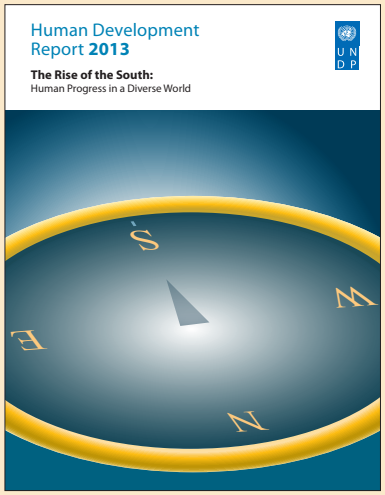
POPULATION NETWORK NEWSLETTER
POPNET
Wolfgang Lutz, Editor
No. 44, Winter 2012/13



Editorial

The newly published Human Development Report 2013 focuses on the "The Rise of the South." This is the latest in a series of reports published by UNDP that has probably become the most influential publication series in global development. An important feature of these reports is that they emphasize the human/social side of development, as well as its economic aspects. The publications also give appropriate attention to environmental concerns, and as a result cover all three dimensions of sustainable development.

This new report provides prominent coverage of recent research carried out at IIASA's World Population Program in collaboration with the other pillars of the Wittgenstein Centre. It includes extensive coverage of alternative population and education scenarios for individual countries as produced at IIASA, and illustrates the critical importance of investments in education for future human development. More importantly, in its overall approach the report builds on what is the founding idea of the Wittgenstein Centre, namely, the multi-dimensional analysis of the dynamics of human populations by age, gender, education, and health status.

—Wolfgang Lutz

Wittgenstein Centre
FOR DEMOGRAPHY AND GLOBAL HUMAN CAPITAL
A COLLABORATION OF IIASA, VID/ÖAW, WU

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IIASA
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New Wittgenstein Centre Projections by Age, Sex, and Education for 171 countries

Global Human Capital Projections form the Human Core of new IPCC SSP Scenarios

The Intergovernmental Panel on Climate Change (IPCC) is currently finalizing its Fifth Assessment Report (AR5). In this context the global modeling community on Integrated Assessment (IA) and Vulnerability, Risk and Adaptation (VRA) has recently agreed to refer to a common set of Shared Socioeconomic Pathways (SSPs) that describe alternative future worlds with respect to social and economic mitigation and adaptation challenges. Unlike the previous generation of scenarios that only considered total population size in addition to GDP, this new set of scenarios provides alternative population projections by age, sex, and six levels of education for all countries in the world. By doing so, it much more comprehensively covers the human core of the SSPs.

The completion of these SSPs coincided with the finalization of the major new expert-argument based projection effort carried out by the Wittgenstein Centre in collaboration with Oxford University (see book outline on p. 5). More specifically, the medium scenario of these new projections – which is considered the most likely in terms of future fertility, mortality, migration, and education trends – was set to be identical with SSP2 which reflects a "middle of the road" narrative about future trends. Figure 1 shows the world population by age, sex, and four levels of educational attainment as given for 2010 and as projected under this most likely scenario to 2050. It shows that not only will the world population grow by another two billion, but it will also be older and better educated.

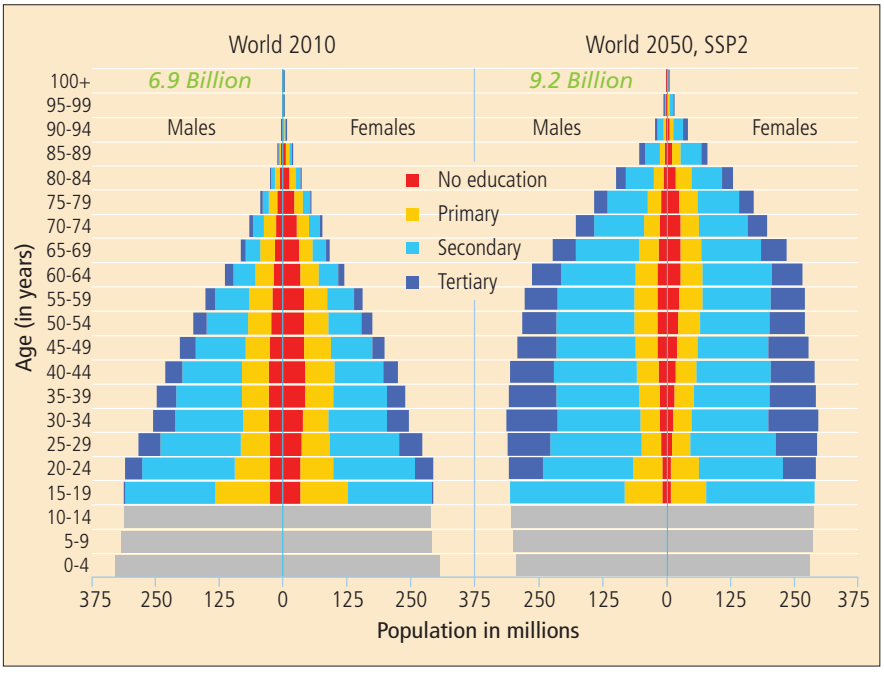

Fig. 1. World in 2010 and in 2050 under SSP2.

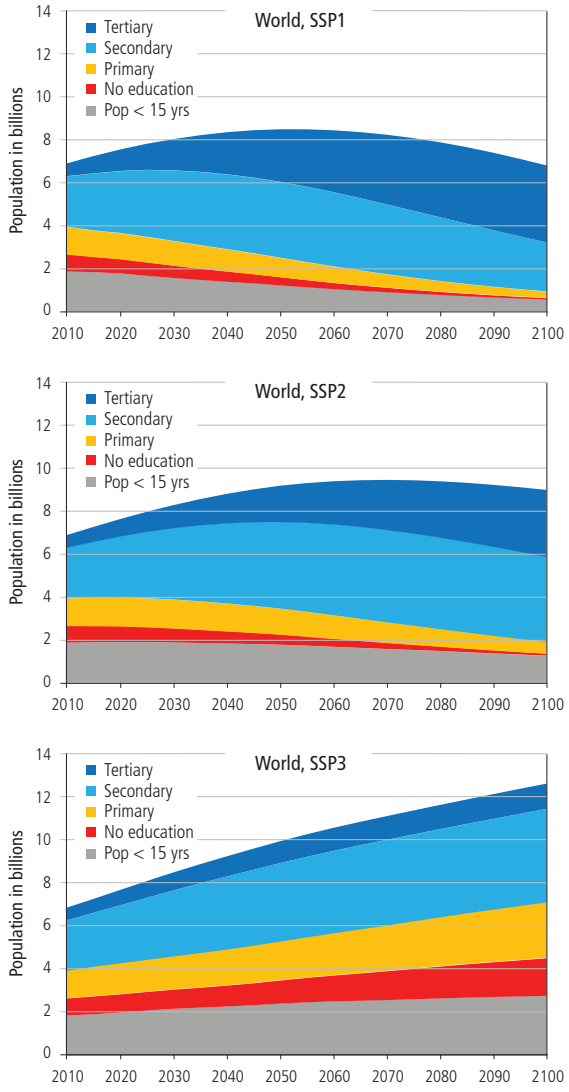

Fig. 2 The three SSP scenarios shown above depict vastly different worlds. SSP1 envisages a rapidly developing world with more education, lower mortality, and a more rapid fertility decline in high fertility countries. SSP2 is considered the most likely in terms of future fertility, mortality, migration, and education. SSP3 assumes increasing global inequality with social and economic stagnation, with stagnant school enrolments and retarded demographic transition.

The scenario story lines in SSP1 envisage a rapidly developing world with more education, lower mortality, and a more rapid fertility decline in high fertility countries. For today's rich OECD countries this scenario, based on economic prosperity, assumes medium fertility as couples are assumed to be better able to realize their childbearing aspirations. SSP3 assumes increasing global inequality in the context of social and economic stagnation leading to stagnant school enrolment rates and retarded demographic transition. For the rich OECD countries, again, the picture is different with adverse economic conditions assumed to result in low fertility. As Figure 2 and Table 2 illustrate, by 2050 SSP1 and SSP3 differ greatly in terms of resulting population size and education structures. Total population size will differ by as much as 1.5 billion over the coming four decades (8.5 billion for SSP1 and 10.0 billion for SSP3 in 2050). By the end of the century total population size under SSP1 will have declined to 6.9 billion, under SSP2 to 9.0 billion, and under SSP3 increased to 12.6 billion. Given the very different educational compositions of the world population, it is indeed plausible to assume that these scenarios refer to very different future levels of human wellbeing, with SSP1 showing a world of less than 7 billion increasingly well educated, and therefore healthy and wealthy, people who will be better able to cope with the consequences of already unavoidable climate change. In contrast SSP3 shows a world of almost 13 billion less educated, less healthy and less wealthy people likely to be much more vulnerable to environmental change.

These differences in total population size are to a large extent due to a different educational composition for women of reproductive age because fertility rates differ by level of education. Lutz and KC (2011) recently showed that by 2050 different education scenarios alone (when assuming identical education-specific fertility trajectories) result in a difference of about one billion. The SSPs also alter the levels of education-specific fertility and thus produce an even larger inter-scenario difference.

Figure 3 shows the results of the different SSP assumptions for the example of Kenya. Because Kenya is in the early stages of the fertility transitions, the future population range is much more open and uncertain than in the case of more advanced countries or at the global level. SSP1 shows that with significant further investments in education over the coming decades, Kenya by 2050 could reach an education structure (of the younger adult population) that is similar to that of Europe today. SSP3 and SSP4 show the cases of stalled development

Shared Socioeconomic Pathways Defined

SSP1 (Sustainability): This scenario assumes a future that is moving toward a more sustainable path, with educational and health investments accelerating the demographic transition, leading to a relatively low world population. The emphasis is on strengthening human wellbeing.

SSP2 (Continuation): This is the middle-of-the-road scenario in which trends typical of recent decades continue, with some progress toward achieving development goals, reductions in resource and energy intensity, and slowly decreasing fossil fuel dependency. Development of low-income countries is uneven, with some countries making good progress, while others are left behind.

SSP3 (Fragmentation): The scenario portrays a world separated into regions characterized by extreme poverty, pockets of moderate wealth, and many countries struggling to maintain living standards for rapidly growing populations. The emphasis is on security at the expense of international development.

SSP4 (Inequality): This is a world of high inequalities both among and within countries. There is increasing stratification between a well-educated, internationally connected society and a poorly educated society that works in labor-intensive industries.

SSP5 (Conventional Development): In this world conventional development oriented toward economic growth is viewed as the solution to social and economic problems. Rapid development leads to energy systems dominated by fossil fuels, resulting in high greenhouse gas emissions. The emphasis on market solutions and globalization implies high migration.

Table 1. Matrix with SSP definitions

	Country Groupings	Fertility	Mortality	Migration	Education
SSP1	HiFert	Low	Low	Medium	High
	LoFert	Low	Low	Medium	High
	Rich-OECD	Medium	Low	Medium	High
SSP2	HiFert	Medium	Medium	Medium	Medium
	LoFert	Medium	Medium	Medium	Medium
	Rich-OECD	Medium	Medium	Medium	Medium
SSP3	HiFert	High	High	Low	Low
	LoFert	High	High	Low	Low
	Rich-OECD	Low	High	Low	Low
SSP4	HiFert	High	High	Medium	CER*
	LoFert	Low	Medium	Medium	CER
	Rich-OECD	Low	Medium	Medium	CER
SSP5	HiFert	Low	Low	High	High
	LoFert	Low	Low	High	High
	Rich-OECD	High	Low	Low	High

*CER: assumption of constant school enrolment rates

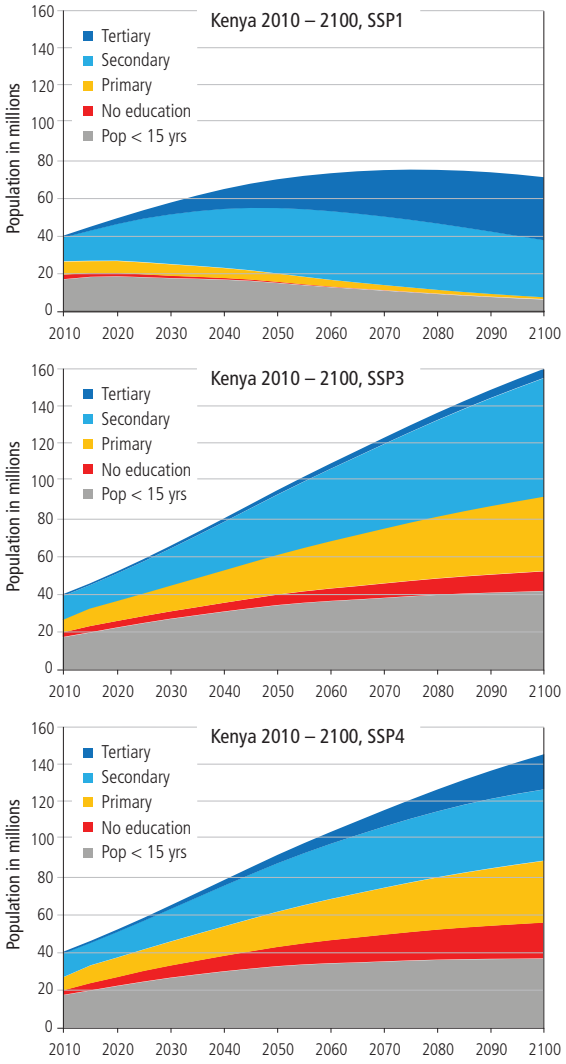

Fig. 3. Three SSP projections for Kenya 2010-2100. SSP1 shows that with significant further investments in education over the coming decades, Kenya by 2050 could reach an education structure for its younger adult population that is similar to that in Europe today. SSP3 and SSP4 show the cases of stalled development that are associated not only with much lower education levels, but also with rapid increases in population growth.

that are associated, not only with much lower education levels, but also with significantly more rapid population growth. While under SSP1 Kenya's population will "only" increase from currently 41 million to 72 million by the end of the century, under SSP3 it will increase by a factor of four to an incredible 161 million. As implied by the story lines, SSP4 shows a clearly more polarized development than SSP3, although the mean years of schooling are quite similar.

These SSPs, as briefly presented here, have been defined through the collaboration of groups of environmental and economic modelers from all continents. The demographic part of these scenarios was produced by IIASA's World Population Program in collaboration with other Wittgenstein Centre demographers. As a next step, the resulting age and education structures, together with appropriate assumptions about future productivity gains, are converted into consistent scenarios of GDP growth for all countries for the rest of the century. For this the relationship between human capital and economic growth as assessed by Lutz, Crespo and Sanderson (2008) will be used. In another line of research, IIASA has recently produced a series of studies that have empirically established the strong link between improvements in education and a reduction in vulnerability to natural disasters. Several of these studies are forthcoming in a special issue of the Journal *Ecology and Society*.

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2. Wolfgang Lutz, Samir KC (2011). Global Human Capital: Integrating Education and Population. *Science* 333(6042):587–592 (29 July), [DOI: 10.1126/science.1206964].

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Table 2. Results for major world regions and selected countries, SSP1–SSP5

		Population (in millions)					Mean Years of Schooling, Pop 15+				
Region	Year	SSP1	SSP2	SSP3	SSP4	SSP5	SSP1	SSP2	SSP3	SSP4	SSP5
World	2010	6,871	6,871	6,871	6,871	6,871	8.6	8.6	8.6	8.6	8.6
	2050	8,461	9,166	9,951	9,122	8,559	12.1	11.2	9.0	8.7	12.1
	2100	6,881	9,000	12,627	9,267	7,363	14.1	13.4	8.3	8.1	14.2
Africa	2010	1,022	1,022	1,022	1,022	1,022	5.8	5.8	5.8	5.8	5.8
	2050	1,764	2,011	2,333	2,251	1,737	11.0	9.7	6.3	5.7	11.0
	2100	1,865	2,630	3,947	3,622	1,808	13.8	12.7	6.4	5.8	13.8
Asia	2010	4,141	4,141	4,141	4,141	4,141	7.9	7.9	7.9	7.9	7.9
	2050	4,734	5,140	5,656	4,965	4,721	11.8	10.9	8.8	8.5	11.8
	2100	3,293	4,417	6,712	4,076	3,300	14.0	13.3	8.4	8.2	14.1
Europe	2010	738	738	738	738	738	12.0	12.0	12.0	12.0	12.0
	2050	769	762	681	716	847	13.7	13.5	13.0	12.8	13.7
	2100	657	702	543	535	915	14.5	14.1	12.8	12.9	14.5
Latin America & the Caribbean	2010	590	590	590	590	590	9.0	9.0	9.0	9.0	9.0
	2050	679	746	859	710	655	12.6	11.9	10.2	9.6	12.6
	2100	487	673	1,085	567	453	14.7	14.1	10.3	9.9	14.6
Northern America	2010	344	344	344	344	344	13.8	13.8	13.8	13.8	13.8
	2050	460	450	372	424	535	14.8	14.6	14.3	14.1	14.8
	2100	521	513	290	406	801	15.3	15.1	14.4	14.2	15.2
Oceania	2010	36	36	36	36	36	12.1	12.1	12.1	12.1	12.1
	2050	56	57	51	56	64	14.2	13.7	12.8	12.7	14.2
	2100	59	65	50	61	87	15.2	14.9	12.4	12.6	15.3
China	2010	1,341	1,341	1,341	1,341	1,341	8.8	8.8	8.8	8.8	8.8
	2050	1,225	1,263	1,307	1,183	1,225	12.1	11.7	10.9	10.5	12.1
	2100	644	767	1,028	555	645	13.9	13.5	11.2	11.3	13.9
Republic of Korea	2010	48	48	48	48	48	12.6	12.6	12.6	12.6	12.6
	2050	48	46	41	44	51	15.0	15.0	14.9	14.8	14.9
	2100	32	30	18	24	42	15.5	15.5	15.2	15.0	15.5
India	2010	1,225	1,225	1,225	1,225	1,225	6.0	6.0	6.0	6.0	6.0
	2050	1,550	1,734	1,971	1,601	1,547	11.6	10.1	7.1	6.8	11.6
	2100	1,138	1,603	2,609	1,169	1,134	14.5	13.7	7.3	7.4	14.5
Indonesia	2010	240	240	240	240	240	8.5	8.5	8.5	8.5	8.5
	2050	271	288	307	261	269	12.4	11.8	10.3	9.8	12.4
	2100	184	228	292	152	180	14.8	14.3	10.6	10.7	14.8
Germany	2010	82	82	82	82	82	15.6	15.6	15.6	15.6	15.6
	2050	82	79	67	75	92	16.6	16.4	16.2	16.0	16.6
	2100	67	67	38	52	99	17.2	17.0	16.3	16.1	17.1
Russian Federation	2010	143	143	143	143	143	10.6	10.6	10.6	10.6	10.6
	2050	131	137	134	127	138	11.3	11.1	10.8	10.3	11.3
	2100	93	123	149	88	102	11.5	11.3	10.8	10.2	11.5
Kenya	2010	41	41	41	41	41	9.2	9.2	9.2	9.2	9.2
	2050	70	78	96	92	68	13.6	12.8	9.2	8.4	13.6
	2100	72	96	161	145	67	15.0	14.5	9.3	9.0	15.0
South Africa	2010	50	50	50	50	50	9.6	9.6	9.6	9.6	9.6
	2050	62	63	62	56	65	12.7	11.7	10.4	9.9	12.7
	2100	49	58	71	39	52	13.9	13.3	10.4	10.6	13.9
Egypt	2010	81	81	81	81	81	7.6	7.6	7.6	7.6	7.6
	2050	113	125	141	112	111	12.3	11.8	9.8	9.3	12.3
	2100	97	131	198	91	94	14.1	13.7	10.1	10.1	14.1
Turkey	2010	73	73	73	73	73	7.3	7.3	7.3	7.3	7.3
	2050	87	96	109	92	87	11.3	10.4	8.1	7.6	11.3
	2100	66	90	149	73	66	13.7	13.1	8.2	7.9	13.7
United States of America	2010	310	310	310	310	310	13.7	13.7	13.7	13.7	13.7
	2050	411	402	334	379	476	14.8	14.5	14.2	14.1	14.7
	2100	467	459	262	365	713	15.3	15.1	14.3	14.2	15.2
Brazil	2010	195	195	195	195	195	8.1	8.1	8.1	8.1	8.1
	2050	215	232	254	215	213	11.5	10.9	9.7	9.2	11.5
	2100	141	188	276	135	139	13.8	13.1	10.0	9.9	13.8

Forthcoming Book with Oxford University Press

World Population and Human Capital in the 21st Century

Editors – Wolfgang Lutz, William P. Butz, and Samir KC

One of the Wittgenstein Centre's first collaborative projects is an ambitious new set of science-based population projections by age, sex and level of educational attainment for more than 180 countries through the end of the century. Published by the Oxford University Press, the book will present the most comprehensive analysis to date of what is known about the drivers of global population change and the range of likely trends between now and 2100.

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   Contributing Authors: Donatien BEGUY; John CASTERLINE; Teresa CASTRO MARTIN; Youssef COURBAGE; Gavin JONES; James K.S.; John MAY; Blessing MBERU; Laura RODRIGUEZ WONG; Bruno SCHOUMAKER; David SHAPIRO; and Brenda YEPEZ-MARTINEZ.
4. *Future Fertility in Low Fertility Countries*
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5. *Future Mortality in High Mortality Countries*
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   Contributing Authors: Michel GARENNE; Bruno MASQUELIER; Francois PELLETIER
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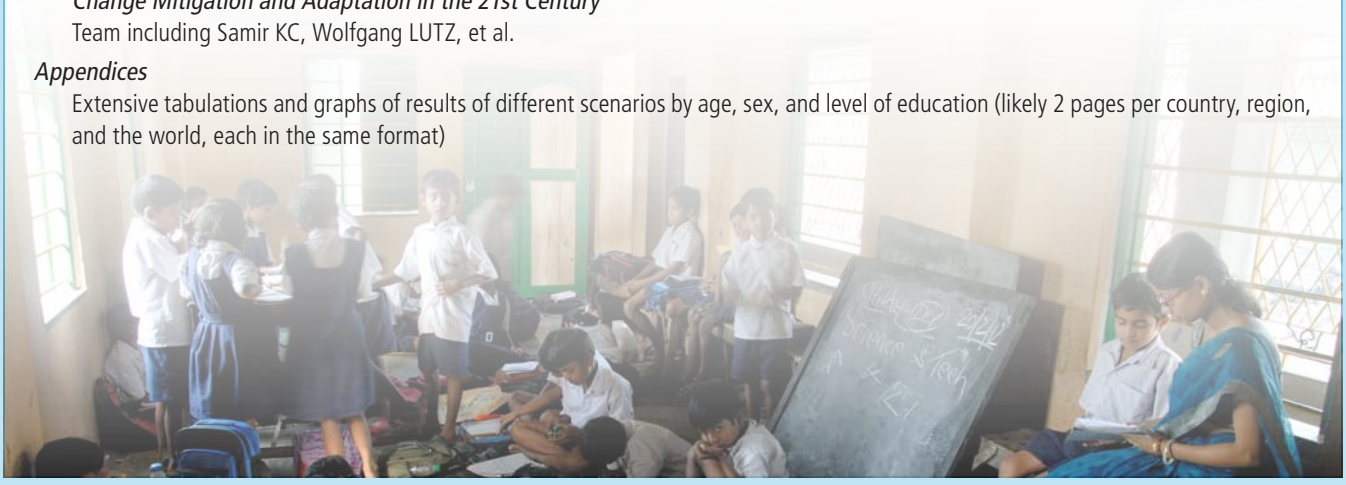
Appendices

Extensive tabulations and graphs of results of different scenarios by age, sex, and level of education (likely 2 pages per country, region, and the world, each in the same format)



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Summary of article published in *Population and Development Review*, February 2013

Demographic Metabolism: A Predictive Theory of Socioeconomic Change

Wolfgang Lutz

This essay introduces a general theory of how societies change as a consequence of the changing composition of their members with respect to certain relevant and measurable characteristics. These characteristics can either change over the life course of individuals or from one generation to the next. While the former changes can be analytically identified and described by certain age- and duration-specific transition schedules, the latter changes resulting from cohort replacement can be modeled and projected using standard models of population dynamics.

Building on earlier qualitative work by Karl Mannheim and Norman Ryder, who introduced the notion of demographic metabolism, this new theory applies the quantitative tools of multi-dimensional mathematical demography to forecast the future composition of a population according to relevant characteristics. In the case of persistent characteristics (such as highest educational attainment) that typically do not change from young adulthood until the end of life, quantitative predictions about the distributions of such characteristics in the population can readily be made for several decades into the future. For other characteristics that tend to change over the life course (such as labor force participation), standard age/duration specific patterns can be assumed. Hence, unlike other models that are called "theories" but cannot be used to make explicit quantitative statements about the future, this theory of socioeconomic change can make such statements in a way that can potentially be falsified. It can therefore be called a theory with predictive power according to Karl Popper's criteria (Popper 1959).

A macro-level theory based on people as units

This is a theory predicting aggregate-level change rather than individual behavior. It is a macro-level theory focusing on the changing composition of a population and hence has no micro-level analogue. It can be called a "demographic" theory of socioeconomic change, implying that its inspiration and approach are demographic though its purpose is not. It is not primarily intended to explain and forecast demographic variables (such as population size, birth and death rates, migration, and the like); rather the goal is to predict socioeconomic change in a broader sense (ranging from values and religions to skills and productivity of the labor force) using a demographic paradigm.

The foundations of this theory can be presented in the form of four propositions:

Proposition 1: *People—individual humans—are the primary building blocks of every society and the primary agents in any economy. Hence, they form the basic elements of any theory of social and economic change.*

In the terminology of the pre-Socratic philosophers, people are the atoms of society. Theoretically, one could delve into sub-atomic structures: modern brain research shows that any decision at the individual level is the result of complex interactions among different parts of our brains. But for the present purpose, it is sufficient to assume that decisions happen at the level of individuals, who then interact with other individuals.

Proposition 2: *For any population, members can be sub-divided into disjoint groups (states) according to clearly specified and measurable individual characteristics (in addition to age and sex) for any given point in time.*

In principle, any subdivision of people that satisfies this criterion is legitimate and allows the application of the theory described here. Age is a special characteristic for forecasting because it automatically changes in tandem with chronological time. Hence, the applications and illustrations of the theory are designed to divide the entire population by the particular characteristics of interest and then further to sub-divide all people in this category by age and sex. Over time, people stay in their categories and simply become one year older every calendar year unless they die or move to another category.

Proposition 3: *At any point in time, members of a sub-population (state) defined by certain characteristics can move to another state (associated with different characteristics), and these individual transitions can be mathematically described by a set of age- and sex-specific transition rates.*

Transitions may occur not only to another state inside the system but also to an absorbing state (death) or to a state outside the system (out-migration). New individuals arriving (through birth or in-migration) will be immediately allocated to one state within the system. Not all transitions among a given set of states are possible. Some transitions are only possible in one direction, such as from lower to higher educational categories or from the single to the married state, from which people may move to the divorced or widowed state.

Proposition 4: *If any given population consists of sub-groups that are significantly different from each other with respect to relevant characteristics, then a change over time in the relative size of these sub-groups will result in a change in the overall distribution of these characteristics in the population and hence in socioeconomic change.*

The choice of a characteristic that is worth studying with respect to its changing distribution in a society is necessarily context-specific. Hence, the definition of relevant sub-groups depends on the questions asked.

The multi-dimensional cohort-component model

Most demographic methods deal with the transitions of people from one state to another over a certain time interval and are in one way or another based on the life table. In its most fundamental form the two states are being alive and being dead. Life tables were calculated separately for men and women because observed age-specific mortality rates tended to differ substantially by sex. Aside from this differentiation by age and sex, conventional demography still considers populations to be largely homogeneous—for example, assuming that all men aged 50–54 are exposed to the same risk of death. In the multi-state case this restriction is relaxed and mortality rates can differ for sub-groups as defined by the above discussed characteristics.

The multi-state model is based on the generalization of the simple life table (single decrement table) to multiple-decrement and increment-decrement life tables. Essentially such tables describe movements of people that can go back and forth between more than two states. These methodological advances, made in the 1970s largely by scholars affiliated with the International Institute for Applied Systems Analysis (IIASA), led naturally to the multi-state population projection model that can simultaneously project the populations of different categories (states, regions) with different fertility, mortality, and migration

From: *Population and Development Review*, February 2013, Special Supplement in Honor of Paul Demeny

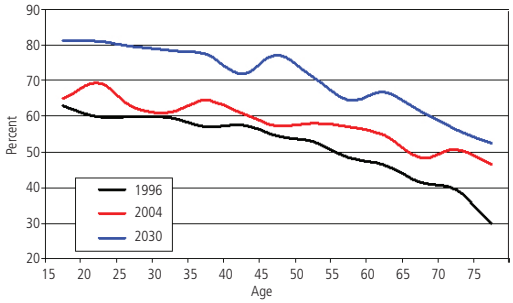
patterns as well as movements among the categories.

After the initial focus on regionally defined states, applications were expanded to the analysis of marital status transitions, the analysis of labor force participation, the analysis of health and morbidity, family status, and most recently, educational attainment. Since the highest educational attainment is typically achieved at younger ages and then maintained throughout life, and since comparable data exist for most countries, educational attainment distributions by age and sex could already be reconstructed and projected according to different scenarios for most countries in the world (see report on SSPs on preceding pages).

Predicting "soft" variables such as preferences and identities

Many political observers of the current economic crisis and its effect on the euro and the future of the European Union expect a revival of nationalism in many member countries and as a result a possible dissolution of the EU. It is often argued that existing economic interdependencies (particularly in the banking sector) are the main force that still holds the EU together. These observers overlook the major force of demographic metabolism when it comes to changing distribution of opinions and identities of the people who make up Europe.

Lutz et al. (2006) conducted an analysis along these lines using time series of Eurobarometer data on strictly national versus partly European identity by age. As the figure shows, there is a clear decline in European identity with age. If interpreted as an age effect, this would imply future declines in the prevalence of European identity in the context of population aging. If it were to be a cohort effect (with young cohorts being socialized into a more European context and maintaining this higher European identity throughout their lives) we would expect an increasing prevalence of European identity. Based on statistical analysis of the time series the paper establishes a strong cohort effect and uses this to project the likely prevalence of European identity to 2030. The model predicts that with a continuation of this cohort effect demographic metabolism will result in a clear majority of the European adult population with a European identity in addition to their national one.



Proportion of the European population with multiple identities (including European identity) by age, 1996, 2004, and forecast for 2030. Source: Lutz et al. (2006)

Reaching far beyond demography

This demographic theory can possibly bring innovation to economics as well as sociology. Demographers tend to use many sociological and economic concepts in their work. Why should a genuinely demographic concept, applied far beyond the traditional realm of demography, not also advance thinking in those other disciplines? For sociology, political science, and the study of social change the applicability of this theory is immediately clear, but there are many possible applications in economics as well. Wherever in economics the almost ubiquitous assumption of strictly homogeneous human agents is considered as too strong, this model offers a quantitative way of explicitly addressing heterogeneity. This can range from distinguishing between groups of people who have different sets of indifference curves underlying their choices to groups of people with different discount rates in their assessment of utilities or to people who have different degrees of rationality in their behaviors.

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The Laxenburg Declaration: a policy statement for the Rio+20 Conference

Demography's Role in Sustainable Development

In preparing for the RIO+20 Earth Summit, the world community must acknowledge that population trends interact strongly with economic development and environmental change at local and global levels. The International Institute for Applied Systems Analysis (IIASA) recently convened leading experts to consider how demographic factors promote or impede sustainable development. The panel concluded that human beings—their numbers, distribution, and characteristics—are at the center of concern for sustainable development. The evidence is clear that demographic differences fundamentally affect people's contribution to environmental burdens, their ability to participate in sustainable development, and their adaptability to a changing environment. The developmental challenges are by far the most significant where population growth and poverty are the highest, education is the lowest, and vulnerabilities to environmental change are the greatest. Within families, women and children are most vulnerable.

As members of this panel, we put forward five action implications: (i) Recognize that the numbers, characteristics, and behaviors of people are at the heart of sustainable development challenges and of their solutions. (ii) Identify subpopulations that contribute most to environmental degradation and those that are most vulnerable to its consequences. In poor countries especially, these subpopulations are readily identifiable according to age, gender, level of education, place of residence, and standard of living. (iii) Devise sustainable development policies to treat these subpopulations differently and appropriately, according to their demographic and behavioral characteristics. (iv) Facilitate the inevitable trend of increasing urbanization in ways that ensure that environmental hazards and vulnerabilities are under control. (v) Invest in human capital—people's education and health, including reproductive health—to slow population growth, accelerate the transition to green technologies, and improve people's adaptive capacity to environmental change.

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(From: *Science*, 24 February 2012, Vol 335)

Variation in cognitive functioning as a refined approach to comparing aging across countries

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Edited* by Joel E. Cohen, The Rockefeller University, New York, NY, and approved November 14, 2011 (received for review July 28, 2011)

Comparing the burden of aging across countries hinges on the availability of valid and comparable indicators. The Old Age Dependency Ratio allows only a limited assessment of the challenges of aging, because it does not include information on any individual characteristics except age itself. Existing alternative indicators based on health or economic activity suffer from measurement and comparability problems. We propose an indicator based on age variation in cognitive functioning. We use newly released data from standardized tests of seniors' cognitive abilities for countries from different world regions. In the wake of long-term advances in countries' industrial composition, and technological advances, the ability to handle new job procedures is now of high and growing importance, which increases the importance of cognition for work performance over time. In several countries with older populations, we find better cognitive performance on the part of populations aged 50+ than in countries with chronologically younger populations. This variation in cognitive functioning levels may be explained by the fact that seniors in some regions of the world experienced better conditions during childhood and adult life, including nutrition, duration and quality of schooling, lower exposure to disease, and physical and social activity patterns. Because of the slow process of cohort replacement, those countries whose seniors already have higher cognitive levels today are likely to continue to be at an advantage for several decades to come.

The world population is growing older (1, 2). Comparisons of the burden of aging across countries hinge on the availability of valid and comparable indicators. Demographic indicators like the old-age dependency ratio and median age are widely used to characterize and rank how old countries are. Based on these measures, the populations of Germany, the United States, and Japan are much older than those of India, China, or Mexico. However, the fact that these indicators are exclusively based on chronological age distributions limits their usefulness in terms of drawing conclusions about the consequences of and possible responses to population aging. Alternative approaches to comparing the extent of aging across countries are based on subjective health, life expectancy, and economic activity (3–5). These studies show that different countries can be considered to be the oldest in the world depending on how aging indicators are defined. Such measures, however, can be influenced by culture- and nation-specific interpretations of health level and disability and by business cycle fluctuations.

In contrast to existing studies, we here compare the extent of aging across nations according to age variation in cognitive abilities. Recently released surveys allow us to compare country-level variation in seniors' cognitive functioning across populations with younger and older age distributions.

Studies have found that cognitive ability levels predict individual productivity better than any other observable individual characteristics and that they are increasingly relevant for labor market performance (6–10). This finding applies to a variety of countries and settings, including poorer countries and rural settings (11, 12). In the wake of long-term advances in countries' industrial composition and technological advances, the ability to handle new job procedures is now of high and growing importance, which increases the importance of cognition over time (7, 13).

The growing importance of seniors for the labor market and the fact that certain cognitive abilities decline considerably during late adult ages are the reasons why we focus our study on the population that is 50 y and older (14–18). The length of time for which individuals can retain high cognitive performance will influence the age until which they can potentially stay active in the labor market. We use standardized questions based on representative surveys from different world regions. These international comparable surveys of seniors include English Longitudinal Study of Aging (ELSA), Health and Retirement Study (HRS), World Health Organization (WHO) Study on global AGEing and adult health (SAGE), and Survey of Health, Aging and Retirement in Europe (SHARE), which together allow us to cover almost one-half (45.5%) of the world population (see *SI Materials and Methods* for more details). These surveys include a measure of cognitive ability that is operationalized comparably across all surveys, namely, immediate recall of a certain number of given words, which is a measure of short-term memory (19). Other variables that measure cognitive abilities, like delayed word recall or fluency, are either not included in every survey or not measured in a comparable way. Analysis for countries where these measures can be compared corroborates the results we get for immediate word recall (see Figs. S1 and S2, Tables S1 and S2, and *SI Results* for more details). This study compares seniors' age variation in cognitive abilities across countries from both developed and emerging economies by using results from standardized testing procedures. The inclusion of seniors from world regions with chronologically younger populations has become possible only recently with the release of SAGE.

Immediate recall has been shown to be important for a variety of outcomes, ranging from financial decisionmaking to the risk of developing dementia (20–23). Moreover, technological advances and changes in working procedures imply that the importance of the ability to learn and remember is increasing (24). Employers are particularly concerned that their employees are able to learn new work procedures and process new information (25), which also suggests that employers view the ability to immediately recall information as advantageous to labor market performance.

Results

Fig. 1 shows the age variation in immediate recall across countries and country regions. It depicts the proportion of words (out of 10 read out nouns) which the respondents are able to recall within 1 min (18 countries) and 2 min (UK and the US; 95% of

Author contributions: V.S. designed research; E.L. and D.W. prepared and analyzed data; and V.S., E.L., and D.W. wrote the paper.

The authors declare no conflict of interest.

*This Direct Submission article had a prearranged editor.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1112173109/-/DCSupplemental.

From: *PNAS*, January 17, 2012, 770–774, vol. 109, no. 3.

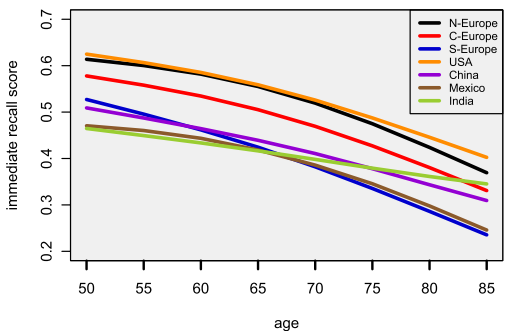

Fig. 1. Mean age-group–specific immediate recall scores (values between 0 and 1, where a score of 0.4 means being able to recall 40% of the given words). Curves are smoothed by using spline interpolations. Logistic regression to test for significant age-related decline, significance levels $P < 0.001$. Analysis of variance to test for differences between countries, significance levels $P < 0.01$.

the US participants completed the task within 1 min. See *SI Materials and Methods* for more details). In Table 1 summary statistics for all used variables of our dataset are provided.

The findings highlight a statistically significant age-related decline in all countries within the 50–85 age interval. Immediate recall age trajectories for northern and continental European countries and the United States run parallel to those of southern Europe, Mexico, and China, whereas the decline in India proceeds at a much slower pace. Our findings show statistically significant differences in the levels of cognitive performance between countries. Thus, seniors in the United States and northern and continental European countries have the highest immediate recall ability, whereas their peers in China, India, Mexico, and southern Europe perform worse.

To take the observed differences in cognitive functioning of seniors into account when comparing aging across countries, we propose an additional indicator that focuses on cognition and demographic change: cognition-adjusted dependency ratio (CADR). For this measure, the denominator is composed of everyone who is 15 to 49 y old and the 50+ population (no upper age bound) with good cognitive functioning (approximated by those who are able to recall at least one-half of the words in the test). The numerator consists of the number of persons aged 50+ who recall fewer than one-half the words in the test.

Our aging indicator is presented and compared with the usual old-age dependency ratio (OADR), which is defined as the ratio of the number of persons aged 65+ to the number of persons between the ages of 15 and 64, in Table 2. The rank ordering of the different countries and regions changes as we apply the alternative aging indicator: Mexico, India, and China do less well compared with the rank order based on the OADR, whereas the United States and continental and northern Europe do better.

This result implies that although continental European countries have a larger population share above the age of 65 than China, their lower CADR would suggest that these countries are effectively "younger." That is, they have a lower share of seniors with poor cognitive performance.

Discussion

One potential source of explanation for the international variation in seniors' cognitive functioning levels are life-course differences among the cohorts we consider. Present-day seniors in different countries have varying experiences with respect to a large number of influences, including their average length and quality of schooling, nutrition (prenatal, early life, and adult), exposure to famines, disease, and pollutants, physical and social activity patterns, and whether working conditions have been stimulating or detrimental to cognitive performance (26–37).

An increase in cognitive performance among successive cohorts describes a phenomenon that has been observed in many countries for an extended period (38–40). In the United States, such evidence began with comparisons of test performances of conscripts from World War I and World War II, with continued cognitive improvements having been documented for most of the 20th century. Successive cohorts in western countries have been shown to generally perform better at cognitive tests for long periods, whereas in other countries, cohort improvements have only been documented for recent cohorts. The likely later onset of cognitive improvement would follow the observed delayed onset of drivers of cognitive improvements, including mortality decline, universal education, improved nutrition, and better economic conditions (40–44).

In some countries, particularly in India, the cohorts presently 50 y and older have grown up during periods of widespread poverty and deprivation and where mortality levels were high, which could lower the overall levels of cognition among the cohorts presently old (41, 45). At the same time, large socioeconomic mortality differentials within a population could imply that the population is positively selected at a more advanced age. Given that those with higher cognitive performance live longer,

Table 1. Summary statistics of the survey subsets

	HRS	SAGE			SHARE (Northern Europe)	SHARE (Continental Europe)	SHARE (Southern Europe)
Measurements	United States	China	India	Mexico	Denmark, England, Ireland, Sweden	Austria, Belgium, Czech Republic, France, Germany, Netherlands, Poland, Switzerland	Greece, Italy, Spain
Year	2006/07	2007–2009	2007–2009	2007–2009	2006/07	2006/07	2006/07
Sample size	17,995	13,367	7,150	2,306	4,736	14,948	6,153
Females, %	58.3	53.1	49.4	60.5	53.4	55.2	54.6
Birth cohorts	1901–1956	1910–1959	1909–1957	1904–1959	1907–1957	1903–1957	1905–1957
None of the words recalled, %	0.7	1.3	1.0	2.8	0.4	1.9	2.9
All words immediately recalled, %	0.7	0.4	0	0	0.9	0.4	0.5

Table 2. Different measures for the burden of aging

Country/group	Rank (ratio) CADR	Rank (ratio) OADR
United States of America	1 (0.10)	4 (0.19)
Northern Europe (Denmark, England, Ireland, Sweden)	2 (0.12)	5 (0.24)
India	3 (0.14)	1 (0.07)
Mexico	3 (0.14)	2 (0.09)
China	5 (0.15)	3 (0.12)
Continental Europe (Austria, Belgium, Czech Republic, France, Germany, Netherlands, Poland, Switzerland)	6 (0.18)	6 (0.25)
Southern Europe (Greece, Italy, Spain)	7 (0.32)	7 (0.27)

Source: Population data for the year 2005 from UN (2009) and for England for the year 2005 from the Office for National Statistics (2010); survey data from HRS, SAGE, and SHARE.

this could entail a "flatter" age-cognition curve (46, 47), such as for India (48–50).

A few studies suggest that there has been a leveling off and reversal in cognitive increases among recent generations of younger men in some countries; however, it will take several decades until these cohorts attain senior age (51, 52).

Education has been identified as significantly raising levels of cognitive functioning, including memory (16, 53, 54). The countries in our study with better cognitive functioning levels are also the countries with higher educational attainment. Northern Europeans and Americans have globally the highest educational attainment among their 50+ population, whereas education levels are much lower in the Chinese and Mexican senior populations. Epidemiological research has identified low educational attainment as an important risk factor for low cognitive functioning and Alzheimer's disease (55, 56). Education is related to better cognitive performance in late life, and researchers relate the effect to occupational complexity and the acquisition of a lifelong ability to sustain attention and conceptualize problems. Although it is uncertain whether education affects the rate of decline (57), it can affect the cognitive level for all age groups (53, 54). Being mentally active, through courses and cognitive training, has been shown to improve cognitive functioning among older people (33, 58–60). Education may increase the synaptic density in the neocortical association cortex and, therefore, delay cognitive decline and dementia by several years (61). At the same time, lower childhood intelligence in early life appears to be a reliable proxy for lower cognitive ability later in life (62–64).

Later born cohorts with higher cognitive functioning will eventually replace older cohorts with poorer cognitive performance. If this trend continues, cognitive performance is likely to improve along cohort lines at senior adult ages (65). In Mexico, where time series data allow comparison of successive cohorts, we find that individuals of the 1941–45 cohorts at age 60 were able to remember on average 4.2 words, whereas those born 1946–50 were able to recall 5.1 words at the same age. The same holds for England's 60-y-olds: Here, we find an increase from 6.0 to 6.3 recalled words for the 1941–45 relative to the 1946–50 cohorts. Overall, these developments suggest that there will be a universal increase in cognitive functioning among seniors in the coming decades. However, as cohort replacement is a slow process, the countries whose seniors have higher cognitive levels today are likely to continue to have an advantage for several decades ahead.

Age-related norms (such as at which age a person is regarded as being "old") can vary by countries and cultures (66, 67). They may be influenced by age-related laws and regulations, including official retirement ages, which vary significantly between countries (68). Retiring at older ages can imply that one stays mentally active until higher ages, which could improve the level of cognitive functioning until higher ages (69).

Conclusion

The current study's shift in focus from chronological age distributions to actual cognitive functioning at older ages leads to a relevant additional possibility to compare aging across countries. This shift in perspective is crucial because it changes focus from predictable changes in the demographic age structure toward the importance of improving and maintaining cognitive abilities. Because the adjustment for aging requires long-term investments and changes in training policies and lifestyles, it is essential to implement policies and efforts that prepare societies for an older population by maintaining cognitive abilities throughout the life cycle (70, 71).

The degree to which demographic aging translates into societal challenges depends to a considerable extent on the age at which mental functioning becomes significantly impaired. Technological improvements increasingly allow seniors to participate longer in the working life (72, 73). Normal aging, however, also tends to involve a decline in certain cognitive abilities, where technological innovations are less likely to be able to compensate to a significant extent for cognitive decline. At the same time, the need for cognitive fitness seems to continue to increase. Nations that are truly challenged by aging may be those where the cognitive performance among their seniors is poor; not those who have chronologically older age structures.

Materials and Methods

A growing number of surveys are focusing on the elderly (for an overview of selected cross-national and single-country databases, see ref. 1). However,

Table 3. Overview of all used datasets

Dataset	Country/region	Year	Sample size
ELSA (English Longitudinal Study of Aging)	England	2006/07	9,771
HRS (Health and Retirement Study)	United States	2006/07	18,469
MHAS (Mexican Health and Aging Study)	Mexico	2003	13,704
SAGE (WHO Study on global Aging and adult health)	China, India, Mexico	2007/09	32,696
SHARE (Survey of Health, Aging and Retirement in Europe)	Europe	2006/07	26,515

the number of surveys that contain the information we need for our analysis is limited (Table 3). The main reasons for excluding data sources are (*i*) The survey only includes people above 60 or 65, which is higher than our lower age bound of 50 y and (*ii*) the measure for cognitive ability is not included in the survey or not comparable to our measure of word recall.

Data Sources and Variables. ELSA, representative for the population aged 50+ of England, consists of four waves (2002–2009) (74). HRS is representative for the 50+ population of the United States. It started 1992 and was conducted every year until 1996. Thereafter it was done only every other year. So far, 11 waves are available. For our purpose we took the RAND HRS dataset, a user-friendly subset of HRS (75). SHARE is a European survey that is representative of the participating countries' population aged 50+. The first survey was conducted in 11 countries in 2004/2005. Three more countries were added for the second wave in 2006/07. We divided the individual country files of SHARE into three regional datasets: continental (Austria, Belgium, the Czech Republic, France, Germany, the Netherlands, Poland, and Switzerland), southern (Greece, Italy, and Spain) and northern Europe (Denmark, Sweden, and Ireland) (76). Mexican Health and Aging Study (MHAS) consists of two waves. The baseline survey was conducted in 2001, the follow-up in 2003. The survey population is representative of Mexicans aged 50+ (77). SAGE was initiated by WHO to collect longitudinal information on health and well-being of adults (18+ with an emphasis on 50+). We use this data for China, India, and Mexico (78).

ELSA is part of the Northern European country group. All "don't know" and "refused" answers are coded as missing in all surveys. For cross-country comparison we use the 2006/07 waves to compare cognitive performance by age and country/region for a similar period. MHAS was only used for obtaining cohort differences in cognitive functioning. All provided results are gained by including the provided cross-sectional individual sample weights or individual sample weights for longitudinal investigations.

CADR. As described above, we introduce CADR, which is formally defined by the following equation.

$$CADR = \frac{|\{x \in P | (m_x < 0.5) \wedge (age_x \geq 50)\}|}{|\{x \in P | (15 \leq age_x < 50\} \cup \{m_x \geq 0.5) \wedge (age_x \geq 50)\}|},$$

where m_x represents the memory score of person x, age_x represents the age of person x, and P is the population.

Trends in Cognitive Abilities. We use all four waves of ELSA and calculate the mean immediate recall score at age 60 for the cohorts born between 1941 and 1945 and the cohorts born between 1946 and 1950. MHAS data for 2001 and 2003 are combined with SAGE data for 2007/09, because both surveys are representative for the 50+ population in Mexico. The cohorts born between 1941 and 1945 and the cohorts born between 1946 and 1950 are analyzed in an analogous manner to ELSA.

ACKNOWLEDGMENTS. We acknowledge the support of Victoria Schreitter and Gwen Fisher. This paper uses data from the WHO Study on global AGEing and adult health (SAGE) and SHARE release 2.3.0, as of November 13, 2009. SHARE data collection in 2004–2007 was primarily funded by the European Commission through its fifth and sixth framework programs by Project Numbers QLK6-CT-2001-00360; RII-CT-2006-062193; and CIT5-CT-2005-028857). Additional funding provided by US National Institute on Aging Grants U01 AG09740-13S2, P01 AG005842, P01 AG08291, P30 AG12815, Y1-AG-4553-01, OGHA 04-064, and R21 AG025169 and by various national sources is gratefully acknowledged (see http://www.share-project.org for a full list of funding institutions). The Health and Retirement Study is sponsored by National Institute on Aging Grant NIA U01AG009740 and is conducted by the University of Michigan. The English Longitudinal Study of Ageing was developed by a team of researchers based at University College London, the Institute of Fiscal Studies, and the National Centre for Social Research. The funding is provided by the National Institute on Aging in the United States (Grants 2RO1AG7644-01A1 and 2RO1AG017644) and a consortium of UK government departments coordinated by the Office for National Statistics. The developers and funders of ELSA and the Archive do not bear any responsibility for the analyses or interpretations presented here. We acknowledge support by a Starting Grant of the European Research Council, Grant Agreement 241003-COHORT.

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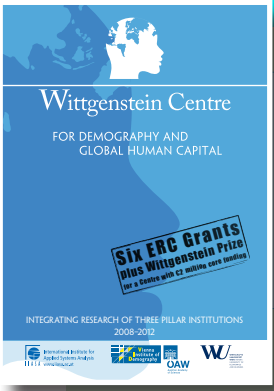
Wittgenstein Centre receives three new ERC Grants

Three Wittgenstein Centre researchers recently received new European Research Council grants totaling more than €3.6 million. The latest grants bring the number of ERC grants at the Centre to six. The new grants are:

- Demographer Tomáš Sobotka received a €1.3 million Starting Independent Research Grant for VID for the project, Fertility, Reproduction and Population Change in 21st century Europe. Sobotka will study fertility research in contemporary Europe, fertility intentions, and the links between fertility, migration, and population change.
- Demographer Sergei Scherbov received a €2.25 million Advanced Grant for IIASA to support his work on redefining age. Scherbov will develop methods for the analysis of aging that include such factors as remaining life expectancy, health, disability, cognition, and the ability to work.
- Centre Director Wolfgang Lutz received a €150,000 Proof of Concept Grant that could bring methods developed under FutureSociety, his Advanced ERC Grant, to commercial use. The new grant, won in collaboration with WU marketing professor Thomas Reutterer, explores potentials for a demographic market forecasting tool.



Wittgenstein Centre publishes Five-Year Report

The Wittgenstein Centre, a collaboration among IIASA, VID/ÖAW and WU, recently published a report that summarizes the achievements and work of its scientists. The report, entitled "Integrating Research of Three Pillar Institutions 2008–2012," provides information about the Centre's six ERC grants, describes selected research topics, and highlights selected publications. The report is available at the Centre's web site: www.wittgensteincentre.org.

Call for Papers
Wittgenstein-VID Seminar on
Health, Education, and Retirement over the Prolonged Life Cycle
Vienna, 27-29 November 2013

Much of the world's population has experienced an unprecedented increase in healthy life expectancy in the past several decades, and that increase raises questions about how the longer life expectancy has been shaped by, and will shape, individual behavior over the life cycle. This increase in life expectancy poses policy challenges for social security and the cohesion of society, given that social groups benefit from a longer life to a varying extent. This conference invites social science researchers to present work on the causes and consequences of a prolonged life cycle at both the micro and macro levels. Empirical and theoretical papers as well as overviews are welcome.

Conference coordinators are Alexia Prskawetz and Michael Kuhn. Selected conference contributions will be published in the thematic issue of the *Vienna Yearbook of Population Research 2014*.

Please send your 1-page abstract to
conference.vid@oeaw.ac.at by 30 June 2013.

New staff at the Centre

Since the publication of the last Popnet, in November 2011, nine people have joined the Centre:

Stephanie Andruchowitz (IIASA)
Eva Beaujouan (VID)
Zuzanna Brzozowska (VID)
Jim Dawson (IIASA)
Florian Habersberger (WU)
Desiree Krivanek (VID)
Andrea Seidl (VID)
Markus Speringer (VID)
Angela Wiedemann (VID)

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Managing Editor: Wolfgang Lutz
Printed by Remaprint, Vienna

IIASA is an international scientific institute that conducts research into key global issues that we face in the twenty-first century: Energy and Climate Change, Food and Water, Poverty and Equity.

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ZVR-Nr: 524808900