.8
2. Age Shares	6730.5	22925.4
INDIA		
1. Pop Growth	5171.4	20179.0
2. Age Shares	7492.1	19574.8
JAPAN		
1. Pop Growth	49365.2	57411.5
2. Age Shares	64796.1	87203.5
SWEDEN		
1. Pop Growth	17038.0	161943.0
2. Age Shares	56670.0	62818.2
USA		
1. Pop Growth	45615.4	51948.1
2. Age Shares	59994.0	70122.6
WORLD		
1. Pop Growth	6646.9	9269.6
2. Age Shares	8176.3	8736.8

Table 6: Comparison of Models: Mean Square Error

Country	No Demography	Demography
Belgium	0.056	0.029
Sweden	0.035	0.023
Japan	0.054	0.034
USA	0.069	0.039
China	0.201	0.110
India	0.100	0.072
World	0.018	0.013

5 Discussion and Conclusion

Using long memory (age-structured) population projections, this paper provided income forecast of the world economy along side a selected developed and developed countries. ML (2005) research has been extended in the long-memory framework (in a univariate setting). Literature is replete with the evidence that long-memory DGP of a time series permeate more dynamics of the observed system and has the ability to model future with rich information about stochasticity of a variable. Indeed, the use of ARFIMA framework for modeling age-specific population and concomitantly employing fractional framework for GDP forecasting offers advantage in that we are able to incorporate more dynamic information of the demographic and economic system in the forecasting model. Endogenous nature of population growth is assumed (this is a model characteristics due to the occurrence of possible feedback effect from demography to the economy and vice versa) which contributes to the economic growth and affect long-term variation in growth. The assumption of autoregressive population structure accommodates endogenous nature of population and when it interacts with economic output, an endogenous economic system is generated. In this sense the inclusion of long-memory demographic information in the GDP forecasting model describes economic system quite distinctly.

The thrust of the paper lies in the recognition that demographic variables, like other macroeconomic variables, may be subject to shocks, and that the shocks may have more than mere short-run impacts on the demographic system. Hence there is a need to model demographic variables in a flexible framework that incorporates both short- and long-run dynamics. Outright assumption of stationarity of these variables straightaway eliminate the possibility of shocks having long-run impact. Therefore, the assumption of long-memory data generating process for demographic variables allows us to understand its interaction with the rest of the economy. Important points emerge from the comparison of forecasts between our long-memory demographic model (Model 2 and 3) and ML's simple and interaction models.

Note that ML's simple model (which incorporates only age-shares) is in fact the long-memory demographic model of this paper. We have not added life-expectancy in the equation, and hence there is no interaction. Effect of life-expectancy is expected to be captured by the long-memory dynamics of the demographic system. The main idea of the inclusion of life expectancy in the demographic model is that the relationship between income and demographic variables is likely to shift over time and stage of development. Interactions occur in the system between the expected rate of return from education and life expectancy, which ultimately govern the growth of income. However, this interaction - which appears to be complex in nature, needs an exhaustive modelling. Once again there could arise the questions of stochastic or non-stochastic nature of the variable and implications of its interactions given this backdrop.

In ARFIMA, the memory parameter is expected to capture the nature of persistent shock in the economy. Autoregressive structure would capture endogeneity in the system, specifically the way the current state of the economy reacts to or depends on the past. Independent or autonomous changes are captured by intercepts. It is not surprising to see that the forecasts based on long-memory demographic model (with age share) is similar to the forecasts from ML's interaction model. Though more investigation is required to substantiate the argument that forecasts from interaction model (with life expectancy) is comparable to ARFIMA forecast with demographic model (without life expectancy), it provides a first-hand information about the simplicity of ARFIMA model and the rich stock of information it carries with to explain the demographic system. Some distinct differences in the forecast emerge as summarised below.

For the convenience of comparison we have estimated a raw model (without demographic information) and compared the projections from this model with that of demographic models. We find that inclusion of demographic variations predicts higher forecasts and given the smallest mean square error this is reliable. The relevance of demography in our forecast model however qualifies ML's argument that demography-based income forecast is more informative as economy responds to demographic changes more acutely (Lindh and Malmberg, 1999). In general we find that long-memory forecasts with demographic variations have a little higher projection than ML's interaction model, though the difference is not substantial. The forecast accuracy has been checked looking at the 95% confidence interval.[6] Narrow confidence band is indicative of better accuracy of forecast.

Our age-specific population forecasts show that young age population (0-14) will experience decline both in developed and developing countries, a bit faster for the latter, for instance India and quite steadily for countries like USA and the European countries, viz., Belgium and Sweden. Working age population will substantially fall for Japan but at the same time there will be an alarming rise of the retired people. Belgium and Sweden are likely to experience steady increase both working age and retired people, almost by an offsetting amount. Generally, a visible difference in the population number of three age groups exert various income effects on the economy and thereby affect the intergenerational transfer and management of resources. European countries will mostly experience a steady rise in the growth rate. The currently aging developed countries will experience a stagnating or even negative growth trend in GDP. Most developing countries will, however, experience accelerating growth and converge to although not reach the income levels of the developed world. The main exceptions to this are to be found in sub-Saharan Africa where the impact of AIDS on the age distribution postpone any growth take-off. However, even in these countries the UN assumptions that the AIDS epidemic will be brought to an end results in increasing growth rates toward the end of the period.

Fractional framework (be it in a univariate or panel set up) is a very useful tool to accommodate movement of shocks and model their interaction with the economy. This recognition is getting popularity in the demographic analysis recently,

[6]Instead of the confidence band, the relevant standard errors could be reported. However, our preference for the confidence band is based on the standard reporting in the forecasting literature. Added motivation is that the confidence band gives us an idea about the tightness or wideness of the actual forecast.

though the literature is very sparse till date. Our strategy of modelling demographic variables in a long memory framework and use the dynamic information for long-run forecasting of income would provide a new direction of research in the demographic context - a departure from conventional wisdom. Though we have extended ML (2005) framework in a long-memory set up in the univariate context, an extension to panel framework will be interesting. The efficacies of long-memory in panel data are yet to be theoretically established, which we preserve for an extension of the current research.

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