Mason, Lee, and members of the NTA network, **Six Ways Population Change Will Affect the Global Economy**

Appendix: Supplemental Materials

Age profiles of labor income and consumption (Figure 1)

Labor income is composed of wages and salaries of employees, and the value of the labor of self-employed and unpaid family workers. The age profile of per capita labor income incorporates age variation in labor force participation, unemployment, hours worked and wage rates. The age profile of consumption consists of both public and private consumption. Details for constructing estimates of labor income and consumption are described in Lee and Mason (2011) and the NTA manual (United Nations Department of Economic and Social Affairs: Population Division 2013).

NTA is part of a comprehensive system of accounts that quantify how people at every age acquire and use economic resources to meet current needs, to support others, and to provide for the future. The accounts have been constructed by research teams from more than 60 countries. The consumption and labor income profiles have been adjusted from local currency units in current prices to constant 2010 international dollars (2010$). The countries included are reported in Table A1 with more information about the research teams responsible for each economy available at www.ntaccounts.org. Age profiles of consumption and labor income for the additional economies, bringing the total to 186, are constructed using a model based on the profiles for which estimates are available.

Table T1 about here

Standardized per capita consumption and labor income profiles are constructed by expressing each single-year-of-age value as a proportion of the averages of the 30-49 age groups. To model the age profiles of consumption and labor income, the standardized profiles are grouped based on contrasts identified using principal component analysis (PCA). We used the first four components in the PCA reported below, which capture 80% and 84% of variations in standardized per capita labor income and consumption age profiles, respectively, resulting in a total of sixteen (16) clusters. Economies with NTA estimates are assigned to one of these clusters based on their score in each retained principal component.

Country-specific propensities for cluster membership, $\pi_j(k)$, are estimated using multinomial logistic (MNL) regression using a sample of countries with NTA data. For any economy, the estimated propensity is given by

$$\widehat{\pi_j(k)} = \frac{\exp\left(\widehat{\beta_k} Z_j\right)}{1 + \sum_{q=1}^{K-1} \exp\left(\widehat{\beta_q} X_j\right)} \qquad (1)$$

where Z_i is a vector of economy-specific characteristics, and $\widehat{\beta_k}$ are cluster-specific regression weights estimated from our MNL model. The same MNL weights are used to predict $\pi_i(k)$ in countries without NTA estimates. The estimated $\pi_i(k)$ are combined with archetypal profiles, calculated as the simple average of standardized age profiles from each cluster, to provide an estimate of the economic age profiles in these countries. Figure A1 plots the archetypal profiles.

Figure A1 about here

The vector Z_j is chosen to provide a good fit of the observed age profiles, as well as to maximize the number of countries that may be included. These variables include general and age-specific economic activity, demography, inequality and consumption levels. Data on labor force participation rates by age groups are sourced from the International Labour Organization statistical database (International Labour Organization 2020). Other variables are directly sourced or derived from estimates available from World Bank's World Development Indicators (World Bank 2019).

Three sets of controls were used. In the basic model, the aim was to maximize the potential number of countries that may be covered by using only variables that are available for all 186 economies in both databases. In the more elaborate models, additional variables that improve the fit of the base model were included, although at a cost of reducing the number of countries that are covered. Table A2 provides a summary of the variables used in each specification.

Table T2 about here

Table A3 provides a summary of the model fit of the standardized consumption and labor income per capita age profiles using our sample of NTA countries. Support ratios based on the modelled age profiles were likewise calculated and compared with support ratios calculated using NTA estimates. Overall, the models provide good fit of the data. The estimated models for each economy group are ranked based on overall model fit. Based on this group-specific ranking of models and the available predictors for each economy, modelled age profiles are used for countries with no NTA data.

Table T3 about here

GDP growth (Table 1)

For any economy *j* the effective number of workers of age x in year *t, L(j,x,t),* is defined as:

$$\begin{aligned} L(j,x,t) &= \tilde{y}_l(j,x)P(j,x,t) \\ \tilde{y}_l(j,x) &= y_l(j,x,b) \Big/ \sum\nolimits_{x=30}^{49} y_l(j,x,b)/20 \end{aligned} \quad (2)$$

where $\tilde{y}_l(x)$ is the standardized age profile of labor income equal to the per capita labor income of persons age *x* relative to the average per capita income of persons aged 30-49 years calculated in the base year b. $P(j,x,t)$ is the actual or projected population for country j of age *x* in year *t*.

The global effective number of workers in year t, L(t), is:

$$L(t) = \sum_{j=1}^{J} \sum_{x=0}^{\omega} L(j,x,t) \quad (3)$$

where the maximum years lived is ω.

GDP in economy j is equal to the product of productivity (output per effective worker), $w(j,t)$, and the number of effective workers for economy j, $L(j,t)$:

$$GDP(j,t) = w(j,t)L(j,t). \quad (4)$$

Global GDP is given by:

$$\begin{aligned} GDP(t) &= \sum_{j=1}^{J} w(j,t)L(j,t) \\ &= \sum_{j=1}^{J} \left(1+\lambda(j)\right)^{t-b} w_b(j)L(j,t) \end{aligned} \quad (5)$$

where $w_b(j)$ is equal to GDP per effective worker in international $ in the base year in 2010. Assuming that productivity growth is identical across all countries, we have:

$$GDP(t) = (1+\lambda)^{t-b} \sum_{j=1}^{J} w_b(j) L(j,t) \tag{6}$$

The growth rate of GDP is given by:

$$\frac{GDP(t+1)}{GDP(t)} - 1 = (1+\lambda) \frac{\sum_{j=1}^{J} w_b(j) L(j,t+1)}{\sum_{j=1}^{J} w_b(j) L(j,t)} - 1 \tag{7}$$

We define

$$\begin{aligned} &gr(GDP(t)) \text{ as } \frac{GDP(t+1)}{GDP(t)} - 1 \\ &gr(w_b L(t)) \text{ as } \frac{\sum_{j=1}^{J} w_b(j) L(j,t+1)}{\sum_{j=1}^{J} w_b(j) L(j,t)} - 1. \end{aligned} \tag{8}$$

The growth rate of GDP is equal to:

$$gr(GDP(t)) = (1+\lambda)(1+gr(w_b L(t))) - 1. \tag{9}$$

The rate of growth of productivity is:

$$\lambda = \frac{1+gr(GDP(t))}{1+gr(wL(t))} - 1. \tag{10}$$

In Table 1, population data (column A) is based on the medium scenario from World Population Prospects 2019. Effective labor (column B) is based on the population data weighted by effective labor income in the base year of 2010 as in equation 1. The age profile of labor

$w_b L$, reported in column C use weights (w_b) equal to GDP per effective worker in 2010 in international dollars from the World Bank. GDP growth rates (D) and productivity growth rates (E) from 1950-2020 are based on historical data (see Table notes). Projected productivity growth rates, 2021 and later, are assumed to be constant at the 2000-2020 level.

Support ratio and the first demographic dividend

The support ratio is a measure of population age structure that emphasizes the balance between the number of workers and the number of consumers in any population. The support ratio incorporates differences across countries in the age patterns of labor income and consumption at each age. The support ratio rises when the population becomes concentrated at the age in which people have high labor income or low consumption relative to those at other ages.

The effective number of workers, defined above, and the effective number of consumers are defined in similar fashion with *N(x,t)*, the effective number of consumers age x in year t, equal to:

$$\begin{aligned} N(x,t) &= \tilde{c}(x)P(x,t) \\ \tilde{c}(x) &= c(x,b)/c(30-49,b) \end{aligned} \tag{11}$$

where $\tilde{c}(x)$ is the standardized consumption age profile that measures how consumption at each age compares with consumption by those of age 30-49 years. The country indicator *j* is dropped to simplify notation. The total effective consumers in year t is:

$$N(t)=\sum_{x=0}^{\omega}N(x,t). \tag{12}$$

The channels through which population influence standards of living is framed in the following fashion. By definition total income (or GDP), Y(t), is equal to:

$$Y(t)=\frac{Y(t)}{L(t)}\times L(t). \tag{13}$$

Income per effective consumer is equal to the product of output per effective worker and the support ratio (L/N):

$$\frac{Y(t)}{N(t)}=\frac{Y(t)}{L(t)}\times\frac{L(t)}{N(t)}. \tag{14}$$

Holding output per worker constant, an increase in growth in the support ratio leads to a one-for-one increase in the growth of output per effective consumer. The annual growth of the support ratio is called the first demographic dividend. Demographic change that leads to growth in output per effective worker (Y/L) is called the second demographic dividend. Capital deepening referred to in the main text is one way population will produce a second dividend effect (Lee, Mason and Members of the NTA Network 2014; Mason and Lee 2007). Another is that low fertility may lead to greater investment in human capital (Lee and Mason 2010).

Child and old-age gap ratios

The child and old-age gap ratios measure dependency incorporating the extent to which young and old are consuming more than they are producing in a given year:

$$\text{Child Gap Ratio} = \sum_{x=0}^{24} C(x,t) - Yl(x,t) \Big/ Yl(t)$$
$$\text{Old-Age Gap Ratio} = \sum_{x=65}^{\omega} C(x,t) - Yl(x,t) \Big/ Yl(t) \qquad (15)$$

Longitudinal effects of aging and the wealth gap

A longitudinal perspective is important to an economic assessment of old age. Any cohort approaching old age faces the prospect of lifecycle deficits over the remainder of its life. The wealth gap is a hypothetical measure of the wealth that would be required to fund the gap between prospective consumption and labor income over the entire retirement phase of any cohort. The wealth gap turns positive during the pre-retirement phase of the lifecycle and peaks when the retirement phase begins, at about the age when consumption is first expected to exceed labor income. In the US, for example, the per capita wealth gap based on 2011 age profiles increases from zero at age 48 and peaks in excess of $400,000 at age 68 (Figure A2). After age 68, the wealth gap declines at older ages because the expected years of remaining life are lower. The wealth gap reaches zero at the end of life. The total wealth gap is computed by summing the wealth gap of all cohorts currently belonging to the pre-retirement and retirement phases of the lifecycle.

The wealth gap is hypothetical because consumption and labor income profiles are likely to shift in the future. If that did not happen, however, the wealth gap would be funded by relying on assets and transfer wealth. Assets consist of pension funds, personal saving, a farm or business, and owner-occupied residences, for example. Transfer wealth is the present value of transfer inflows less outflows. Public transfers wealth consists of the value of public pensions, publicly funded health care, and other public cash and in-kind spending less taxes. Private transfer wealth consists primarily of the present value of family transfers received less transfers given.

A detailed discussion of the method used to estimate the wealth gap and the ages at which pre-retirement and retirement begin are available in Mason et al. (2017)

TABLE T1 Countries by Income Group with NTA Estimates of Consumption and Labor Income

High Income	Upper-Middle Income	Lower-Middle Income	Low Income
Argentina (2016)	Botswana (2010)	Bangladesh (2010)	Benin (2007)
Australia (2010)	Brazil (2008)	Cambodia (2009)	Burkina Faso (2014)
Austria (2010)	Bulgaria (2010)	Cameroon (2017)	Central African Republic (2008)
Belgium (2010)	China (2014)	Congo (2011)	Chad (2011)
Canada (2013)	Colombia (2008)	Côte d'Ivoire (2015)	Democratic Republic of the Congo (2014)
Chile (2012)	Costa Rica (2013)	El Salvador (2010)	Ethiopia (2005)
Cyprus (2010)	Ecuador (2011)	Eswatini (2011)	Gambia (2015)
Czechia (2010)	Gabon (2005)	Ghana (2005)	Guinea (2012)
Denmark (2010)	Iran (Islamic Republic of) (2011)	India (2012)	Guinea-Bissau (2010)
Estonia (2010)	Jamaica (2002)	Indonesia (2012)	Mali (2015)
Finland (2006)	Malaysia (2009)	Kenya (2005)	Mozambique (2008)
France (2011)	Maldives (2016)	Lao People's Democratic Republic (2012)	Nepal (2011)
Germany (2013)	Mexico (2014)	Mauritania (2014)	Niger (2014)
Greece (2010)	Namibia (2012)	Mongolia (2018)	Senegal (2011)
Hungary (2005)	Paraguay (2012)	Nigeria (2016)	Sierra Leone (2011)
Ireland (2010)	Peru (2014)	Philippines (2015)	Togo (2018)
Italy (2008)	Romania (2010)	Republic of Moldova (2014)	
Japan (2004)	Russian Federation (2013)	Sao Tome and Principe (2011)	
Latvia (2010)	South Africa (2005)	Timor-Leste (2011)	
Lithuania (2010)	Thailand (2013)	Viet Nam (2012)	
Luxembourg (2010)	Turkey (2006)		

Netherlands (2012) Poland (2016) Portugal (2010) Republic of Korea (2016) Singapore (2013) Slovakia (2010) Slovenia (2010) Spain (2012) Sweden (2010) Taiwan (2015) United Kingdom (2012) USA (2015) Uruguay (2013)			

Note: Figure in parentheses refers to year of NTA estimate.

TABLE T2   Variable List for Lifecycle Profile Models

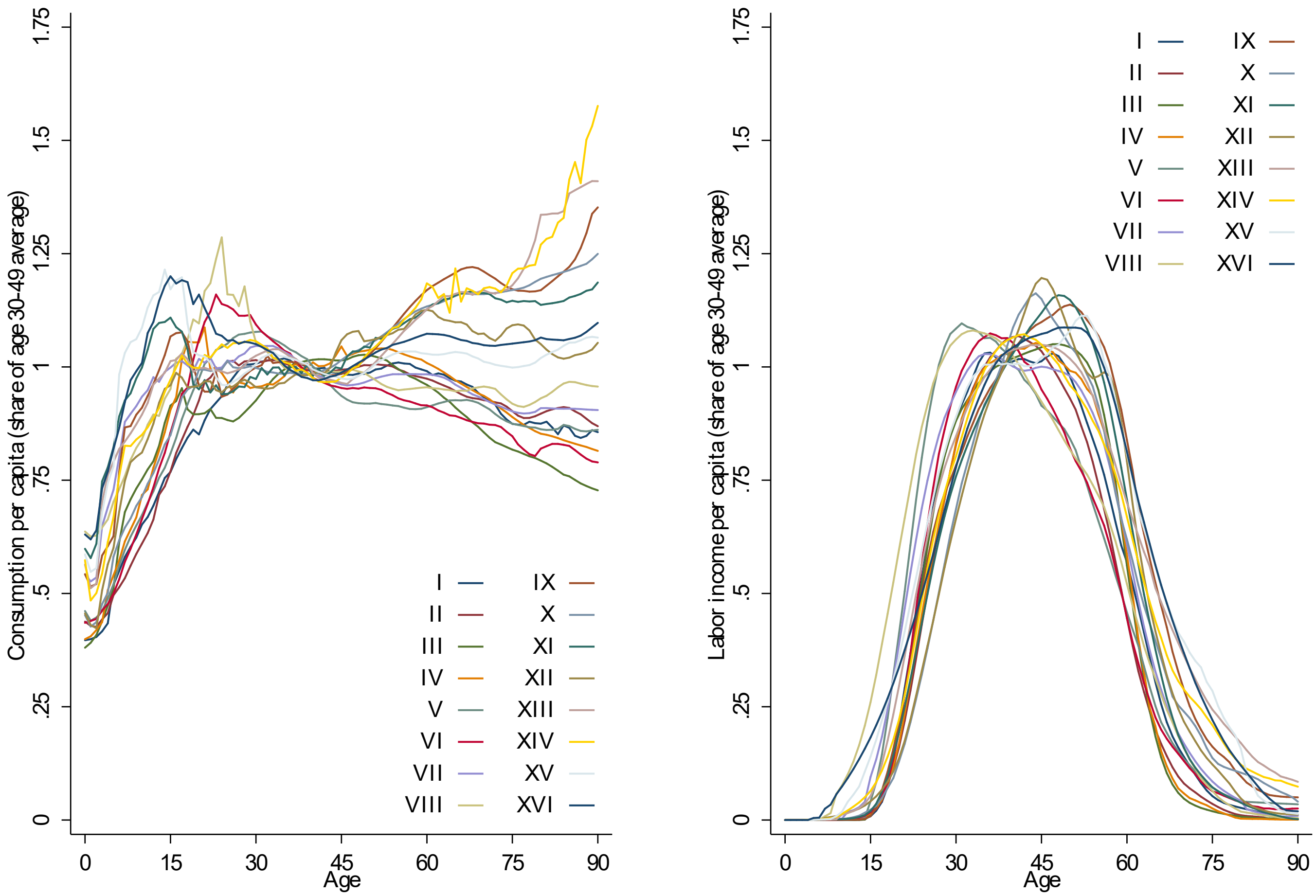
Variable	Model 1		Model 2		Model 3	
	C	Yl	C	Yl	C	Yl
Demographic support ratio	✓	✓	✓	✓	✓	✓
Proportion of population living in urban areas	✓	✓	✓	✓	✓	✓
Labor force participation rate, 15-19 years old		✓		✓		✓
Labor force participation rate, 65+ years old		✓		✓		✓
Difference in female and male life expectancies at birth	✓	✓	✓	✓	✓	✓
log(GDP per capita)			✓	✓	✓	✓
Government expenditure as share of GDP					✓	
Health expenditure-to-GDP ratio/total dependency ratio					✓	✓
Education expenditure-to-GNI ratio/young dependency ratio					✓	✓
Coverage potential (Number of countries)	193	185	186	179	167	171

TABLE T3 Model Fit

	Model 1			Model 2			Model 3		
	C	Yl	SR	C	Yl	SR	C	Yl	SR
R2									
<25	0.74	0.87		0.76	0.88		0.78	0.89	
25 to 64	0.46	0.78		0.49	0.78		0.62	0.81	
64<	0.56	0.66		0.61	0.66		0.64	0.72	
All age groups	0.72	0.96	0.66	0.74	0.96	0.69	0.77	0.96	0.78
RMSE									
<25	0.12	0.06		0.11	0.06		0.11	0.06	
25 to 64	0.05	0.11		0.05	0.11		0.04	0.10	
64<	0.13	0.08		0.12	0.08		0.12	0.08	
All age groups	0.10	0.09	0.04	0.10	0.09	0.04	0.09	0.08	0.04

FIGURE A1 Model Consumption and Labor Income Profiles, 16 clusters

A. Consumption B. Labor Income



Note: Per capita age profile estimates are standardized relative to the average values for persons aged 30-49. The income groups are identified based on the economy's per capita income in the year of the NTA estimate. The numbers inside the parentheses reflect the consumption and labor income group for the economy, respectively, as identified in the cluster analysis. Argentina (14,11); Australia (13,7); Austria (11,3); Bangladesh (4,7); Belgium (13,3); Botswana (3,10); Brazil (1,11); Bulgaria (11,7); Cambodia (1,8); Cameroon (5,13); Canada (14,11); Central African Republic (5,7); Chad (5,15); Chile (13,6); China (16,5); China, Taiwan Province of China (15,14); Colombia (12,16); Congo (6,11); Costa Rica (5,1); Cyprus (7,3); Czechia (16,4); Denmark (13,3); Ecuador (2,13); El Salvador (10,13); Ethiopia (6,14); Estonia (7,6); Finland (14,4); France (13,3); Gabon (2,10); Gambia (1,7); Germany (9,3); Ghana (5,9); Greece (15,2); Guinea (2,10); Hungary (12,3); India (8,15); Indonesia (3,13); Iran (Islamic Republic of) (10,10); Ireland (13,2); Italy (15,3); Côte d'Ivoire (8,14); Jamaica (12,7); Japan (14,11); Kenya (5,6); Republic of Korea (15,2); Lao People's Democratic Republic (3,14); Latvia (7,6); Lithuania (16,3); Luxembourg (13,4); Malaysia (1,13); Maldives (11,5); Mali (2,4); Mauritania (7,12); Mexico (12,11); Mongolia (4,5); Republic of Moldova (16,9); Mozambique (6,8); Namibia (3,12); Nepal (8,6); Niger (8,12); Nigeria (4,14); Paraguay (6,15); Peru (10,15); Philippines (10,5); Poland (13,2); Portugal (7,3); Timor-Leste (16,6); Romania (14,2); Russian Federation (7,6); Sao Tome and Principe (2,13); Senegal (6,16); Sierra Leone (6,11); Singapore (3,2); Slovakia

(9,3); Viet Nam (4,5); Slovenia (15,2); South Africa (3,4); Spain (13,11); Eswatini (3,2); Sweden (13,11); Thailand (7,7); Togo (6,16); Turkey (2,15); United Kingdom (10,3); United States of America (10,9); Burkina Faso (5,13); Uruguay (10,3).

FIGURE A2 The Wealth Gap and Phases of the Lifecycle, United States, 2011 Baseline Values