# Human capital, ageing and economic growth

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# Human Capital and Income I

**Mincerian earnings equations** describe the relationship between hourly wages and their determinants, most importantly education

$$\ln w_i = \alpha + \beta ed_i + \sum_j \theta_j \mathbf{x_{ji}} + u_i$$

| | | |
|---|---|---|
| $w_i$ | ... | hourly wage of individual $i$ |
| $ed_i$ | ... | years of education of individual $i$ |
| $\mathbf{x_{ji}}$ | ... | vector of control variables: individual, household, sectoral, occupational and regional characteristics |

# Human Capital and Income II

- Empirical studies show high and significant returns to education
- Econometric difficulties: the most prominent ones are ability bias and sample selection (see Card (2001) for a detailed discussion)
- Cross-country growth regressions often do not show positive effects of increases in educational attainment on growth (see for example Benhabib and Spiegel (1994), Pritchett (2001))

# Human capital as a factor of production I

Mankiw, Romer, and Weil (1992) extend the Solow (1956) model by human capital accumulation and assume the following production function

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} \left[A(t)L(t)\right]^{1-\alpha-\beta}$$

| | | | |
|---|---|---|---|
| $Y(t)$ | ... | total production in $t$ | |
| $K(t)$ | ... | physical capital stock in $t$ | *with:* $\dot{K}(t) = s_k Y(t) - \delta K(t)$ |
| $H(t)$ | ... | human capital stock in $t$ | *with:* $\dot{H}(t) = s_h Y(t) - \delta H(t)$ |
| $A(t)$ | ... | technology in $t$ | *with:* $\dot{A}(t) = gA(t)$ |
| $L(t)$ | ... | labour input in $t$ | *with:* $\dot{L}(t) = nL(t)$ |
| $s_k$ | ... | fraction of output invested in physical capital | |
| $s_h$ | ... | fraction of output invested in human capital | |
| $\delta$ | ... | depreciation rate | |

# Human capital as a factor of production II

Redefining the variables in quantities per unit of effective labour (i.e. $k(t) = \frac{K(t)}{A(t)L(t)}$ and $h(t) = \frac{H(t)}{A(t)L(t)}$) and differentiating yields

$$\dot{k}(t) = s_k y(t) - k(t)(\delta + n + g)$$

$$\dot{h}(t) = s_h y(t) - h(t)(\delta + n + g)$$

Notice that $y(t) = \frac{Y(t)}{A(t)L(t)} = \frac{K^\alpha H^\beta}{[A(t)L(t)]^{\alpha+\beta}} = k(t)^\alpha h(t)^\beta$.

# Human capital as a factor of production III

Thus, to obtain the steady state values for physical and human capital per effective worker

$$\dot{k}(t) = 0 \Rightarrow k = \left(\frac{s_k}{\delta+g+n}\right)^{\frac{1}{1-\alpha}} h^{\frac{\beta}{1-\alpha}}$$
$$\dot{h}(t) = 0 \Rightarrow k = \left(\frac{\delta+g+n}{s_h}\right)^{\frac{1}{\alpha}} h^{\frac{1-\beta}{\alpha}}$$

# Human capital as a factor of production IV

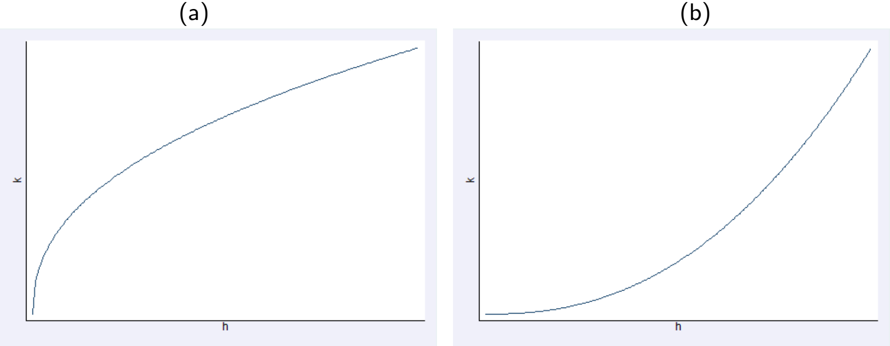



Figure: steady state values for different values of the alternative input factor: (a) physical capital per effective unit of labour; (b) human capital per effective unit of labour

# Human capital as a factor of production V

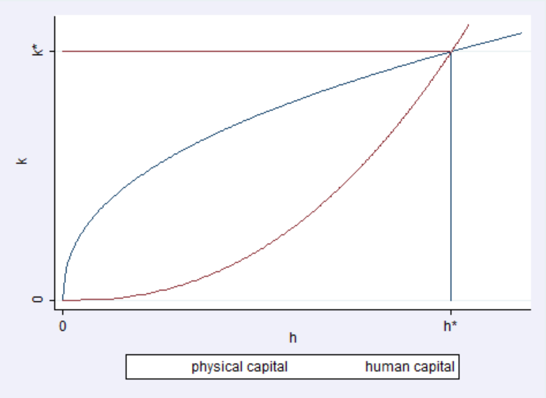



Figure: Steady state values

# Human capital as a factor of production VI

- Differences in human capital accumulation are able to explain differences in GDP per capita (and economic growth) across countries
- The model with human capital as an input of production hypothesizes *level effects* of human capital on GDP per capita
- Doesn't human capital (also) affect technology adoption/innovation (Nelson and Phelps (1966) hypothesis)?
- Stock vs. flow of human capital
- What is human capital? Years of education, schooling measures? Quality of education? Health?

# Human capital and technological progress I

Benhabib and Spiegel (1994) specify human capital as technology augmenting factor based on the following hypotheses:

- Romer (1990) hypothesis: human capital increases capacity of nations to *develop* new technoglogies (domestically)
- Nelson and Phelps (1966) hypothesis: human capital speeds up the process of technogology diffusion and *catch-up* to the leading country (technological frontier)

# Human capital and technological progress II

Assume technology dynamics such as

$$\frac{\dot{A}_i(t)}{A_i(t)} = g(H_i) + c(H_i)\left[\frac{A_f(t)-A_i(t)}{A_i(t)}\right]$$

with $g(H_i)$ denoting the endogenous growth rate and $c(H_i)$ the catch-up coefficient. Note, that $\frac{\partial g(H)}{\partial H} > 0$ and $\frac{\partial c(H)}{\partial H} > 0$.

# Human capital and technological progress III

Consider the two alternative production functions:
**Human capital is a standard input of production**

$$Y(t) = A(t)K(t)^{\alpha}H(t)^{\beta}L(t)^{\gamma}$$

**Human capital determines technology diffusion**

$$Y(t) = A(t)K(t)^{\alpha}L(t)^{\gamma} \text{ with } \frac{\dot{A}(t)}{A(t)} = \underbrace{g(H)}_{\text{domestic innov.}} + \underbrace{c(H)\left[\frac{A_f(t) - A(t)}{A(t)}\right]}_{\text{technology diffusion}}$$

# Human capital and technological progress IV

Consider the alternative specifications for growth rates of GDP,

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)} + \alpha \frac{\dot{K}(t)}{K(t)} + \beta \frac{\dot{H}(t)}{H(t)} + \gamma \frac{\dot{L}(t)}{L(t)}$$

and

$$\frac{\dot{Y}(t)}{Y(t)} = g(H) + c(H) \left[ \frac{A_f(t) - A(t)}{A(t)} \right] + \alpha \frac{\dot{K}(t)}{K(t)} + \gamma \frac{\dot{L}(t)}{L(t)}$$

Estimation of both models using the data for 78 countries (1965–1985) from Benhabib and Spiegel (1994), human capital proxied by *Average years of schooling*

# Empirical findings I

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| $\frac{\dot{K}(t)}{K(t)}$ | 0.46 (5.36) | 0.50 (5.01) | 0.54 (8.31) | 0.50 (5.01) | 0.49 (6.50) | 0.44 (4.23) |
| $\frac{\dot{H}(t)}{H(t)}$ | 0.06 (0.80) | | -0.06 (-1.02) | | | |
| $\frac{\dot{L}(t)}{L(t)}$ | 0.21 (1.01) | 0.11 (0.52) | 0.13 (0.79) | 0.11 (0.52) | 0.27 (1.62) | 0.17 (0.77) |
| $H(t)$ | | -0.10 (-1.48) | | -0.10 (-1.48) | 0.16 (2.32) | 0.38 (2.91) |
| $H(t)\left(\frac{A_f(t)}{A(t)} - 1\right)$ | | | | | | 0.04 (3.31) |
| $\left(\frac{A_f(t)}{A(t)} - 1\right)$ | | | 0.19 (5.26) | | 0.24 (5.43) | |
| $R^2$ | 0.52 | 0.53 | 0.68 | 0.53 | 0.69 | 0.62 |
| Obs. | 78 | 78 | 78 | 78 | 78 | 78 |

Figure: Cross country growth regressions, 78 countries

# Population Pyramid for Kenya in 2000

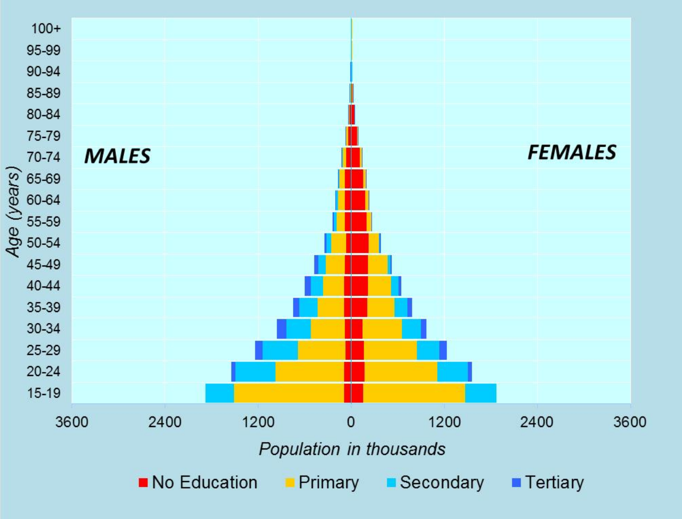



Figure: **Kenya in 2000**: Population by Age, Sex and Educational Attainment

# Population Pyramid for Kenya in 1990

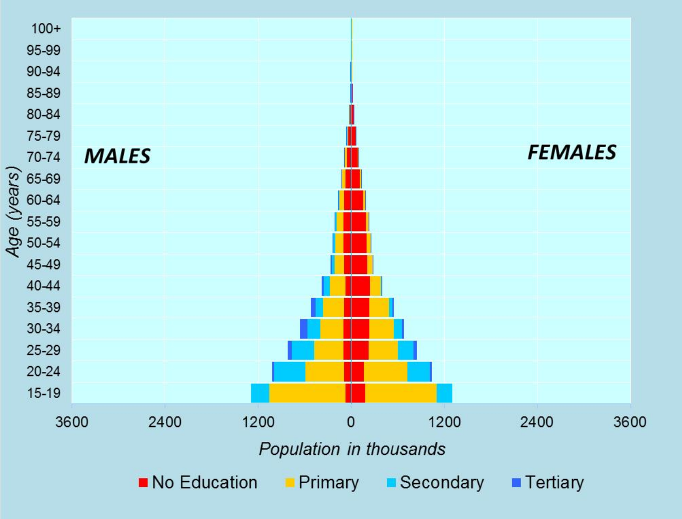



Figure: **Kenya in 1990**: Population by Age, Sex and Educational Attainment

# Population Pyramid for Kenya in 1980

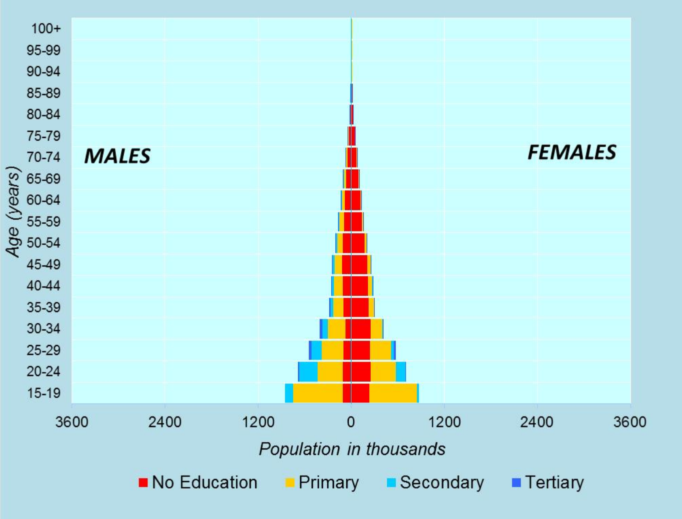



Figure: **Kenya in 1980**: Population by Age, Sex and Educational Attainment

# Population Pyramid for Kenya in 1970

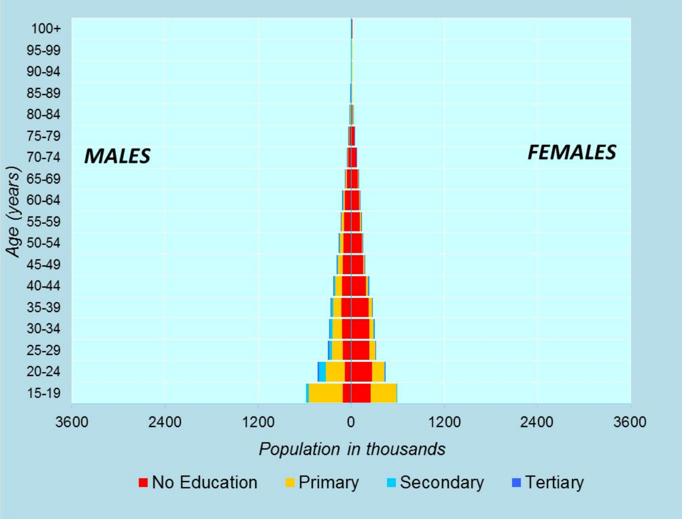
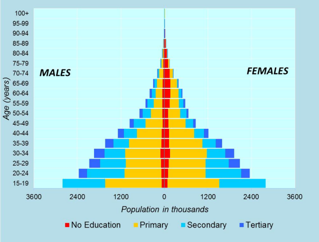


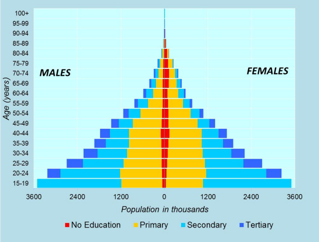

Figure: **Kenya in 1970**: Population by Age, Sex and Educational Attainment

# Population Pyramids for Kenya in 2020-2050 (GET)

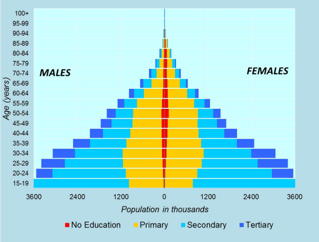
(2020)



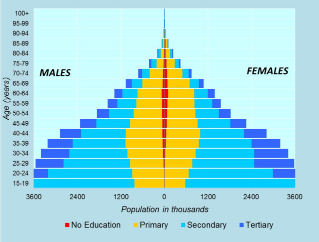

(2030)




(2040)




(2050)



# The Demography of Educational Attainment and Technology Adoption I

Lutz, Crespo Cuaresma, and Sanderson (2008) estimate a growth regression of the following form

$$\Delta \ln Y_{i,t} = \Delta \ln A_{i,t} + \alpha \Delta \log K_{i,t} + \sum_j \sum_k \beta_{jk} \Delta \ln L_{ijk,t}$$

where the labour force corresponding to age group j, education level k and country i at time t is denoted by $L_{ijk,t}$. Similar to Benhabib and Spiegel (1994), technological growth is modeled as suggested by Nelson and Phelps (1966)

$$\Delta \ln A_{i,t} = \underbrace{g\left(\frac{L_{ijk,t}}{L_{i,t}}\right)}_{\text{Catch-up speed}} \underbrace{(\ln y_{max} - \ln y_{0i,t})}_{\text{"Backwardness"}}$$

# The Demography of Educational Attainment and Technology Adoption II

Basic idea of this specification: the growth rate of TFP depends on the implementation of technological improvements

- gap between the technological frontier and the current productivity as a determinant of technological improvements
- the rate at which income gap is closed depends on the level of human capital
- $\longrightarrow$ interaction between *backwardness* and human capital

**Table S1. Production function estimation: IIASA-VID data with age detail.**

| Variable | Full sample, income interaction effect | OECD sample, income interaction effect | Non-OECD sample. income interaction effect | Full sample, no income interaction effect |
|---|---|---|---|---|
| Intercept | −0.178*** (0.041) | −0.272*** (0.053) | −0.193*** (0.043) | −0.149*** (0.038) |
| $\Delta \log L_{i11,t}$ | 0.182*** (0.039) | 0.015 (0.041) | 0.395*** (0.090) | 0.348*** (0.113) |
| $\Delta \log L_{i21,t}$ | 0.415*** (0.105) | 0.177*** (0.051) | 0.409*** (0.14) | 0.234*** (0.045) |
| $\Delta \log L_{i12,t}$ | −0.310*** (0.109) | −0.264*** (0.052) | −0.511*** (0.109) | −0.301*** (0.11) |
| $\Delta \log L_{i22,t}$ | −0.050*** (0.018) | −0.090 (0.166) | −0.005 (0.024) | −0.026 (0.039) |
| $\Delta \log L_{i13,t}$ | 0.336*** (0.049) | −0.002 (0.227) | 0.353*** (0.071) | 0.342*** (0.059) |
| $\Delta \log L_{i23,t}$ | 0.293*** (0.075) | 0.074 (0.128) | 0.312*** (0.081) | 0.254*** (0.071) |
| $\Delta \log L_{i14,t}$ | 0.075 (0.061) | 0.520*** (0.179) | 0.031 (0.081) | 0.077 (0.052) |
| $\Delta \log L_{i24,t}$ | −0.046 (0.06) | 0.318 (0.276) | −0.088 (0.073) | −0.035 (0.07) |
| $(\log y_{max} - \log y_{0i,t})$ | 0.097*** (0.017) | 0.278*** (0.036) | 0.073*** (0.021) | 0.062*** (0.013) |
| $L_{i21,t} / L_{i,t}(\log y_{max} - \log y_{0i,t})$ | −0.079*** (0.028) | −0.125** (0.055) | −0.038 (0.031) | – |
| $L_{i12,t} / L_{i,t}(\log y_{max} - \log y_{0i,t})$ | −0.020 (0.022) | −0.125** (0.061) | −0.007 (0.021) | – |
| $L_{i22,t} / L_{i,t}(\log y_{max} - \log y_{0i,t})$ | 0.017 (0.037) | 0.055 (0.108) | 0.050 (0.042) | – |
| $L_{i13,t} / L_{i,t}(\log y_{max} - \log y_{0i,t})$ | −0.085*** (0.011) | −0.334*** (0.061) | −0.054*** (0.015) | – |
| $L_{i23,t} / L_{i,t}(\log y_{max} - \log y_{0i,t})$ | 0.144*** (0.055) | 0.080 (0.105) | 0.354*** (0.085) | – |
| $L_{i14,t} / L_{i,t}(\log y_{max} - \log y_{0i,t})$ | 0.407*** (0.107) | 0.914*** (0.241) | 0.664*** (0.097) | – |
| $L_{i24,t} / L_{i,t}(\log y_{max} - \log y_{0i,t})$ | −0.427*** (0.101) | −0.986*** (0.411) | −0.827*** (0.098) | – |
| $\Delta \log K_{i,t}$ | 0.106*** (0.035) | 0.253*** (0.07) | 0.104*** (0.04) | 0.117*** (0.038) |
| Within-$R^2$ (unc.) | 0.350 | 0.725 | 0.375 | 0.318 |
| Obs. | 524 | 94 | 430 | 524 |
| Countries | 101 | 17 | 84 | 101 |
| Specification | Fixed country effects, fixed time effects | Fixed country effects, fixed time effects | Fixed country effects, fixed time effects | Fixed country effects, fixed time effects |

One, two, and three asterisks indicate significance at 10, 5, and 1%, respectively. Robust standard errors in parenthesis. The within-R-squared refers to the goodness of fit of the respective (unconstrained) model with GDP growth deviations from country-specific averages as a dependent variable.

Figure: Growth regression, Lutz, Crespo Cuaresma, and Sanderson (2008)

# Income and growth projections

Income level and growth

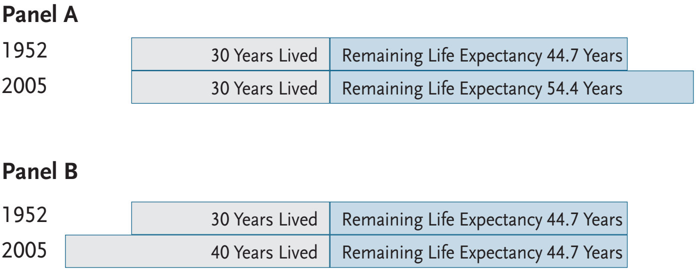
# Ageing in Europe

- The sustained fall of fertility rates and increase in life expectancy in Europe have led to a growing interest in the economic growth consequences of ageing in the continent (see for instance Gill and Raiser, 2012)
- Macroeconomic consequences of ageing are widely discussed in the theoretical literature
- Standard measures of ageing based on the old-age dependency ratio ($OADR$),

$$OADR = \frac{\text{Number of people aged 65+}}{\text{Number of people aged 20-64}}$$

# Reassessing Ageing in Advanced Societies

- But ... isn't 40 the new 30?



# Ageing in Europe

Measurement of ageing has become a central research topic in this area (Sanderson and Scherbov, 2005, 2010) $\rightarrow$ from chronological to prospective age measures

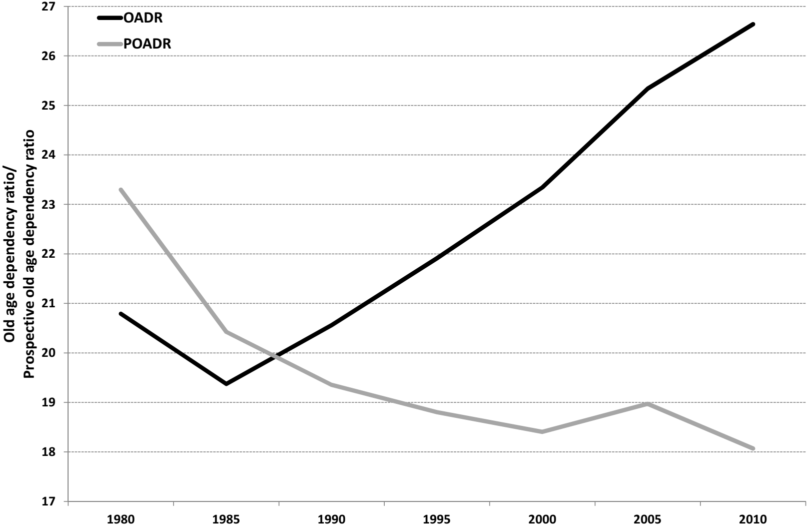
- From the standard *OADR*,

$$OADR = \frac{\text{Number of people aged 65+}}{\text{Number of people aged 20-64}}$$

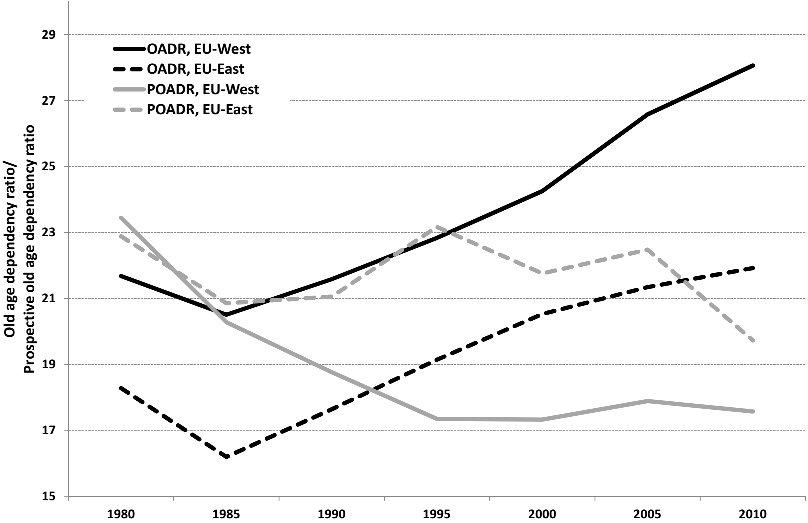
- ... to the prospective OADR,

$$POADR = \frac{\text{People with remaining LE}<15}{\text{People aged 20 - threshold age at which LE}<15}$$

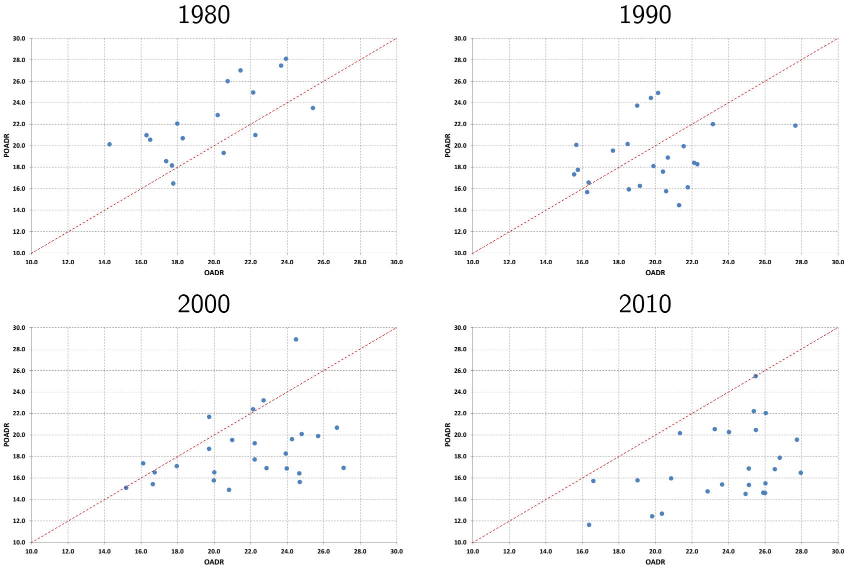
# Ageing in Europe



# Ageing in Europe



# Ageing in Europe



# Economic Growth and Ageing in Europe

- Do ageing measures help explain income growth differences in Europe?
- Panel dataset spanning the period 1970-2010, alternatively at 5, 10 and 20-year intervals.
- Simple income growth specification

$$\begin{aligned} \Delta \log y_{it+\tau} &= \beta_1 \Delta \log POP_{it+\tau} + \beta_2 \Delta \log K_{it+\tau} + \beta_3 \log y_{0,it} \\ &+ \gamma \Delta AGE_{it+\tau} + \theta \Delta AGE_{it+\tau} \times \log y_{0,it} + \varepsilon_{it+\tau}, \end{aligned}$$

- Country and period fixed effects

# Economic Growth and Ageing in Europe

| | 5-year periods | | | |
|---|---|---|---|---|
| Pop. Growth | 0.0705 | 0.149 | -0.0543 | -0.113 |
| | [0.763] | [0.751] | [0.806] | [0.792] |
| Phys. Cap. Growth | 0.564** | 0.512** | 0.574** | 0.554** |
| | [0.238] | [0.246] | [0.237] | [0.237] |
| Initial Income | -0.416*** | -0.395*** | -0.418*** | -0.419*** |
| | [0.0921] | [0.0862] | [0.0903] | [0.0895] |
| Change in OADR | | | -1.169 | -20.08** |
| | | | [0.844] | [9.474] |
| Change in OADR | | | | 1.904* |
| × Initial Income | | | | [0.958] |
| Change in POADR | -0.673 | -15.00* | | |
| | [0.503] | [8.572] | | |
| Change in POADR | | 1.462* | | |
| × Initial Income | | [0.849] | | |
| Observations | 152 | 152 | 152 | 152 |
| R-squared | 0.541 | 0.554 | 0.542 | 0.552 |
| Number of countries | 27 | 27 | 27 | 27 |

# Economic Growth and Ageing in Europe

| | 20-year periods | | | |
|---|---|---|---|---|
| Pop. Growth | 0.312 | -2.012** | 0.201 | -0.0688 |
| | [1.539] | [0.835] | [1.504] | [1.566] |
| Phys. Cap. Growth | -0.0236 | -0.540* | -0.174 | -0.00297 |
| | [0.149] | [0.266] | [0.204] | [0.305] |
| Initial Income | -0.938*** | -1.232*** | -0.979*** | -0.894** |
| | [0.276] | [0.264] | [0.303] | [0.380] |
| Change in OADR | | | -0.261 | 38.73 |
| | | | [0.796] | [50.06] |
| Change in OADR | | | | -3.899 |
| × Initial Income | | | | [5.026] |
| Change in POADR | -0.619 | 62.66** | | |
| | [0.656] | [22.46] | | |
| Change in POADR | | -6.340** | | |
| × Initial Income | | [2.269] | | |
| Observations | 31 | 31 | 31 | 31 |
| R-squared | 0.825 | 0.894 | 0.816 | 0.824 |
| Number of countries | 22 | 22 | 22 | 22 |

# Economic Growth and Ageing in Europe

- Comparable results for chronological and prospective ageing measures at relatively short horizons, the effects are only significant for prospective ageing measures once we move to longer
- The results indicate that the negative effects of ageing on economic growth appear to be more important in economies with a relatively lower income per capita level
- The model estimates give thus evidence that ageing is a particularly serious challenge to sustainable income growth in Eastern European economies, whose income per capita level is below EU average and which are precisely expected to experience further increases in old age dependency ratios (see World Bank, 2013)

# Out-of-sample predictions

- Do prospective ageing measures improve out-of-sample predictions?
- Estimate two alternative 5-year models (using lagged regressors) with OADR and POADR for 1970-1995 and use 1995-2000 as an out-of-sample period
- Repeat for the periods 2000-2005 and 2005-2010 as out-of-sample periods
- Obtain prediction errors. Root mean squared error $\rightarrow$ for OADR & POADR $= 0.16$
- Estimate two alternative 10-year models (using lagged regressors) with OADR and POADR for 1970-2000 and use 2000-2010 as an out-of-sample period
- Obtain prediction errors. Root mean squared error $\rightarrow$ for OADR $= 0.66$, for POADR $= 0.25$
- A Diebold-Mariano test confirms that the differences in prediction error are indeed statistically significant for the 10-year model

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