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THE BASE CASE OF INTERNATIONAL FUTURES (IFs): COMPARISON WITH OTHER FORECASTS

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Table of Contents

Abstract

This paper provides an introduction to the base case of the International Futures (IFs) modeling system. It does so through a review of forecasts made by many organizations and some individuals in all of the major issue areas covered by IFs: population/demographics; economics; energy; food and agriculture; the environment; and socio-political systems. It provides information about the IFs base case in the context of those forecasts, comparing IFs with them and explaining key differences.

Each chapter on an individual issue area begins with a survey of the leading sources of forecasts for the issue, briefly notes the key concepts of interest in the forecast area, and proceeds to the comparative presentation of other forecasts and the base case of IFs. The penultimate chapter quickly surveys families of scenarios that present multiple-issue global futures. That chapter is a prelude to a future report that will compare scenario development within IFs to those families.

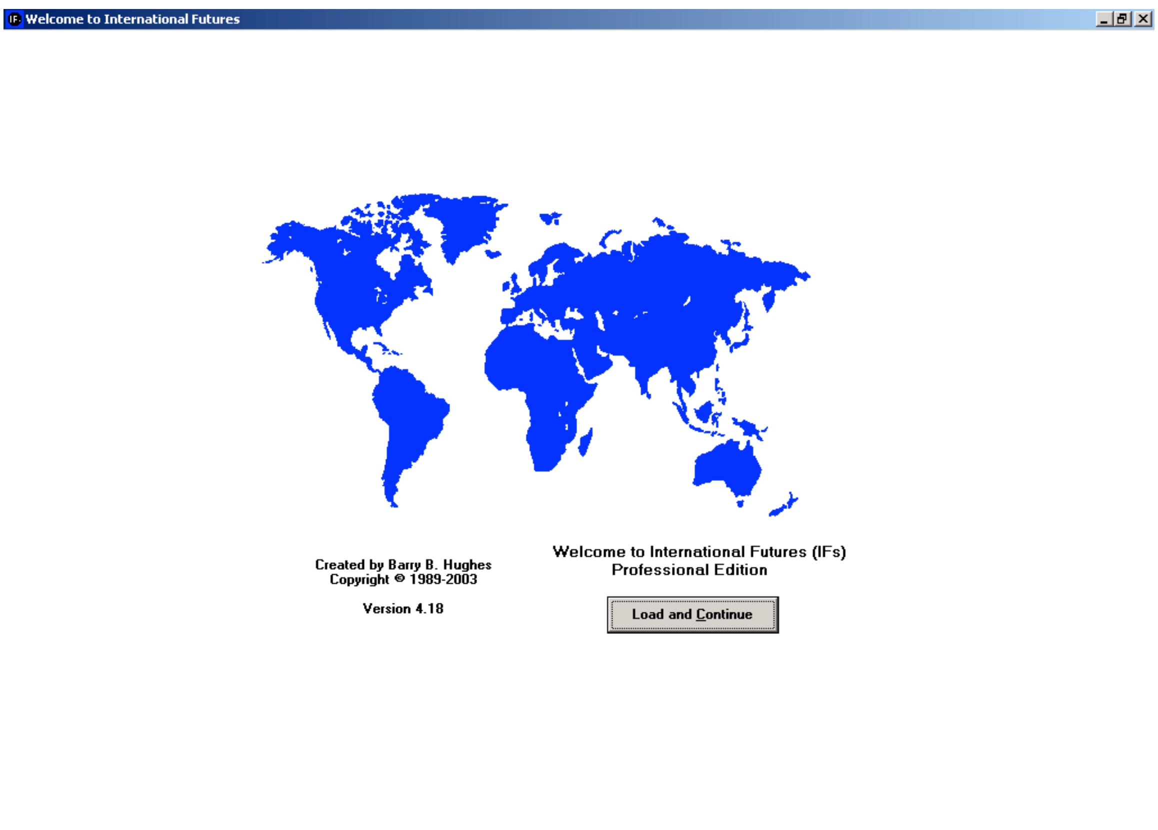

Figure 1. Welcome to IFs.

1. Introduction: The Base Case

Four questions guide most policy analysis that involves longer-term forecasting (Hughes 1999):

1. Where do key drivers and forces seem to be taking us?
2. What are some of the surprises or wild cards that appear most important to consider?
3. What kind of future do we want?
4. How much leverage do we have in moving the systems of interest to us towards the future we want?

This report focuses on the first of these questions with respect to key global systems: demographics, economics, energy, food, the environment, and socio-political change.

The central purpose of the report is to review the base case forecast of the International Futures (IFs) modelling system. There is, however, value in providing a context for the IFs base case by reviewing it in comparison with forecasts made by large numbers of other organizations and individuals. Thus a secondary purpose of the report is to identify some of the important contemporary forecasting literature and to draw upon forecasts from it.[1]

This report makes no effort to explain or document the International Futures (IFs) system. The best documentation is through description, flow charts, equations, and the model code in the Help system of the model.[2]

What is the Base Case? The base case of a model like IFs can be thought of as a central tendency scenario. That is, the base case allows the global system to unfold along a path

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[1] One of the best examples of the review of other globally-focused studies to provide a context for the forecasting of a new one can be found in the Study Addendum of the Hart/Rudman Commission (US Commission on National Security/21st Century, 1999b). That review is an unusually good analysis of futures studies from 25 years earlier, as well as of contemporary efforts. See also Hughes (1985).

[2] The model with Help system can be downloaded from http://www.du.edu/~bhughes/ifswelcome.html. The TERRA Project of the European Commission greatly enhanced IFs during 2001-2003. The Strategic Assessments Group (SAG) of the U.S. Central Intelligence Agency has been another very important sponsor of IFs development in this generation (thanks to Evan Hillebrand and, increasingly, Paul Herman). Frederick S. Pardee and the RAND Pardee Center have more recently come to be important supporters. A grant from the European Union Center at the University of Michigan (thanks to Ronald Inglehart) has helped improve usability of the system. None of these institutions or individuals bears any responsibility for the model structure or analysis presented here, but their support has been greatly appreciated. Thanks also to the National Science Foundation, the Cleveland Foundation, the Exxon Education Foundation, the Kettering Family Foundation, the Pacific Cultural Foundation, the United States Institute of Peace, and General Motors for funding that contributed to earlier generations. Also of great importance, IFs owes much to the large number of students, instructors (thanks to Richard Chadwick), and analysts who have used the system over many years and provided much appreciated advice for enhancement. The project owes great appreciation to Anwar Hossain, Mohammod Irfan, and José Solórzano for data, modeling, and programming support of the most recent model generation.

that seems more or less to be the direction of its historic development. Assuming that expertise should be used when available, issue-specific elements of the base case are to some degree structured and/or "tuned" so as to be similar to common forecasts that specialists within the issue areas create.

Although some people refer to a base case as a business-as-usual scenario, doing so might incorrectly imply that it is only an extrapolation of the present. IFs incorporates many constraints and dynamics that can cause aspects of the base case to unfold in very non-linear fashion. It is also incorrect to think of the base case as a "best guess" about the future, because any single case or scenario is an extremely low probability forecast.

It is best to think of the base case as a starting point for analysis and thought, one that model users can reshape as they believe appropriate and/or can use as a foundation for what-if questions about possible alternative assumptions/interventions.

The Base Case as an Evolving Picture. The base case of IFs is constantly changing and is somewhat different in every release of the model. The initial conditions, formulations, and parameters of the model determine the base case. Therefore every time any one of those change, and those change constantly as the model evolves, the base case will shift. Normally the differences across releases will not be dramatic and many users hardly notice them. Theoretically, a base case should over time become a more solidly-based and plausible starting point for analysis.

Assessing the Base Case. There are many foundations for judging the quality of the base case as a useful starting-point scenario of central tendency. Because they will unfortunately often lead to different assessments, some attention to each is useful:

- **Historic validation**. Many modelers rely heavily on validation of the model against historic data so as to judge the quality of formulations and the plausibility of all forecasts including the base case. Although the IFs project has used historical validation to assess substantial portions of the model, it should be obvious that many possible global processes over the long-term future (e.g. movement of global population towards zero growth; peaking and decline in oil and natural gas production; and the rapid economic and socio-political development of a country the size of China) have no appropriate historic referent. *The future is very much underdetermined by the past.*

- **Strength of theory, data, and estimations**. Especially in the face of patterns and events that have little historic reference, the quality of formulations within the model and of the data, theory, and estimations on which they are based become very important. The IFs project has attempted to draw on high quality foundations in each area and to take care in filling holes, but the reality is that *our theory and empirical analyses are very often less strong than we would like.*

- **Comparative forecasts and "face validity."** Still another approach to assessing the quality of the base case (or any other scenario) is to compare it with forecasts made by recognized experts across the issue areas represented in the model (population, energy, etc.). Sometimes this can be the most convincing basis for assessment because those experts themselves draw heavily on historic analysis, theory, and data, as well as upon their specialized insights. This approach to assessment, however, also has its complications. For instance, IFs is a highly integrated model across issue areas, whereas *most comparative forecasts are produced with expertise rooted deeply in a single area*. In fact, one of the values of IFs lies in producing a base case that will sometimes differ from other forecasts because of linkages to or inputs from other issue areas represented in the model.

Two final comments may be useful to set the stage for this review. First, although many users of IFs, especially within the NIC 2020 project, will be focused on the next 10-20 years, this review of the base case extends the horizon further. The model has been constructed to address issues of longer term global transitions, many of which will play out across the century. Because the next 10-20 years is already a very long time in terms of forecasting, that period will be heavily influenced by many of those same longer term transitions. For those interested in the nearer term, it should add value to understand how the model treats the longer term.

Second, even in a project that draws to some degree on all three above approaches for assessing and enhancing the base case, there is no way in which intelligent judgment can have been brought to bear on all of the numbers in the base case, across very large numbers of variables, countries, and time points. Thus users will find specific forecasts within the base case that are obviously poor ones. This is most likely to happen for smaller countries and for variables beyond the ones most frequently examined, but can occur in any part of the model. Feedback to the development team is always welcome.

2. Population

2.1 Forecasters

Among the key institutions that provide population forecasts with global coverage are:

- Population Division of the UN Department for Economic and Social Information and Policy Analysis. The UN releases revisions of its forecasts biannually under the title *World Population Prospects* (2003). The coverage is global and the forecast horizon is normally through 2050, but in late 2003 they released their first forecasts through 2300, under the title *World Population in 2300* (2003b). They have also produced an important study of *World Population Ageing: 1950-2050* (2002). The UN Population Division (2001) also periodically releases *World Urbanization Prospects*, including the 2001 revision. In addition, the UNAIDS group has gathered HIV/AIDS data over time and its Reference Group on Estimates, Modelling and Projections has developed a forecasting model. The UN has also prepared a database on migration with forecasts through 2050.

- The World Bank. Like the UN it once provided regular, long-term and global forecasts, but it now releases forecasts primarily for country- and project-specific analysis.

- The U.S. Census Bureau began publishing global forecasts with a 2050 horizon by country in 1985 and does so periodically in its World Population Profile. In general, it seems less regular in forecast release than the UN.

- International Institute of Applied Systems Analysis (IIASA). The coverage of IIASA's population forecasting is global and variously through 2050 or 2100, with a focus on 13 global regions. Their web site provides no forecasts made later than 1996, but the project has reported results from forecasts produced in 2001.

Although the CIA does not routinely produce demographic forecasts, in 2001 it released *Long-Term Global Demographic Trends: Reshaping the Geopolitical Landscape*. That report draws on very wide expertise, including the U.S. Census Bureau. It provides forecasts that generally extend to 2020 or 2050.

Another key information resource for understanding population data and forecasting is the Population Reference Bureau. For instance, Brian O'Neill and Deborah Balk (2001) produced an excellent review of approaches to forecasting population and comparative analysis of those who produce them in the form of a *Population Bulleti*n of the PRB. Lamptey, Wigley, Carr, and Collymore (2002) provided a comprehensive review of HIV/AIDS (without forecasts).

Although its does not provide global forecasts, the Population Matters program of RAND does provide targeted demographic forecasts of importance.[3] See, for instance, Bloom, Canning, and Sevilla, *The Demographic Dividend* (2003) and Cook, *Demographic Trends Alter the National Security Scene* (2000).

2.2 Key Concepts/Variables

Total population is often the variable of central interest, although most forecasting systems provide population by age-cohort (normally in 5-year categories) and by sex. The UN uses cohorts up to 100 years of age. Most major projects can generate age-sex profiles by country and across time.[4] Population change is generally understood to be a function of three factors:

1. Fertility rate is the key fertility measure. It is most commonly presented in terms of the total fertility rate (TFR) or the births per woman throughout the child-bearing years, but sometimes by crude birth rates (CBR) or the births per 1000 population.

2. Life expectancy is the key mortality measure. It is supplemented by crude death rates (CDR), the deaths per 1000 population. For forecasting, it is critical to have mortality patterns by age cohort. Specific causes of "excess" mortality such as HIV/AIDS can be important to forecasts.

3. Migration is the third foundational concept and the most difficult to forecast.

Additional important concepts include levels and rates of urbanization and specific representations of population age structure such as:

- Dependency ratios (portions of the population below or above working age relative to the working population)

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[3] See http://www.rand.org/labor/popmatters/; February 2, 2004.

[4] Some forecasters have relied not on full cohort-component methodology, but on simpler trend extrapolation of population levels using various equation forms. For instance, Herwig Birg (1995) undertook extensive forecasts of population through 2150, with varying equation forms (hyperbolic, S-shaped or logistic, and linear) and representing fertility decline and variable speeds of decline (the key unknowns). Birg believed the UN projections of an ultimate global population of 10.7 billion in 2150 to be based on overly aggressive assumptions about global fertility decline (to 2.5 in 2020-25 and 2.3 in 2025-30). He was also less optimistic, however, about increases in life expectancy than is the World Bank (which posits 82.3 years global average by 2100) or the UN (which sees life expectancy of 84.7 in 2150). Carchetti, Meyer, and Ausubel (1996) used logistic curves to model fertility declines and do not assume that they lead to replacement fertility rates. On the contrary, their analysis suggested that fertility in developed countries will stay well below replacement levels, rather than move back up to replacement level. They also argue that logistic curves suggest a much more predictable movement towards an apparently biological limit on life expectancy of about 80 for men and 85 for women.

- Youth bulges (size of the young population relative to the total, such as the portion between 15-24).

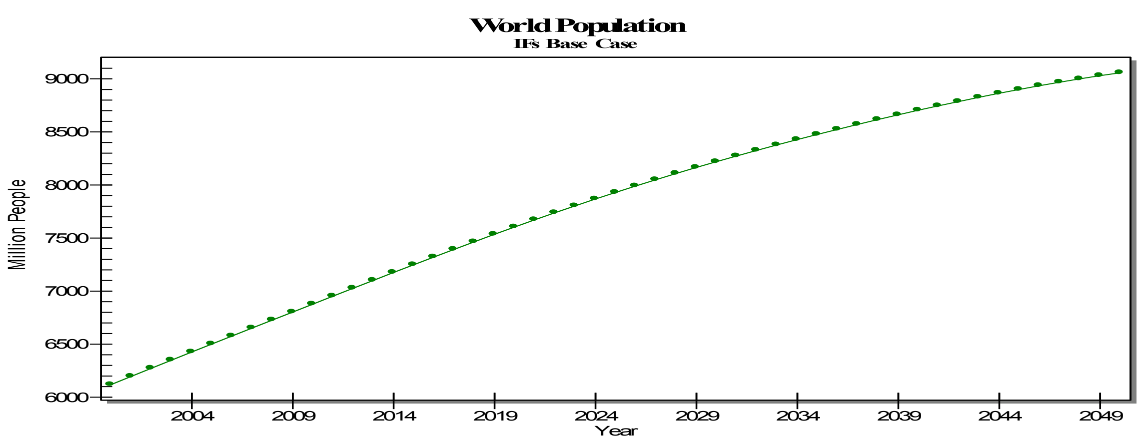
2.3 Forecasts Through 2050

Population Levels. The 2002 Revision of the UN's *World Population Prospects* provides high, medium, and low forecasts. The medium variant forecast is for a global population of 8.9 billion in 2050. High and low forecasts are 10.6 and 7.4 billion, respectively. The UN's high forecast uses constant fertility rates and must be considered a truly extreme and improbable value. Almost all of the variability across UN forecasts is in the less developed countries, because the range for forecasts for more developed countries in 2050 is only from 1.1 to 1.4 billion.

To break down the UN forecast (2003, Table 1 in Chapter 1 on "World Population Trends"), population of more developed regions in the median variant is expected to grow from 1,194 million in 2000 to 1,220 million in 2050, while that for developing regions grows from 4,877 million to 7,699 million. Numbers for specific geographic regions include 796 million to 1,803 million in Africa, 3,680 million to 5,222 million in Asia, and 520 million to 768 million in Latin America and the Caribbean.

In slight contrast with the UN, the US Census Bureau's forecast in late 2003 for global population in 2050 was 9.1 billion (http://www.census.gov/ipc/www/worldpop.html; January 9, 2004).

The base case of IFs (below) provides a very slightly higher world population forecast for 2050 than the 2002 UN Population Revision, one that is just over 9 billion. This is ironic, because over the last 10 or more years, the IFs model has consistently produced forecasts below those of the UN median variant. Over time, the UN forecasts have regularly been reduced, because they earlier failed to anticipate the rate of decline of fertility around the world. The median forecast for 2050 in 1994 was 9.8 billion, in 1996 it was 9.4 billion, and in 2000 it was 9.3 billion. Other forecasters, including IFs and IIASA, have more accurately anticipated the declines in fertility.



Population forecasts specific to country groupings from the IFs base case are shown in the table below. In that table, as in most of those throughout this report, the country groupings of IFs will not be identical to those of the forecasts reported above. Because country sets used by different forecasting sources vary widely, and are not always fully identified, it is impossible to tailor all of the IFs tables for precise comparison. Most often we attempt to compare the magnitudes and rates of growth in IFs with those of the country sets provided by other sources.

Table Display

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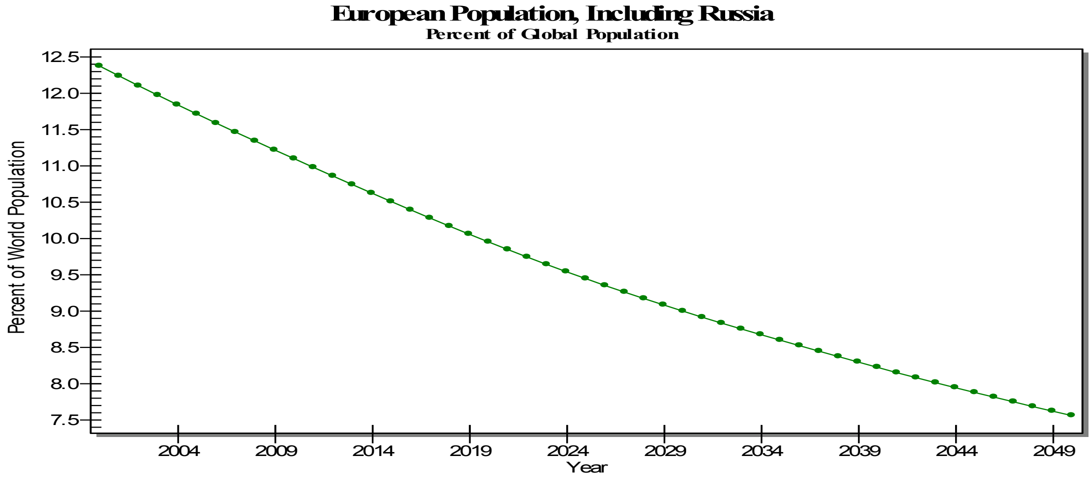
	WPOP[0]	POP[0]	POP[0]	POP[0]	POP[0]	POP[0]
		OECD	non-OECD	Africa & Mideas	Asia&Pacific	Latin America
Year	Mil People	Mil People	Mil People	Mil People	Mil People	Mil People
2000	6,119	1,134	4,826	870.9	3,356	501.9
2005	6,502	1,172	5,172	971.8	3,556	539.0
2010	6,878	1,202	5,518	1,079	3,751	573.3
2015	7,249	1,226	5,864	1,194	3,940	604.2
2020	7,605	1,245	6,201	1,314	4,115	631.9
2025	7,930	1,259	6,513	1,435	4,266	656.2
2030	8,220	1,268	6,795	1,556	4,390	677.8
2035	8,477	1,271	7,048	1,675	4,490	696.4
2040	8,705	1,270	7,278	1,790	4,575	711.3
2045	8,901	1,264	7,481	1,898	4,644	722.2
2050	9,057	1,255	7,648	1,995	4,692	729.1

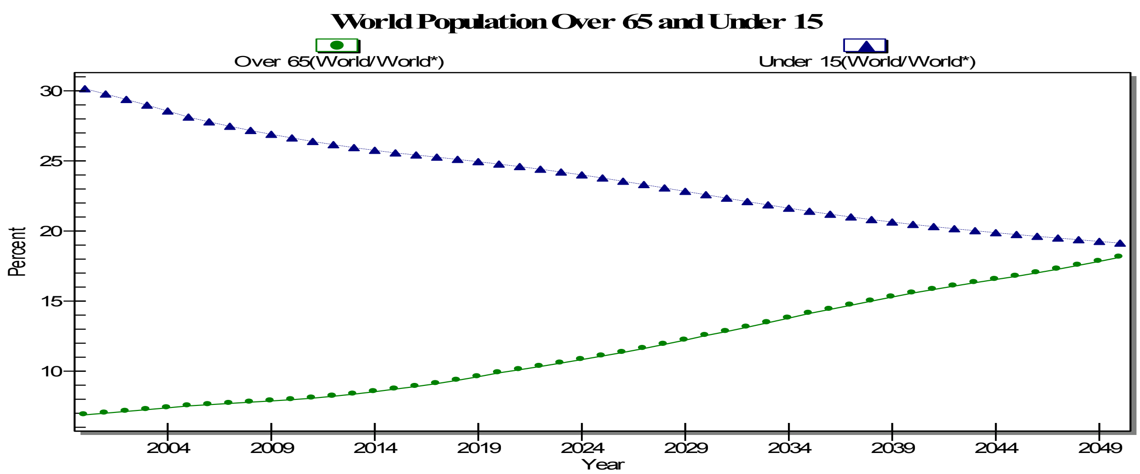
The differences in the IFs base case and the UN forecast are primarily in Sub-Saharan Africa, secondarily in the OECD countries, and to a lesser extent in other regions around the world. As we shall see below, the IFs model is producing somewhat higher fertility and lower AIDS-associated mortality in Sub-Saharan Africa than is the median forecast by the UN. It is also showing slightly higher fertility in OECD countries.

Population Distribution. There are key distributional changes coming for the global population, both geographically and in terms of age structure. With respect to distribution, the CIA (2001: 5) forecasts that Europe and Russia, the focal point of much of twentieth-century history, will decline from 13% of global population to 7.5% by 2050. The IFs base case shows fundamentally the same pattern below.[5]

[5] The IFs variable in the table is POP (Europe) divided by WPOP times 100.



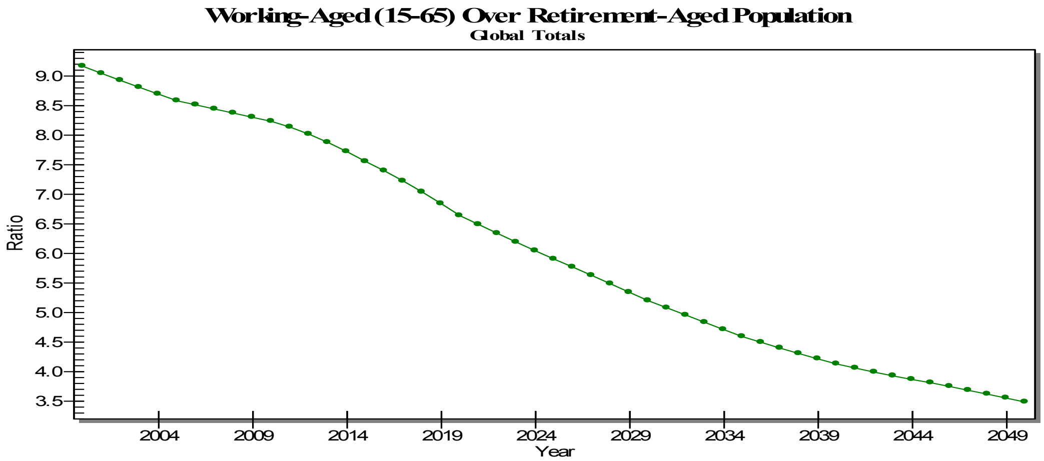
Within demography much attention is appropriately focused on the aging of the world's population. The UN (2002: xxviii) forecasts that by 2050 the older people in the world (defined as 60 or over) will reach 21% of the total (from 10% in 2000) and exceed the number of young people for the first time. This segment of the population is growing at 2% annually, much faster than the larger population. Even in developing countries the aged will make up 20% of the total (1/3 in developed countries). The CIA (2001:5), looking at those over 65, forecasts the aged to reach 1.5 billion or 16% of global population by 2050. Focusing on those over 65, the IFs base case forecast is for even slightly faster growth. This is almost certainly because IFs uses 2002 population revision data, not available to the CIA in 2000-2001; recent global fertility rate forecasts, tend to be lower than those in earlier datasets, leading to even faster growth in the share of aged.[6]



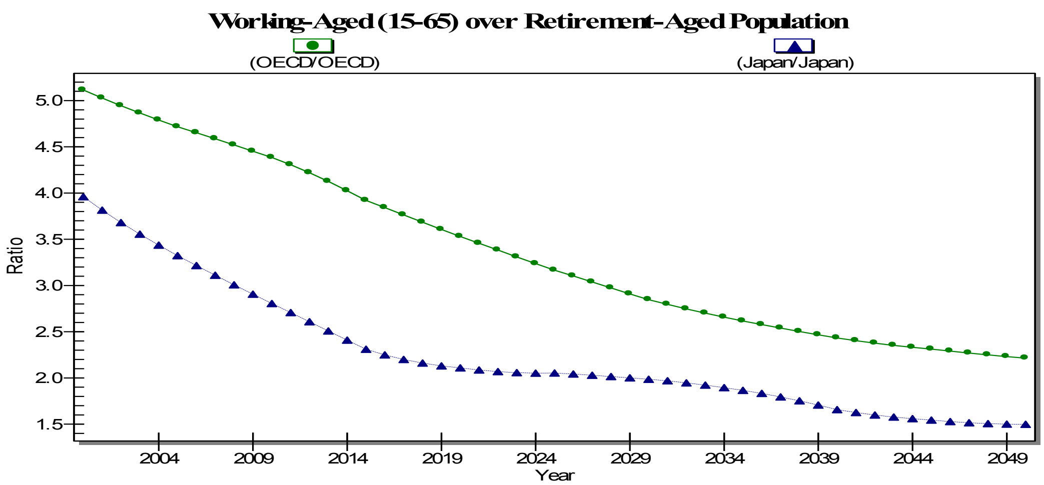
Another key number is the ratio of older people (this time defined by the UN as those over 65) relative to the number of those more often in their working years (15-64). The

[6] The IFs variable in the graph is POPGT65 (World) divided by WPOP times 100.

UN (2002:xxix) says this number will fall globally from 9 in 2000 to 4 in 2050. The IFs base case forecast, below, is very similar.[7]

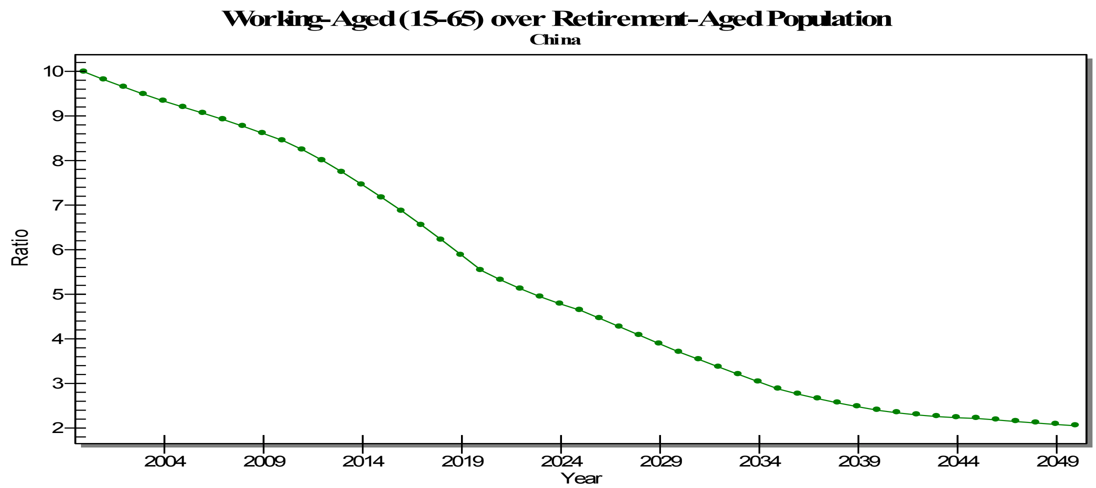


The CIA (2001:7) suggests that the same ratio for "industrialized nations" will fall from 4 to 1 by 2050. The graph below from IFs looks at OECD countries, including Mexico and a few other newer industrialized countries that may not be in the CIA set. The numbers on both ends are a little higher than those of the CIA, but for a few countries like Japan the ratio is even lower than 2:1 by mid-century.

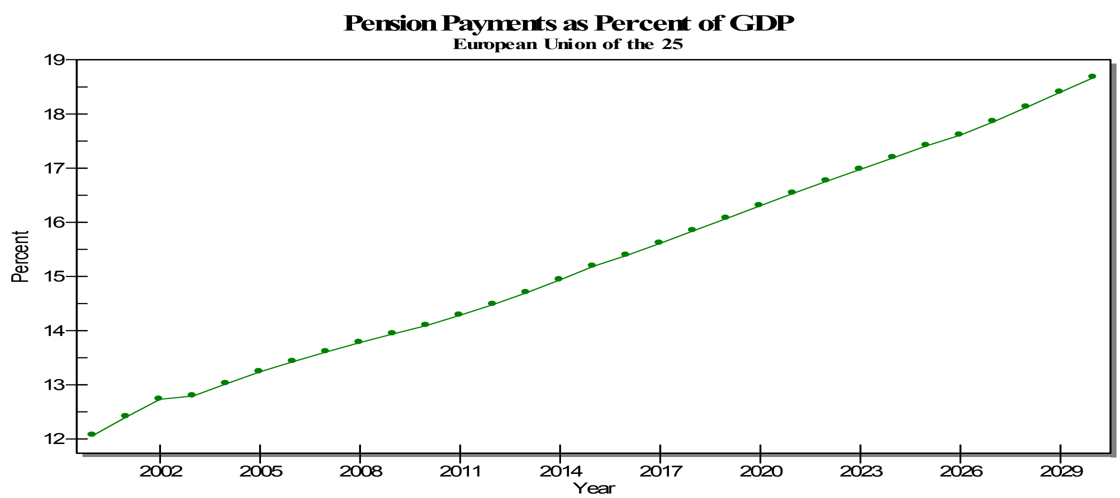


The really striking change in this ratio in terms of speed, however, is in China. The graph below from IFs shows a decline of it from 10 to about 2 by 2050 (already to 6-to-1 by 2020). The ramifications of such rapid change across all elements of society can hardly be exaggerated.

[7] The IFs variable in the next three graphs is POP15TO65(World or OECD or Japan or China) divided by POPGT65(World…).



Across the world, the growing share of the aged will have a significant impact on the pension bills of government. The CIA reports an OECD conclusion that the bill for public pensions in Europe will grow by more than 6 percent of GDP over the next three decades (CIA 2001: 27). That is almost exactly the same growth increment shown in the IFs base case, below.[8]



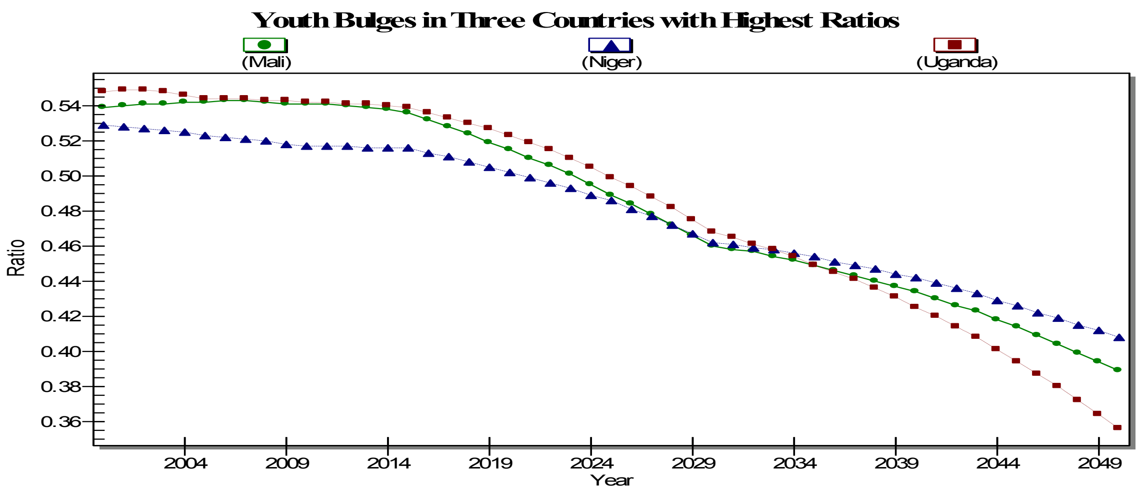
Another population distribution concept of importance is the youth bulge. It is widely recognized that a large portion of 15-29 year-old males in a population is historically associated with greater socio-political instability. One difficulty is that there are multiple ways of operationalizing the youth bulge. Sometimes that age group (or even some variant of it such as 15-24) is compared with the age groups up through 54.[9] Other times the comparison is made to all adults over 15, or to all adults over 30 (Cincotta, Engleman, and Anastasion 2003; see especially Data Sources and Methodology, p. 89). In the comparisons with 30-54 year-olds, the rule of thumb is that ratios above 1.2 (sometimes 1.29) are especially problematic; in the comparison with all adults, the rule of thumb is

[8] The IFs variable in the graph below is GOVHHPENT(EU25) over GDP(EU25) times 100.

[9] The CIA population study (2001) defined the reference group in Figure 14 as 39-54 year-olds and on page 39 as 30-54 year-olds.

that ratios above 0.4 or 40% can lead to difficulties. In any case, almost all observers focus attention especially on countries in the Middle East and in Africa as having the largest prevalence of youth bulges. The CIA (2001: 36) identified Sub-Saharan Africa as the most problematic area though 2020, naming Botswana, Namibia, Zambia, and Ethiopia as among countries that would still be above their warning threshold of 1.29 in 2020.

IFs is now using the 15-29/all adults (defined as 15 or older) version of the measure. Using its filtering technique for identifying values near to or above 50% in 2020, the IFs base case finds Angola, Burkina Faso, Congo, Eritrea, Malawi, Mali, Niger, Uganda, Yemen, Zaire, and Zambia to be cases for attention. Of these, Mali, Niger, and Uganda have and will have especially high ratios.[10]



Fertility. In the 2002 Revision the UN (2003) has considerably reduced its median forecasts of fertility. "For the first time, the United Nations Population Division projects that future fertility rates in the majority of developing countries will likely fall below 2.1 children per woman … at some point in the twenty-first century." (Executive Summary, p. v).

To be more specific on UN forecasts (2003),[11] the total fertility rate forecasts of the medium variant in 2045-2050 are 2.02 globally, with 1.85 for more developed regions and 2.04 for less developed regions. The rates are 2.4 for Africa, 1.91 for Asia, and 1.86 for Latin America and the Caribbean.

The IFs base case forecast is shown below. The primary difference is Africa, where IFs forecasts a total fertility rate of nearly 2.7 in 2050, relative to the UN forecast of 2.4. The major reason for the difference in IFs is quite probably the impact of the AIDS epidemic, which, as we shall see, leads to a lower economic growth forecast for Africa in IFs than is being produced by the World Bank. The linkage of economic growth to fertility rate is strong. Another reason to anticipate a slowing of fertility declines in Africa is the

[10] The variable in IFs is YTHBULGE (Mali, etc.).
[11] Table 2 in Chapter 1 on "World Population Trends."

mortality associated with AIDS itself; traditionally, populations have responded to increased mortality with higher fertility.

	TFR[0] World	TFR[0] OECD	TFR[0] non-OECD	TFR[0] Africa	TFR[0] Asia&Pacific	TFR[0] Latin America
Year	Births	Births	Births	Births	Births	Births
2000	2.7734	1.80	3.0384	5.0457	2.6120	2.5847
2005	2.6750	1.719	2.9208	4.7734	2.5153	2.4148
2010	2.5786	1.705	2.7926	4.5014	2.4107	2.2296
2015	2.4818	1.689	2.6665	4.2306	2.3051	2.1017
2020	2.3917	1.682	2.5488	3.9837	2.2007	1.9988
2025	2.3056	1.693	2.4351	3.7353	2.1025	1.9445
2030	2.2225	1.708	2.3270	3.5082	2.0041	1.9233
2035	2.1587	1.721	2.2443	3.2975	1.9415	1.9049
2040	2.1098	1.734	2.1809	3.0875	1.9126	1.8882
2045	2.0647	1.746	2.1232	2.8808	1.8896	1.8719
2050	2.0199	1.758	2.0671	2.6816	1.8678	1.8603

The fertility course of populations that have fallen below replacement fertility is full of uncertainty for forecasters, but the IFs base case arbitrarily posits that long-term fertility rates for developed countries will move back up towards replacement rates (although staying below them throughout the century), rather than staying at levels nearer to 1.5 as in several OECD countries currently.

Mortality. The UN 2002 revision increased anticipated mortality from HIV/AIDS, estimating 278 million total excess deaths by 2050. This estimate assumes that infection prevalence will begin to decline globally after 2010. In spite of the ravages of AIDS, the UN forecasts an increase in global life expectancy to 74 years by 2045-2050 (reaching 73 in developing countries and 82 in the most developed).

To be more specific on UN forecasts (2003),[12] the life expectancies of the medium variant in 2045-2050 are 74.3 globally, with 81.6 for more developed regions and 73.1 for less developed regions. The rates are 64.9 for Africa, 76 for Asia, and 78.5 for Latin America and the Caribbean.

The life expectancy forecasts from IFs are shown below and are quite similar to those of the UN, but slightly higher in all cases. The major difference is that, as we shall see below, the forecasts for deaths from HIV/AIDS in the IFs base case are lower than those of the UN.

[12] Table 3 in Chapter 1 on "World Population Trends."

Table Display

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	LIFEXP[0]	LIFEXP[0]	LIFEXP[0]	LIFEXP[0]	LIFEXP[0]	LIFEXP[0]
	World	OECD	non-OECD	Africa & Mideas	Asia&Pacific	Latin America
Year	Years	Years	Years	Years	Years	Years
2000	66.44	76.71	64.21	52.51	66.90	70.40
2005	66.93	77.16	64.77	51.65	67.94	70.95
2010	67.76	77.91	65.67	52.59	68.99	72.06
2015	69.02	78.59	67.12	55.99	70.15	73.02
2020	70.43	79.18	68.69	59.85	71.33	74.08
2025	71.66	79.75	70.08	62.20	72.58	75.34
2030	72.86	80.21	71.46	63.82	74.03	76.53
2035	73.80	80.67	72.53	64.91	75.26	77.49
2040	74.72	81.13	73.57	65.68	76.57	78.33
2045	75.58	81.60	74.54	66.35	77.82	79.14
2050	76.33	82.12	75.39	66.99	78.84	79.98

HIV/AIDS. With respect to HIV/AIDS, key forecasting issues are obviously initial infection rates and the growth in them. Perhaps even more important are estimates concerning the peak years for various countries of infection prevalence and the infection rates in those years. For most African countries, UN forecasting assumptions posit that the year of peak HIV prevalence is already past or will be early in the first decade of the century.[13] The UN identifies only a few African countries still moving towards peak incidence: Angola (up to 6.1 percent in 2006, Equatorial Guinea (up to 4.4% in 2009), Eritrea (up to 3.2% in 2007), Liberia (up to 7.2% in 2006), and Sierra Leone (up to 9.8% in 2008).

Countries in other regions with prevalence peaks expected beyond 2005 are China (up to 1.1% in 2016), India (up to 1.9% in 2019), Myanmar (up to 2.9% in 2011), Dominican Republic (up to 3% in 2010), Honduras (u to 3.4% in 2009), Trinidad and Tobago (up to 3.4% in 2009), Russia (up to 1.6% in 2009), and the United States (up to 0.6% in 2018[14]). After the peaks of prevalence, the UN projects decay of rates to 1/3 of earlier levels over periods of increasing length. This pattern results in considerably lower values in the year 2050: Botswana from 36.8% in 2002 to 20.9%, South Africa from 21.7% in 2002 to 8.6%, China from 1.1% in 2016 to 0.6%, India from 1.9% in 2019 to 0.6%, Russia from 1.6% in 2009 to 0.5%, and the United States from 0.6% in 2018 to 0.2%.

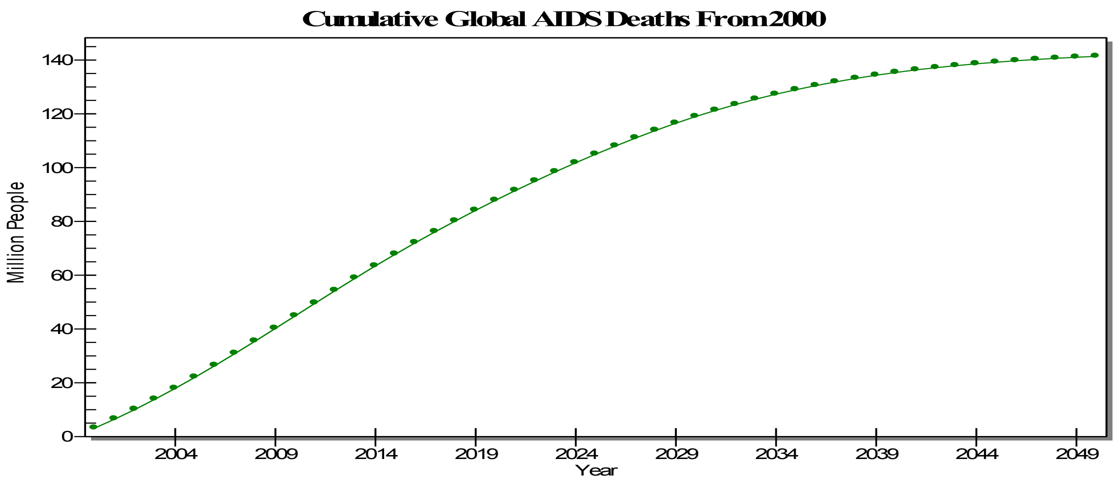
Using a model built on data about the past course of growth in infection rates and assumptions like those above about the unfolding of the epidemic to and beyond its peak, the UNAIDS group has concluded that during the first decade of the century, the excess deaths because of AIDS, across the 53 most affected countries, will be about 46 million and that the total will climb to 278 million by 2050 (UN Population Division 2003: pg. viii in the Highlights).

[13] This does not mean that the peak year of AIDS deaths has been reached, because those infected in years with higher rates will continue to die for a considerable period of time.

[14] This may be a typo, because U.S. rates in 2001 were 0.4%, compared to earlier UNAIDS data showing 0.8% in 1997 and 0.61% in 1999, suggesting strongly that the US has passed the peak.

The UN concludes also that the total population in the seven Sub-Saharan African countries with the greatest infection rates will be dramatically affected, with outright reductions by 2050 for Botswana, Lesotho, South Africa, and Swaziland.

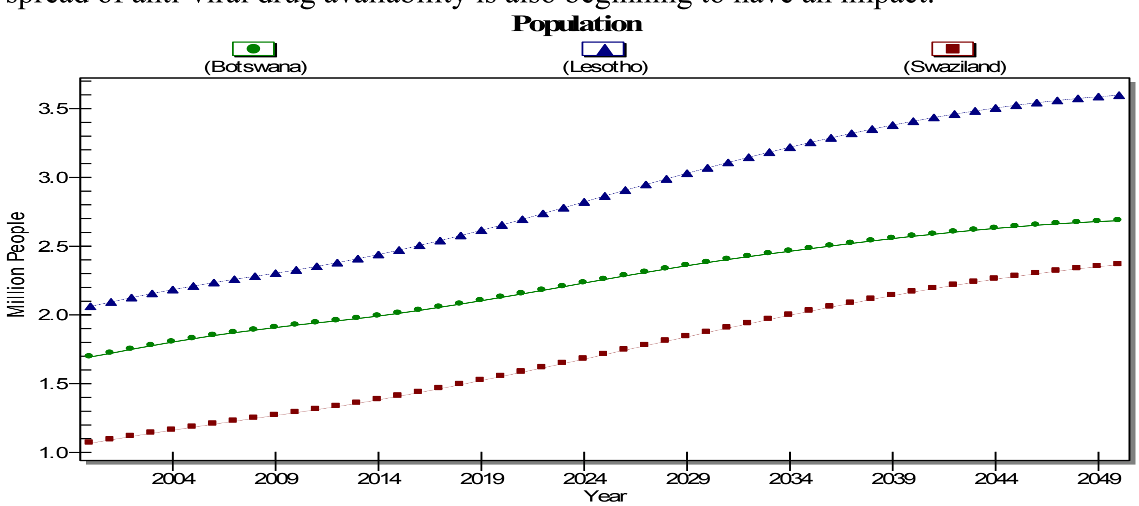
Forecasts for the unfolding of the HIV/AIDS epidemic from IFs are quite close to those of the UN through about 2020, which is hardly surprising because IFs uses UN AIDS data exclusively in the production of them, including the estimates of the UN concerning peak years for infection rates and the levels of those peak rates. After 2020, however, the forecasts for cumulative excess deaths in IFs begin to fall substantially behind those of the UN, reaching about half the UN figure by 2050.



What explains the divergence of IFs and UN forecasts after 2020? As shown below, it is primarily a much more rapid drop in infection rates and associated death rates between 2020 and 2050. Although the IFs project frequently creates scenarios with infection rates that decline as slowly as those of the UN or even more slowly, there is reason to argue that, accepting the UN assumption that global infection rates are likely to peak around 2010, the movement back down the infection rate curve will be slower than was the movement up (if only because infections persist until death), but that the tail on the downward size of the bell curve will not be as dramatically longer as indicated by UN assumptions of rates for 2050. Although it is a small piece of corroborating evidence, it is interesting that the UN's AIDS Epidemic Update 2003 revised downward slight the total number of humans living with AIDS relative to the 2002 volume The volume (UNAIDS 2003: 2) also pretty clearly indicates a slowing in the global curve of total infections. As is commonly said in forecasting, "a trend is a trend is a trend until it bends." The bending point of the HIV/AIDS trend is very hard to forecast, but some weak signals have begun to appear.

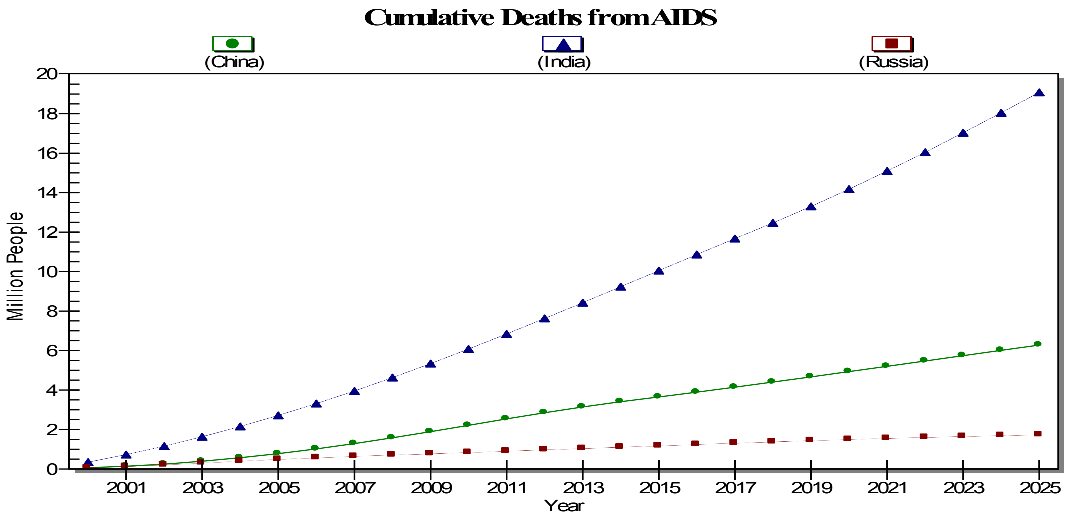
	HIVRATE[0]	HIVRATE[0]	HIVRATE[0]	HIVRATE[0]	HIVRATE[0]	HIVRATE[0]
	World	Botswana	South Africa	China	India	Russia
Year	Percent	Percent	Percent	Percent	Percent	Percent
2000	1.229	38.8000	20.10	.10	.80	.90
2005	1.359	35.7075	20.24	.345	1.197	1.429
2010	1.35	32.1109	18.20	.52	1.451	1.001
2015	1.209	26.7311	15.15	.384	1.499	.928
2020	1.027	20.5744	11.66	.367	1.40	.797
2025	.826	14.6231	8.287	.325	1.298	.633
2030	.618	9.5850	5.432	.267	1.114	.465
2035	.431	5.7864	3.279	.202	.885	.315
2040	.28	3.2129	1.821	.141	.65	.196
2045	.169	1.6384	.929	.091	.44	.113
2050	.095	.7662	.434	.054	.274	.06

The differences in forecasts of both fertility and mortality rates in Sub-Saharan Africa lead, of course, to differences in total population growth forecasts for the region as a whole and for countries within it. For instance, as shown below, IFs does not forecast absolutely lower populations in 2050 even for the most heavily impacted countries. The spread of anti-viral drug availability is also beginning to have an impact.



Others have, however, become even more pessimistic about the HIV/AIDS epidemic than the UN, which relies heavily on official statistics from member states. Eberstadt (2002) and Lamptey et al. (2002), both drawing in part on analysis from the National Intelligence Council, provide estimates of current infection rates in China, India, and Russia that are above those in UN data, quite substantially above for China and Russia. Eberstadt, focusing on these three countries, suggests the possibility of cumulative AIDS deaths from 2000-2025 in a mild epidemic of 19 million, 21 million, and 3 million, in China, India, and Russia, respectively. In an intermediate epidemic the numbers grow to 40, 56, and 9, respectively, and in a severe epidemic they are 58, 85, and 12 million. Eberstadt proceeds also to estimate the impact that such numbers would have on demographic structures and economic growth.

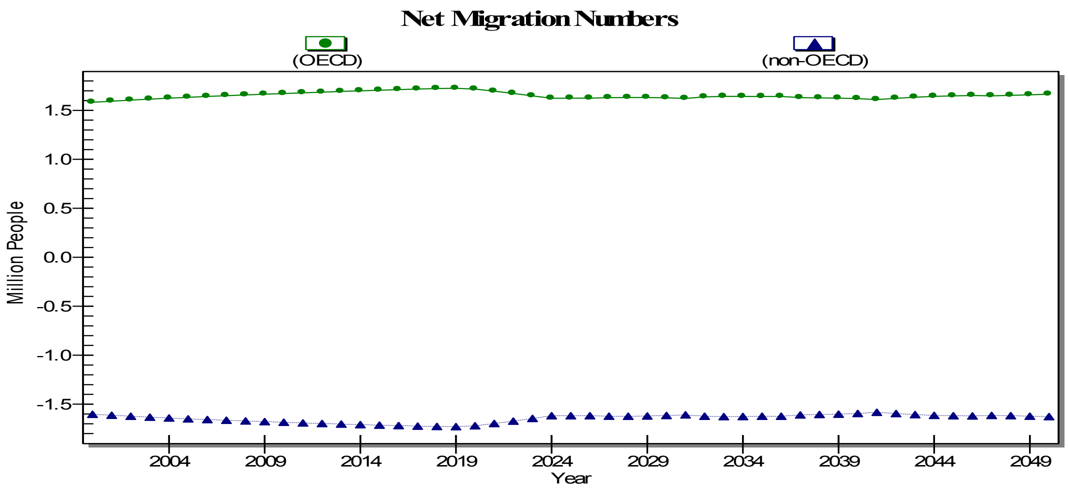
As indicated below, the total deaths from AIDS forecast by IFs for those three countries are below the Eberstadt mild epidemic forecast for India, and considerably below for China and Russia. The reason in this case is the use by IFs of UNAIDS figures for initial infection rates. There is good reason to believe that these are, in fact, too low for China and Russia and the initial rates and corresponding course of the epidemic should almost certainly be raised for these countries in the IFs base case.[15]



Migration. Although migration across countries has no direct impact on global population, UN forecasts are for continued high rates through mid-century, averaging gains of 2 million per year for developed countries, 1.1 million of which will be in the United States.

The forecasts of the IFs base case use the UN rates of migration, so differ little from them. The IFs forecast below is net migration; it is possible that the UN forecasts of 2 million are gross migration (substantial migration is obviously among OECD countries) thereby explaining the discrepancies that do exist.[16]

[15] This is a useful topic of discussion between the IFs project and the NIC. Changes to China, India, and Russia could be made in the base case or in scenarios around it.
[16] The variable within IFs is MIGRANTS(OECD or non-OECD).



Urbanization. Urbanization rates are also important demographic variables. At the beginning of the twenty-first century, about 47 percent of the world's population lived in urban areas. It should be noted, however, that urbanization is not a variable that is easy to measure consistently, and that assessments of the current level of urbanization vary. The CIA (2001: 5) says that a majority of the world will be urban by 2015. The UN forecast is for 5 billion or 60 percent of global population to be urban by 2030 (UNDP 2003b: 5) and for 65 percent by 2050 (UNEP 2002: Synthesis). Percentages in urban areas will reach 82.6 in developed regions and 56.4 in developing regions by 2030.[17] Among the other consequences of this urbanization growth will be the beginning of actual reduction in rural population of developing countries between 2025 and 2030, echoing a decline in developed regions since 1950.

Urbanization forecasts from IFs are quite similar, but are a bit higher. IFs uses a cross-sectional relationship between current urbanization rates and GDP per capita (at PPP) to provide targets for longer-term urbanization rates and that tends to pull up the values with economic growth.

[17] UNDP (2003b). There is somewhat more regional data in Table 3, page 8.

	POPURBAN[0]/ World/World	POPURBAN[0]/ OECD/OECD	POPURBAN[0]/ non-OECD/non-
Year	Mil People/Mil F	Mil People/Mil F	Mil People/Mil F
2000	.462	.769	.382
2005	.488	.784	.414
2010	.517	.80	.45
2015	.546	.815	.486
2020	.573	.829	.518
2025	.595	.842	.545
2030	.615	.853	.569
2035	.631	.862	.588
2040	.647	.87	.607
2045	.665	.877	.629
2050	.684	.883	.651

For the purposes of considering consequences, however, it is not just or perhaps even primarily the size of the urban population that is significant, but the rate of its growth. Cincotta, Engleman, and Anastasion 2003: 54-55 divided countries into four categories of stress based on urban growth rates: extreme stress (above 5%), high stress (4-5%), medium stress (1-4%), and low stress (below 1%). The representation of urbanization in IFs is too crude to trust forecasts around urbanization rates or levels. Nonetheless, initial data and the IFs formulation as it stands now suggest a number of problem countries for much or most of the period to 2020, including Afghanistan, Bhutan, Burundi, Burkina Faso, Burundi, Ethiopia, Gambia, Laos, Lesotho, Nepal, Niger, Papua New Guinea, and Uganda.

2.4 Forecasts Through 2100

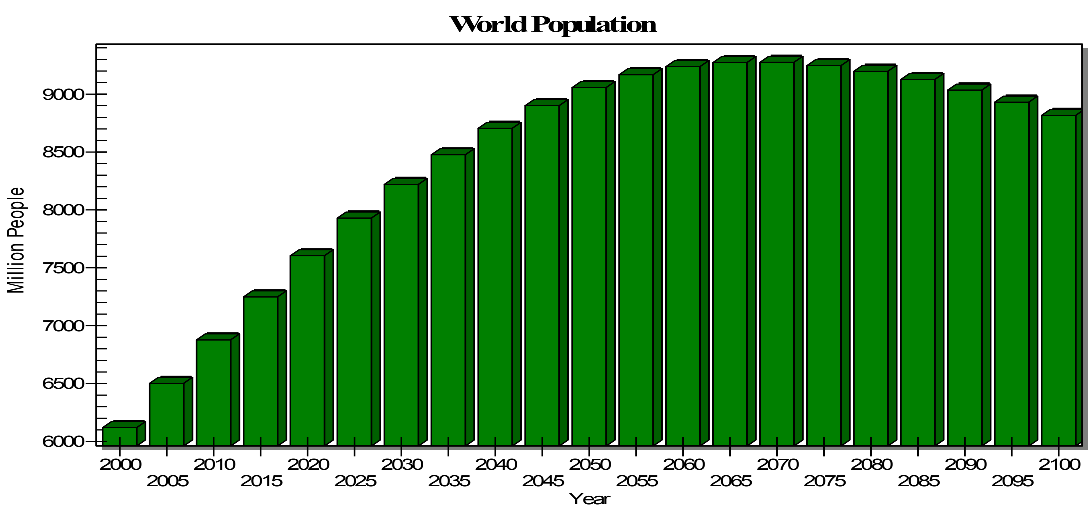
The UN forecasts through 2300 (produced for the first time in 2003) provide a very useful basis for examining the IFs base case through 2100. In the median variant global population rises to a peak of 9.2 billion in 2075 and declines to 8.3 billion in 2175. India will pass China to become the most populous country in the world by 2050.

Assumptions about life expectancy do, of course, have an impact on very long range forecasts. The assumptions in the UN median forecast are for continued but slowing increases to 97 years in 2300 (108 years for Japanese females).

It is, however, fertility assumptions that most significantly shape long-term demographic forecasts. The key long-term question is whether global fertility rates will level off around the replacement rate of 2.1 (the median scenario assumption) or at values above or below replacement. The UN high scenario for the very long term is ¼ child above replacement (2.35) and the low scenario is ¼ child below replacement (1.85). Already by 2100 these different assumptions for post 2050 rates give rise to a range of global population from a low of 5.5 billion, through a medium variant of 9.1 billion, to a high of 14 billion. By 2300 the differences range from 2.3 billion through 9 billion to 36.4 billion.

The 2002 Revision and the study through 2300 brought the UN forecasts more in line with those of IIASA in 2001.[18] IIASA forecast that the world's population could peak by 2070 at about 9 billion, declining to 8.4 billion in 2100.

Forecasts from the base case of IFs are now showing a global population of a little less than 9.1 billion in 2050 rather than the 8.9 billion of the UN, with a further climb to nearly 9.3 billion in 2068, before it turns down, with a fall to below 9 billion by 2100. In short, the forecasts through 2100 are similar to the median UN forecasts. The IFs modelling of longer-term population suggests, however, something of an internal tension between the UN forecasts of fertility drops through 2050 that would hold the global population below 9 billion in that year and UN forecasts for the end of the century (in the outlook to 2300) of 9.1 billion. The IFs model finds, more in line with the IIASA analysis, that if fertility drops of that magnitude occur in the first half of the century, global totals at the end of century are likely to fall below 9 billion.



[18] As reported in Nature http://www.nature.com/nsu/010802/010802-10.html; January 9, 2050.

3. Economy

3.1 Forecasters

Because of the great importance of near-term economic forecasts for markets and governments, there are a great many forecasting services that provide them. See, for instance, the back pages of *The Economist* for regular reports.

A few such services sometimes extend their forecasts to what they consider to be the "long-term," meaning 5-10 years. For instance, in 1999 Data Resources Inc (DRI) and Wharton Econometric Forecasting Associates (WEFA) both produced forecasts for the US through 2011.[19] Those two organizations merged in 2001 to become Global Insight.[20] Also, Oxford Economic Forecasting (OEF) provides forecasts for up to 175 countries, as well as models for use of its clients; the time horizon generally extends as much as 10 years.[21]

Similarly, Goldman Sachs provides forecasts as part of its research service. On occasion such forecasts have extended much further, as when they produced a report on the BRICs (Brazil, Russia, India, and China) through 2050.[22]

The OECD mostly provides short-term forecasts, such as its semi-annual series, the *OECD Economic Outlook*. Those forecasts, for OECD and selected non-OECD countries extend only two years. Yet the OECD also periodically provides forecasts with a longer range. In 1979 it released *Interfutures: Facing the Future*. In 1991 it published a collection of articles in *Long-Term Prospects for the World Economy* with some horizons through 2010 and 2015.[23] Sadly, but with importance as a warning to forecasters, the seeming inability of the U.S. to shake off slow productivity and the great success of Japan in racing ahead appeared for authors at that time to be patterns unlikely to change. By the late 1990s, the OECD (1999d) had turned its attention to analyzing the "Long Boom" in a collection of articles looking to 2025 and other horizons.

The IMF also mostly provides short-term forecasts, as in its semi-annual *World Economic Outlook*, extending about two years. The World Bank (2004) tends to take a longer view, and it prepares forecasts annually in its *Global Economic Prospects* series. The 2003 and 2004 volumes both produced global and regional forecasts through 2015 and additionally included forecasts concerning poverty reduction. These will be especially useful for our analysis in this chapter.

The U.S. Directorate of Intelligence mapped four scenarios in a report on *The Global Economy in the Long Term* (2001). Those scenarios focus on a horizon to 2025:

[19] See http://api.hq.faa.gov/foreca00/econo3.pdf; January 8, 2004
[20] See http://www.globalinsight.com/; January 8, 2004.
[21] See http://www.oef.com/; February 14, 2004.
[22] See http://www.gs.com/insight/research/reports/report6; February 14, 2004.
[23] See http://www.oecd.org/dataoecd/26/29/17783031.pdf; January 16, 2004.

- **Global New Economy.** Technological advance, institutional reform, and rapid economic growth frame a positive future.
- **Rivalry and Resentment Stifle Growth.** Protectionist policies and resistance to new technologies lead to very slow growth.
- **Unipolar World.** U.S. leads in technological innovation and growth.
- **Industrial Convergence.** Europe and Japan do better relative to the U.S., where technological pace slackens**.**

In contrast to the relatively near-term focus of most analysts with interest in financial markets, those interested in energy and the environment produce the truly longer-term economic forecasts. For instance, in 1998 the International Institute for Applied Systems Analysis (IIASA) produced a book with global economic forecasts through 2100 in cooperation with the World Energy Council (WEC) on *Global Energy Perspectives* (Nakićenović, Grübler, and McDonald 1998). Building on IIASA and WEC foundations, the Intergovernmental Panel on Climate Change (IPCC) has needed economic growth forecasts as a foundation for its energy and environmental analyses and has extended forecasts through 2100. These are available in the IPCC Third Report Emissions Scenarios (2001).

3.2 Key Concepts/Variables

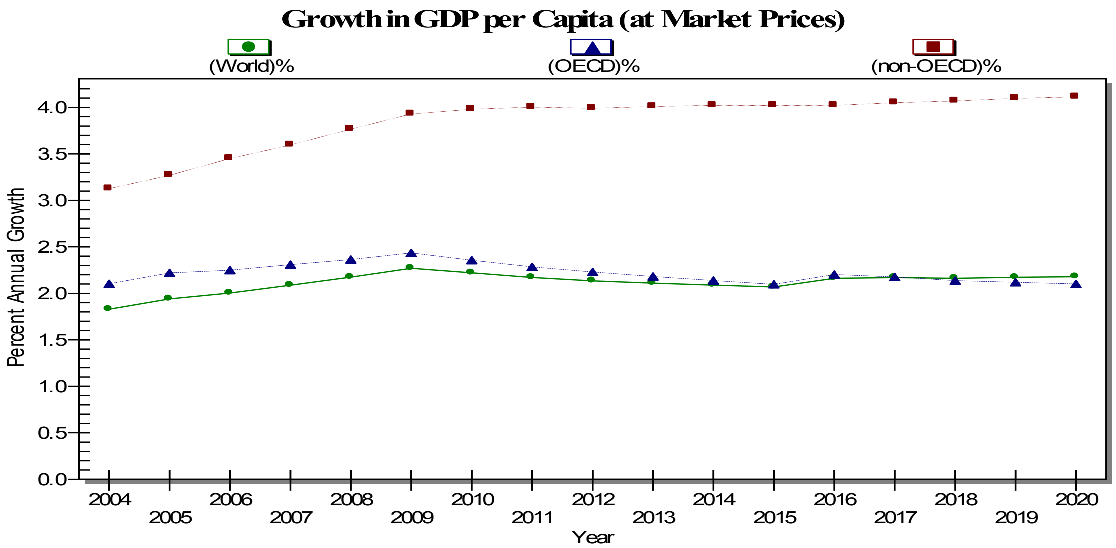
Gross Domestic Product or some variant (Gross National Product or the new Gross National Income) is the central concept. Most forecasts provide it based on some form of trend extrapolation, often computing it based on assumptions about economic growth rates. At the global level we can talk about Gross World Product (GWP). Most, but not all economic forecasts, carefully distinguish between GDP at exchange rates (also called market prices) and GDP at purchasing power parity

Less commonly than focus only on the aggregate size of the economy, GDP may be forecast with an economic model using a production function involving inputs of labor force size, capital stock, and a multifactor productivity (MFP) term, often with differentiation among economic sectors. That is, of course, what IFs does, but in this chapter we look primarily at GDP, except for some discussion at its end.

3.3 World Product Through 2015 and Up to 2050

The World Bank's forecasts in *Global Economic Prospects 2004* are built on an argument that rapid expansion of global trade in the 1990s has set the stage for accelerating growth rates in both developing and developed countries. They note (Figure 1.22 p. 31) an upward trend for developing country growth rates since 1981, in spite of recessions and financial crises. Their 2006-2015 forecasts for annual growth rates in GDP per capita for the world, high-income countries (mostly OECD), and developing countries are 2.2%, 2.5%, and 3.4%, respectively.[24] These are considerable increases over their 2001-2005 forecasts of 1.0%, 1.4%, and 2.7%.[25]

The per capita base case forecasts from IFs, shown below, are fairly similar. They tend, however, to show slightly slower growth rates for OECD countries and slightly higher for non-OECD countries. Understanding the reasons would require a review of the demographic forecasts of the Bank,[26] and most importantly, of the assumptions of the Bank and of IFs with respect to multi-factor productivity growth. The final section of this chapter will return to these issues.

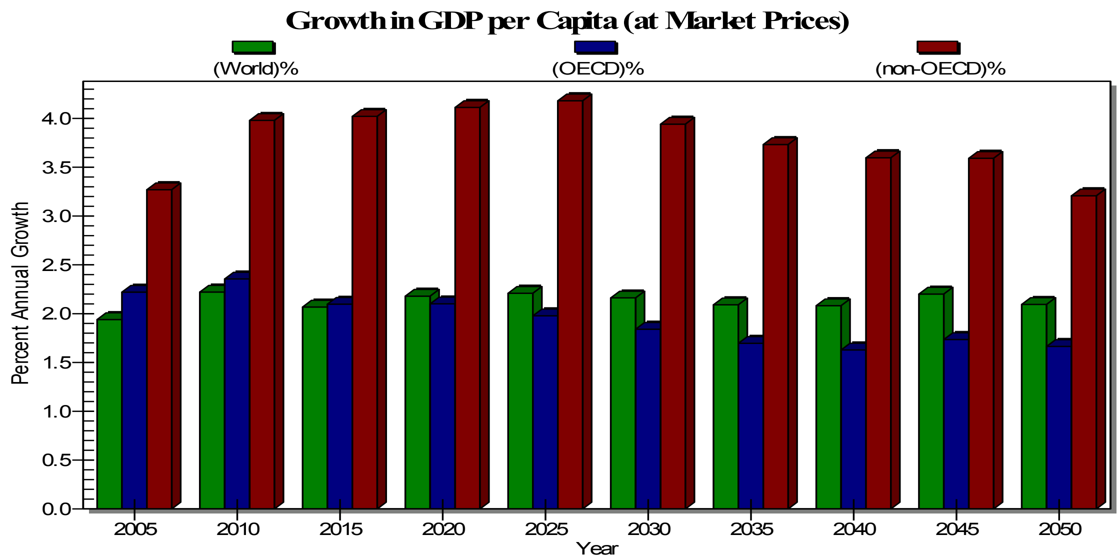


For the purpose of context, the figure below shows economic growth rates in IFs through mid-century. One element of importance in the longer term will be the loss for the developing countries of their current demographic dividends. Not only will their population growth be slowing, but their age distributions will become more like those of OECD countries. Such demographic changes in non-OECD countries will, of course, happen quite rapidly, just as the drops in their fertility rates have been much faster than were those in the demographic transitions of currently developed countries.

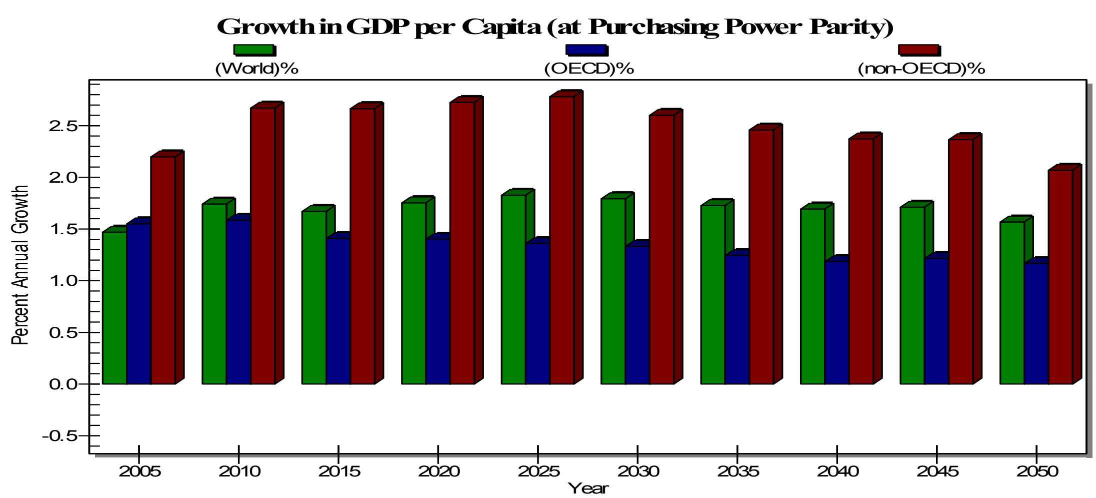
[24]It may seem impossible to have lower growth rates in global GDP per capita than in either more or less developed countries, and it would seem that the world average needs to fall between rates in the high-income and developing groupings. Yet the weighting of GDP per capita by population in producing aggregate levels can sometimes produce that outcome. In fact, IFs also shows lower world growth rates than those in either developed or developing countries for much of the period between 2006 and 2015.

[25] Table 1.5, p. 43 has detail for global regions. For some further context, the global growth assumption of the U.S. Department of Energy in its own forecasting report for 2003 was 3.1% between 2000 and 2025. The European Commission used the same 3.1% rate in forecasts of energy futures between 2000 and 2030. On a per capita basis, these are similar to the rates in the IFs base case.

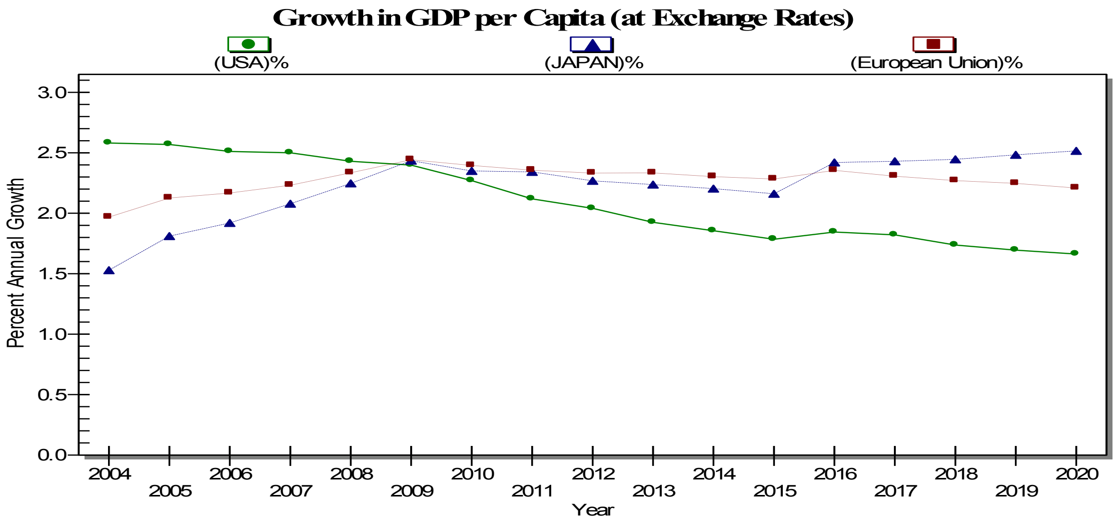
[26] It is possible that the World Bank does not use a full demographic model for developing countries; the use by IFs of such a model does add a "demographic dividend" to their growth.



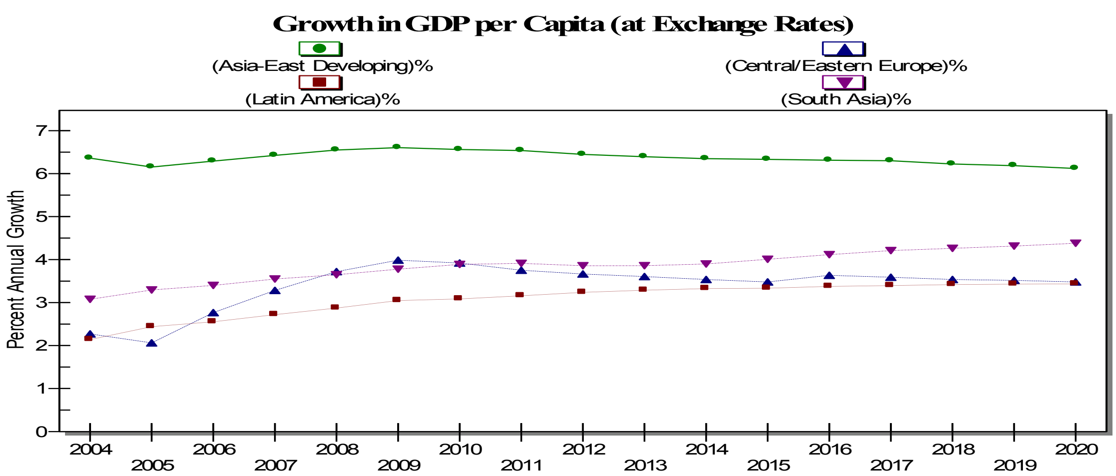
Extending the presentation of the IFs base case one step further, the graph below shows the forecast of growth rates at purchasing power parity, instead of at exchange rates. GDPs at purchasing power parity for non-OECD countries as a whole are about three times the level of GDPs at market prices (or exchange rates); the ratio of the two GDP measures for OECD countries (including now Mexico, South Korea and a few other newly "developed" economies) is about 1.6 to 1. Therefore as convergence of developing countries towards the GDP levels of developed countries occurs, the growth rates at purchasing power for some of the OECD countries and essentially all of the non-OECD countries will be somewhat slower than those at market rates.



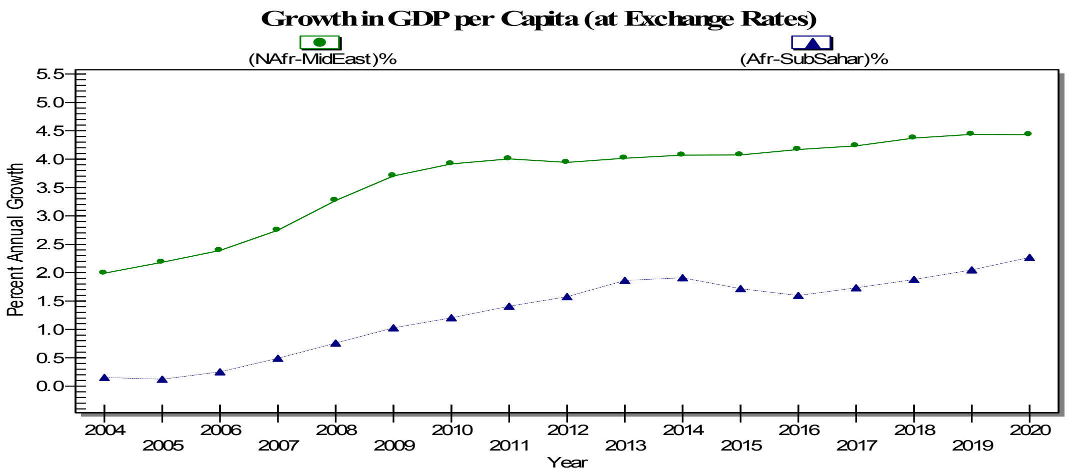
The World Bank provides breakdowns by regions and sub-groupings for per capita growth from 2006 through 2015. For the developed countries these are 2.4% for the OECD, 2.5% for the US, 1.9% for Japan, and 2.3% for the EU. The graph below shows the rates in the base case of IFs (using the current EU of the 15). Although the per capita growth rates of the US, Japan, and EU for the next few years are similar to those of the World Bank forecasts, and thereby extend differentials of the late 1990s, over time the growth patterns in the IFs base case change because of the dynamic underlying model (representing, for instance, some of the financial difficulties that the US may face and some of the potential for restructuring and catch-up of Japan).



For the developing regions outside of Asia the World Bank forecasts of growth rates are 5.4% for East Asia and the Pacific, 3.3% for developing Europe and Central Asia, 2.5% for Latin America and the Caribbean, and 4.1% for South Asia. The figure below shows the IFs base case. China, to be discussed separately later, dominates forecasts for developing East Asia within IFs. Possibly for that reason, IFs forecasts are higher than the numbers of the Bank. Latin America does fairly well in the IFs base case, comparable to the numbers of the Bank. The IFs base case forecasts for Central and Eastern Europe run just a little lower than those of the Bank, and possibly reflect too much of the experience of the 1990s and too little that of the remarkable recovery some of those economies have begun to exhibit. Forecasts for South Asia are dominated by India, but are a little lower than those of the Bank.



For Africa and the Middle East the World Bank per capita forecasts are 2.5% for the Middle East and North Africa and 1.6% for Sub-Saharan Africa. The graph below shows the forecasts of the IFs base case. Forecasts for the Middle East and North Africa start running higher than those of the Bank, probably because the energy submodel of IFs, to be discussed in the next chapter, begins providing higher export revenues. Forecasts for Sub-Saharan Africa are lower than those of the Bank until early in the next decade. In the face of the AIDs epidemic and other difficulties, it is difficult for the IFs base case to be as optimistic about the near-term prospects for Sub-Saharan Africa as is the Bank. Extending the horizon towards 2020, the prospects appear considerably brighter.



3.4 World Product Through 2050 and 2100

Looking still longer term for economic forecasts, we need to turn primarily to those who make energy forecasts and who must necessarily start with economic growth to do so.

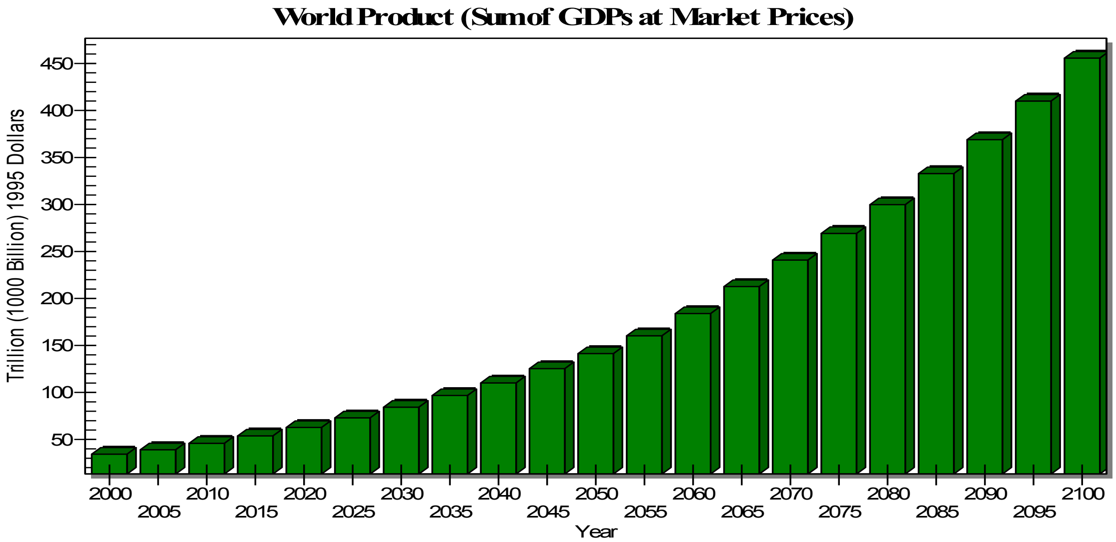
IIASA/WEC produced three long-term scenarios of GWP (Nakićenović, Grübler, and McDonald 1998: 6). The forecasts for 2050 range from 75 to 100 trillion 1990 dollars (relative to 20 trillion in 1990), implying annual growth rates of 2.2% and 2.7%, respectively. In 2100 the forecasts range from 200 to 300 trillion 1990 dollars, implying century-long growth rates of 2.1% and 2.5%, respectively. The forecasts over the twenty-first century involve a bit less than 10-15 fold increases.

The IPCC scenarios from the third assessment report, again in 1990 dollars, range for 2050 from 82 to 187 trillion (growth rates of 2.4% and 3.8%) and in 2100 from 235 to 550 trillion (growth rates of 2.3% and 3.05%). Century-long increases are 12-30 fold.[27] Just as the recent World Bank forecasts have become more optimistic, so have the more recent IPCC forecasts; the experience of the late 1990s has begun to shape such analyses.

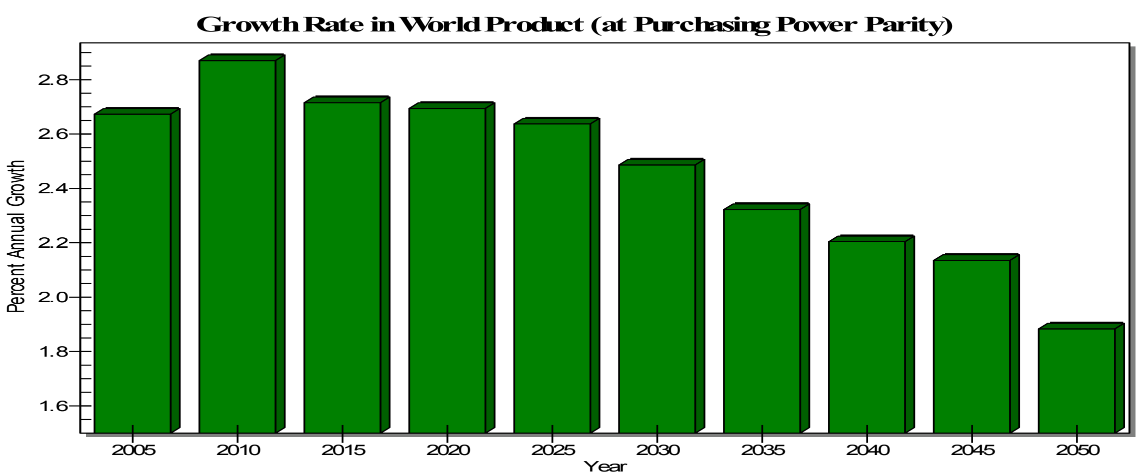
The century-long economic growth of the IFs base case takes the global economy to more than 450 trillion 1995 dollars, as shown below. The average annual growth rate is 2.6%

[27] For comparison, the 2nd IPCC report forecast a 24-fold increase globally, with industrial countries growing by a factor of 13 and developing countries growing by 69 times (IPCC, 1995, Volume 2: 590)

and produces a 13-fold increase. It thus falls within the range of the above studies, but is somewhat on the low side of the newest ones. In structuring the base case of IFs an attempt has been made not to draw quite as heavily on the experience of the late 1990s as some recent forecasts have, but to look at longer-term historic growth patterns.



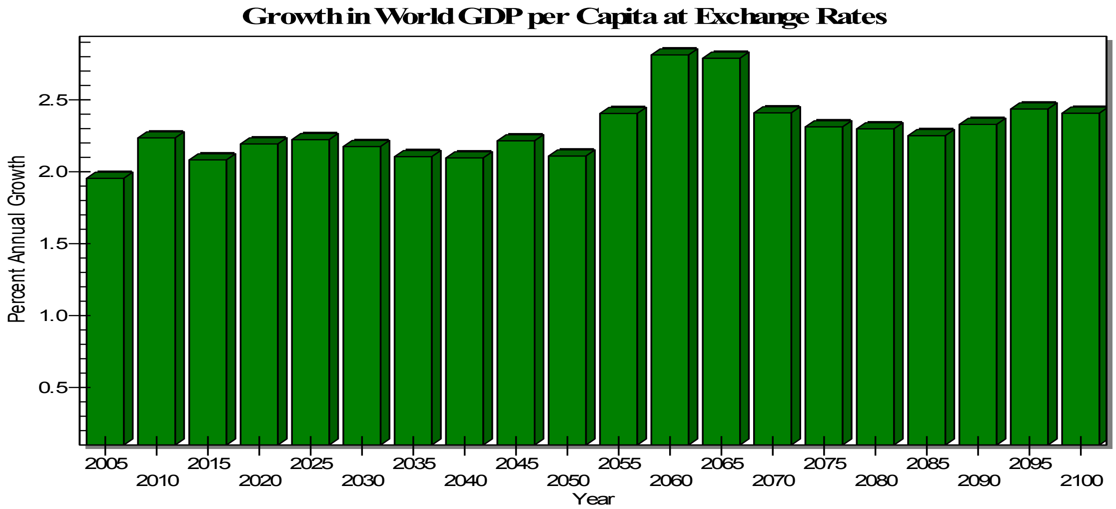
Similarly, the Shell energy analysis (2001: 60) assumes growth rates of GDP at PPP of 3.2% between 2000-2025 and 2.4% from 2025-2050. As shown below, the IFs base case produces 2.5% at PPP between 2000 and 2050, 2.7% in the first half of the period and 2.3% in the second half.



To provide some historic context for these long-term forecasts, Angus Maddison (2001: 126; see also Maddison 1995) estimates that the world economy grew at a rate of 1.6% from 1820-1950, an increase by a factor of 7.9 over 130 years. At a rate of 3%, which is what the global economy achieved between 1973-98, a century would produce a 19-fold increase, about the middle of the IPCC range. At a rate of 4.9%, the rate of the "Golden Age" for the world economy from 1950-73, the world economy would grow by a factor of 120 in a century. In general, the growth rate of the world economy has quite steadily accelerated since the beginning of the industrial revolution. Yet the great surge from 1950-73 and the fall-off after that (even with an historically high rate of 3% in the last quarter century) make forecasting in the 21st century uncertain.

Instead of the historical acceleration identified by Maddison throughout the 20th century, the IFs base case (below) exhibits a gradual de-acceleration in the current century, related heavily to slowing population growth rates. Although the emergence of ICT-driven productivity gains might argue for assumptions of continued growth acceleration going through the century, it is also quite possible that a drop of global population growth rates from a high of 2% in the middle of Maddison's "Golden Age" to a value below 0% in the late 21st century will cause a very considerable de-acceleration of economic growth. As will be discussed later, the graph below actually represents a pattern influenced by both higher productivity and much slower population growth.

The IFs base case produces a fairly stable rate of growth for GDP per capita throughout the century, and one that an earlier graph showed to be quite similar to the forecasts of the World Bank for the next two decades. There is a very slight upward trend in the rate, related to productivity gains, even in the face of aging capital stock.

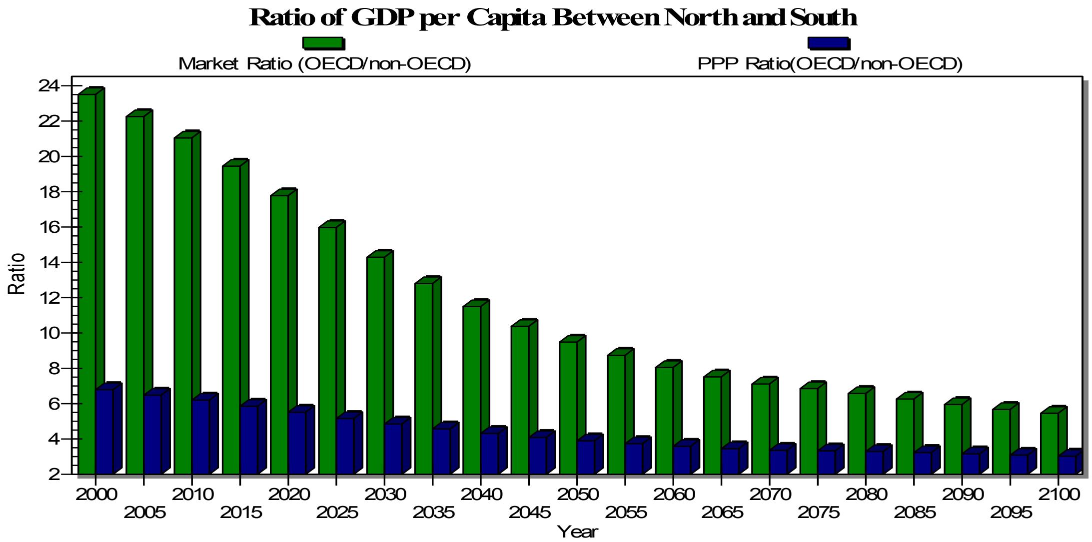


3.5 Decomposing Long-Range Forecasts by Country/Region

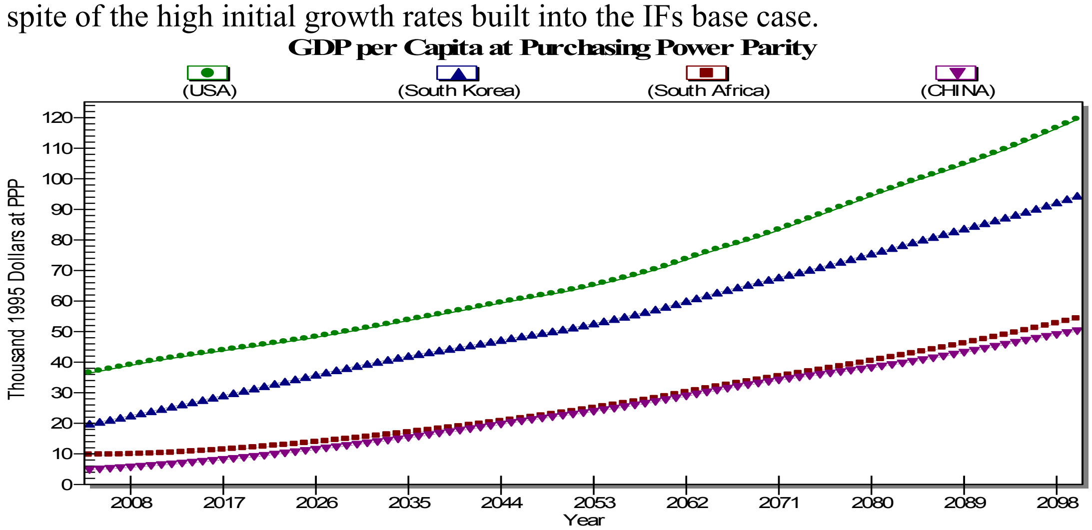
The IPCC scenarios came under intense criticism in late 2003 by Castles and Henderson.[28] The debate does not appear necessarily to be around the total values of the global product. Even the 30-fold increase for the highest growth scenarios of IIASA could be generated by a century of growth at the rate of 3.46%, well below the rate of the Golden Age and only 0.5% higher than that of the 1973-98 period.

Instead the attack is heavily focused on the numbers provided for regions of the world. In particular, in all of the scenarios in the IPCC set, the ratio between GDPs per capita in the developed and developing worlds narrow from 16 to 1 in 1990 to between 1.5-3.0 to 1. That rapid narrowing appears open to challenge and IFs does not anticipate such a substantial reduction. Instead, as indicated below, the IFs base case shows quite fast reduction in the first half of the century, but slowing convergence thereafter as gains become more difficult.[29] Even at purchasing power parity the gap closes only from nearly 8-to-1 to a little less than 3-to-1.

[28]The attacks were reported in *The Economist* and elsewhere. See http://www.lavoisier.com.au/papers/articles/IPPCissues.html; January 8, 2003.
[29] The North-South gap in IFs begins higher than in the IPCC, at more than 22-to-1, using an initial division of countries into rich and poor with a level of $5,000 in 2000. IFs maintains the same countries in each set over time.



Other attacks on the IPCC scenarios may be less meaningful. The IPCC provided numbers for 4 regions and some analysts at the Centre for International Earth Science Information Network have attempted to decompose those into specific countries (perhaps by the dubious technique of applying regional growth rates from IPCC regions to all members of the region, which could produce patently ridiculous results for countries like South Korea and South Africa, relatively rich members of their regions currently).[30] The IPCC cannot be responsible for such use of its regional numbers. And over a century the GDPs per capita of some developing countries, particularly at PPP, could narrow a great deal of the gap with the US and other developed countries. South Korea is one of them, with a high GDP per capita already (at PPP), but one that converges further towards that of the U.S. in the IFs base case. In contrast, however, South Africa barely catches up with the U.S. numbers at the beginning of the century and China may not even do that, in spite of the high initial growth rates built into the IFs base case.

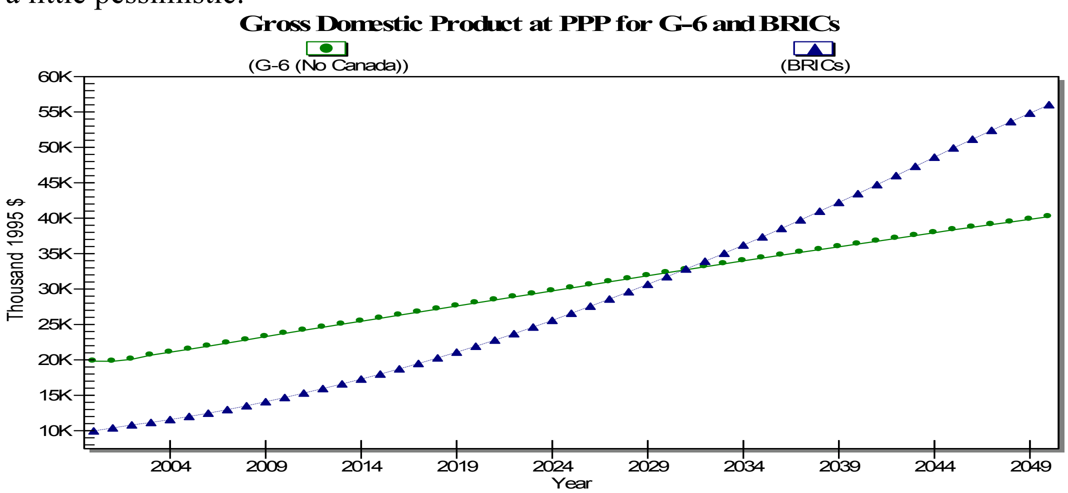


[30] The attacks on the IPCC scenarios have also focused in part on the use of GDP at market prices versus exchange rates. We do not fully explore that aspect of the debate here, but rather seek to be clear about the two measurements of GDP within IFs.

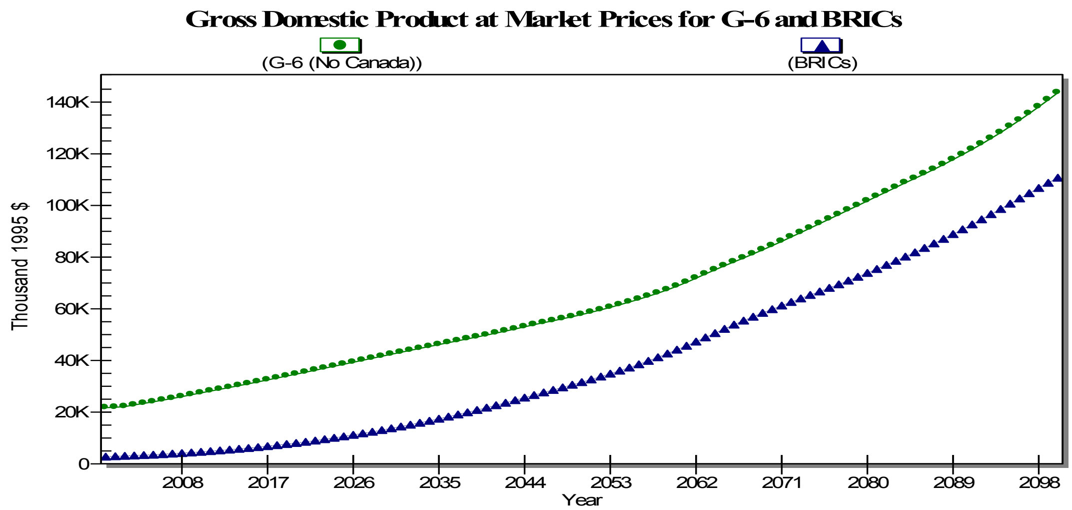
Even if the North-South gap does not close as rapidly as forecast by the IPCC, and even if most developing countries remain far behind the developed countries, much economic power will go South in this century. A study by Goldman Sachs of the BRICs (Brazil, Russia, India, and China) through 2050 focused on four of the most populous developing countries and four widely recognized to have among the best growth prospects. Goldman Sachs used a model that included demographic forecasts, capital accumulation, and productivity growth.

Comparing the BRICS as a group to the G-6 (the current G-7 minus Canada), the study suggested that the gross product of the BRICS will exceed that of the G-6 by 2040. In growth rate terms, China's growth rate in the Goldman-Sachs study falls from 8% to about 5% in 2015 and continues a slow decline. India's growth remains in a 5-6% range for the half century. Brazil and Russia achieve rates from 3-5% for most of the period. In 2003 dollars, the per capita GDP of China (presumably at PPP as in the IFs figure above) reaches $31,357 in 2050, very nearly that of the U.S. in 2000. Brazil is not far behind. The GDP per capita of Russia reaches nearly $50,000, above Germany in 2050 (this is perhaps among the most questionable of the Goldman Sachs results).

The two graphs below show the U.S. forecast for the BRICs versus the artificial G-6. At purchasing power, the Goldman Sachs forecast of overtaking by the BRICs may even be a little pessimistic.

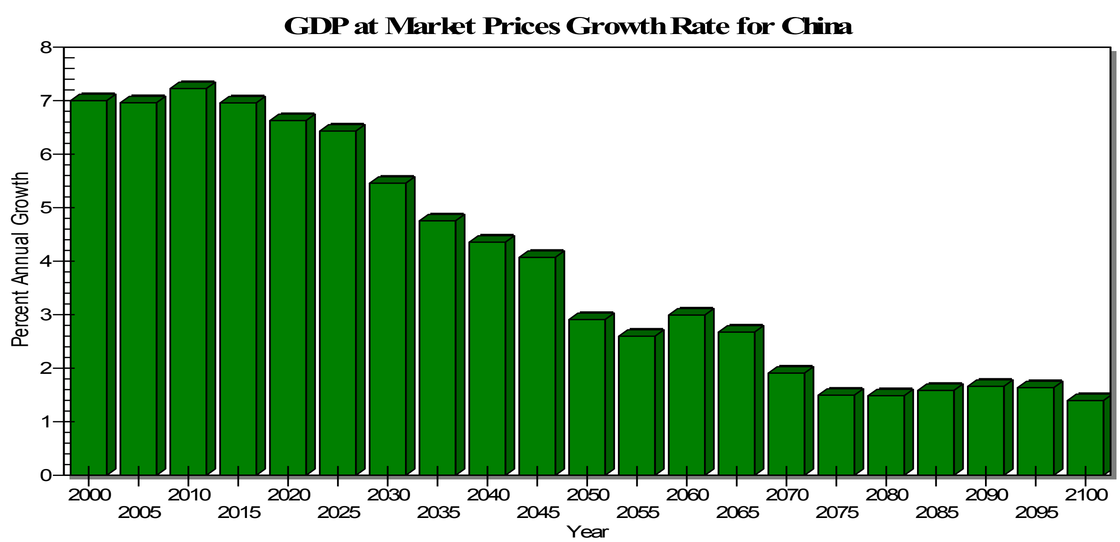


At exchange rates, however, the overtaking appears to be considerably further in the future.



Is that kind of economic growth achievable by these and potentially other developing countries (the Goldman Sachs study also examines South Africa)? Japan, South Korea and Taiwan managed to achieve annual rates averaging nearly 10% for nearly 30 years. China has already had about two decades of 7% and higher rates, and a conclave of economists at the 2003 China Economic Growth Forum concluded that high rates were quite possible for another 20 years.[31] At that meeting, Nobel laureate Lawrence Klein suggested that some slowing of pace, perhaps to 6-7% was likely, consistent with the Goldman Sachs study.

The figure below shows the economic growth rate of China in the IFs base case. It, too, shows continuing rates around 7% for the early years, with steady erosion over the longer run.



Because of the importance of India, the figure below shows long-term growth rates in the IFs base for it as well. In contrast to China, and in part because its economic catch-up is

[31] China Daily, http://www1.chinadaily.com.cn/en/doc/2003-11/10/content_280012.htm; January 9, 2004.

less far along, the higher growth rates it has been achieving in recent years persist in the base case for the first half of the century.

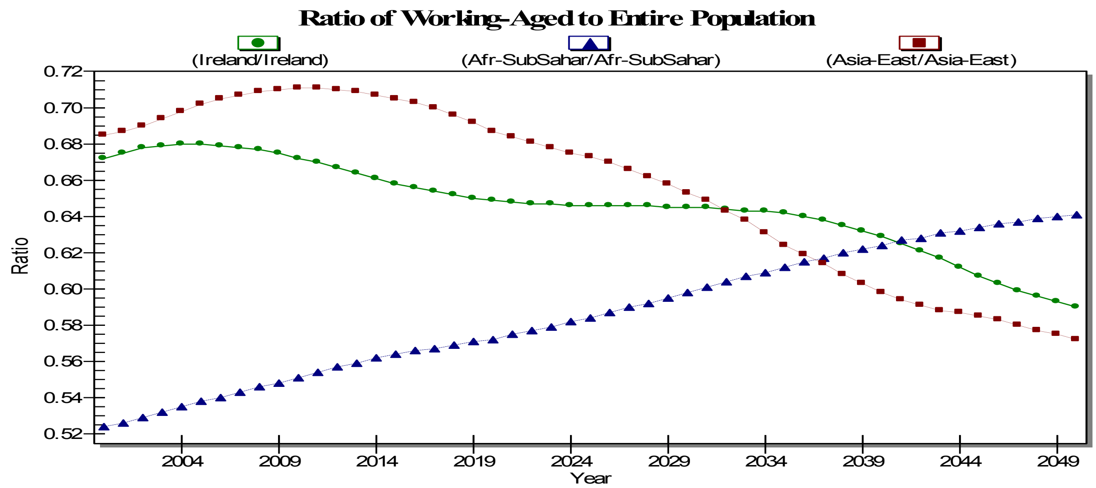
3.6 Decomposing Forecasts by Driving Factors

Another approach to thinking about global, regional and country-specific economic forecasts is similar to that of the Goldman Sachs study (and to the economic model within IFs). That is, the growth prospects can be seen to be a result of three components: labor force, capital availability, and multifactor productivity.

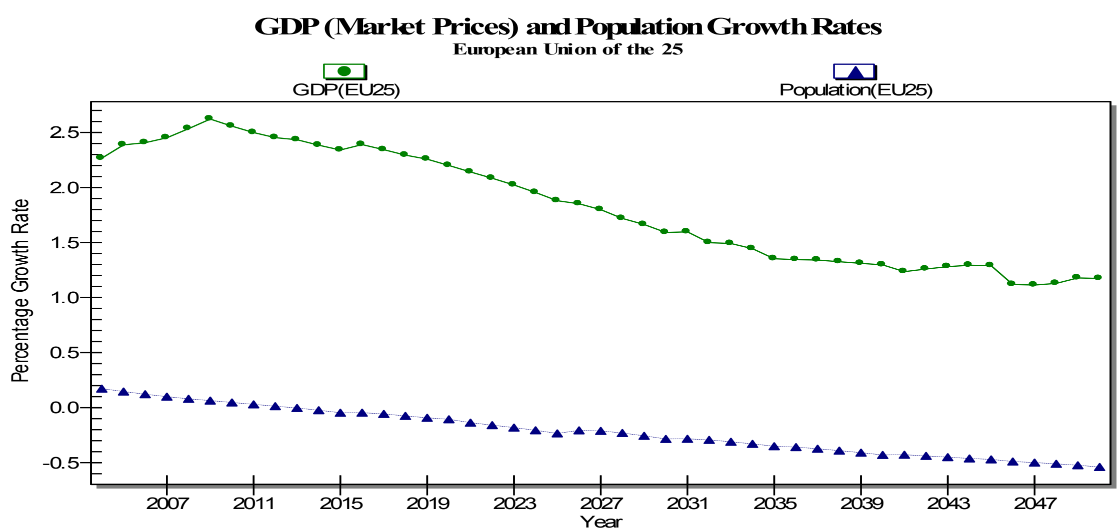
There is little reason to think that total investment or gross capital formation will change significantly relative to the size of the economies. Therefore, one could reasonably argue that global economic growth rate forecasts need to be especially careful about four slightly different components.

The first is growth in the size of population which, as discussed earlier, might well reduce growth of the labor force by 1-2% or more between 2000 and about 2070, even if population age structures were stable.

Yet population age structures are not stable, and the second factor, also discussed above, is changing structure within them. Some countries are now reaping a bonus (often called the "demographic dividend") as population growth rates decline and young age cohorts shrink, while increasing the portion of the population in the labor force. The figure below is the version from the IFs base case of a figure in Bloom, Canning, and Sevilla (2003: 38). It shows that Ireland is essentially at the end of its demographic dividend period, which has run since the 1960s. East Asia will see its period of dividend end before 2015, after a similarly long period of growth in the ratio of those in the working years. But Sub-Saharan Africa, even with the AIDS epidemic, is likely to experience a period of increasing dividend throughout the first half of the century. This is one of the reasons for the relatively optimistic rise in African growth rates shown earlier.



As a general rule, this aging of populations in more developed countries might be expected to further reduce economic growth, on top of reductions linked to the growth rate in population itself. That is, the growth rates of active populations will be even less that the total growth rates. Thus if population growth rates in the European Union decline from 0.15% to -0.54% by the middle of the century, that will in combination with aging, roughly speaking, reduce economic growth in those countries by a full 1% or more. Partly for that reason, the CIA (2001: 7) concluded that GDP growth during the 2025-50 period will drop in Europe to 0.5%, in Japan to 0.6%, and in the U.S. to 1.5%. The base case of IFs, below, is somewhat more optimistic about European (and US) growth rates, partly because of higher rates in the earlier years, but the loss of about 1% in growth rates is apparent.



The third driving factor is the growth in multifactor productivity at the level of system leadership (the U.S. and other technology producers). If the United States is viewed as the global technological leader, with other countries also contributing new technology but adopting relatively more, then MFP in the U.S. is especially important. That contribution could easily vary from about 0.5% to 2.0%. The Information Communications Technology (ICT) revolution might make numbers closer to 1.5% reasonable, but hardly certain for the first part of the century. According to Bauer, Jensen and Schweitzer (2001), MFP growth in the U.S. averaged 1.2% annually from 1948-99. This was highly variable, however, with 1.9% from 1948-73 (the "Golden Age" again) and only 0.3% from 1979-90. Gains picked up again to 1.1% from 1995-99.

The fourth element is the rate at which technology followers (the predominant situation in the BRICs and other developing countries) can adopt and use the technology. There is reason to argue that globalization processes and the achievement by many developing countries of basic economic and human capital levels has accelerated diffusion rates relative to most of the twentieth century. The IFs base case builds in relatively rapid diffusion rates.

Analysis around such decomposition of growth drivers does not easily produce a single base case forecast, but it provides some basis for evaluating one. More research on forecasts in this area and direct comparisons with the IFs base case would be useful.

4. Energy

4.1 Forecasters

Because energy is one of the world's very largest businesses as well as constituting one of the greatest areas of debate concerning likely and desirable futures in the 21st century, it is not surprising that there are many sources of energy forecasts. A handful of regular forecast look out through the first 20-30 years of the century:

> The International Energy Agency (IEA) prepares an annual publication with forecasts through 2030 called the *World Energy Outlook* (in 2003 it was the *World Energy Investment Outlook*, reinforcing the attention by the IEA to analyzing the costs of energy supply forecasts). Most of the work of the IEA tends to have a business-as-usual scenario format with a focus on the fossil-fuel industry.
>
> In 2003, however, the IEA produced a report with a considerably greater attention to alternative paths involving greater renewable energy: *Energy to 2050: Scenarios for a Sustainable Future*. In addition to reviewing a wide range of scenarios from other studies, this report developed three exploratory scenarios of its own and one visionary scenario (2003: 61; 111):
>
> - **Clean but not sparkling**. A world of slow technological change and high environmental concern.
> - **Dynamic and careless**. A world of fast technological change and low environmental concern.
> - **Bright skies.** A world of fast technological change and high environmental concern.
>
> - **Sustainable development.** A normative scenario that sets and explores specific targets, including a 60% share of "zero carbon" energy sources and access to electricity for 95% of the world's population by 2050, and atmospheric carbon dioxide of no more than 550 parts per million by 2100
>
> The OECD overlaps heavily with the IEA in membership and activities. Nonetheless, the OECD periodically produces studies of its own, such as a collection of articles in *Energy: The Next Fifty Years*. (1999).
>
> The European Commission has also become involved in forecasting, having produced *World Energy, Technology and Climate Policy Outlook 2030*. (2003).
>
> In addition, the U.S. Department of Energy's Office Energy Information Administration produces an annual volume. See the *International Energy Outlook 2003*, with forecasts through 2025.

> There are many country and region-specific groupings, including the Asia Pacific Energy Research Centre in Japan, which has produced supply and demand balance forecasts for all members of the APEC (2002) through 2020.

Other sources provide either resources for considering even longer-term forecasts or undertake them:

> The World Energy Council (WEC)[32] builds its forecasting capability on a strong base of data and analysis concerning physical reserves and resources for fossil fuels and evolving technology with respect to both renewable and non-renewable energy forms. Not surprisingly its primary publications therefore review the resource and technology bases, with attention to trends and government goals. See, for example,
>
> > WEC, *Energy for Tomorrow's World* (1993).
> > WEC, *Survey of Energy Resources* (2001a)
> > WEC, *Energy Technologies for the 21st Century* (2001b)
>
> Periodically the WEC also undertakes forecasting with IIASA, as in its work on "Global Energy Scenarios to 2050 and Beyond." That work has been tied to the IPCC scenario development activities. See in particular, Nakićenović, Grübler, and McDonald (1998), *Global Energy Perspectives*.
>
> In addition the WEC collaborated with the UN Development Program and the UN Department of Economic and Social Affairs on the *World Energy Assessment* (2000).
>
> Beyond the IPPC efforts, among the best known of the scenario sets for mid-century is that produced by Shell International (2001, updating work of 1995). Shell provided two scenarios:[33]
>
> - **Dynamics as Usual**. A world in which a variety of forces including concern about energy security push the energy system gradually towards renewables, which have a 1/3 global share by 2050.
> - **The Spirit of the Coming Age.** A world of more revolutionary change in technologies, especially fuel cells, and in the embracing of environmentally-friendly energy choices.
>
> The United States Geological Survey also periodically provides widely-used resource estimates. For instance, in 2003 they released the "USGS World Petroleum Assessment 2000." The *Oil and Gas Journal* provides reserve figures

[32] See http://www.worldenergy.org/wec-geis/; January 11, 2004

[33] In 1995 Shell explored "Dematerialization," which posited especially rapid increases in efficiency of energy use, and "Sustained Growth," which explored maximum rates of growth in renewables leading to a 50% share by 2050, a scenario and number that have since received wide attention.

each year near the end of the year; British Petroleum also provides reserve estimates each year.

And there are a great variety of other sources, including periodic studies by the Worldwatch Institute, special reports by *The Economist,* and popular analyses like that of Rifkin (2002) on *The Hydrogen Economy*.

4.2 Key Concepts/Variables

Demand and supply interact very closely in forecasting of energy – they should be essentially identical, but they both have important individual dynamics as well as interacting and balancing through prices and trade.

On the demand side, GDP and population fundamentally drive it. The key issue is to a considerable degree the relationship between economic growth and growth in energy consumption. Historically, the two have often grown in near lock step, but in recent decades they have become less closely connected in part because of structural change in economies (in general services require less energy than manufactures) and in part because of responsiveness to price changes via changes in technology and use patterns.

On the supply side, the key issue is to a large degree the character of the supply pattern, with the balance between fossil energy and renewable energy becoming increasingly important. With respect to forecasting of supply contributions from fossil fuels, the availability of reserves and ultimately recoverable resources are important uncertainties. With respect to forecasting of supply contributions from all energy forms, and especially currently expensive renewable ones, the pattern of changes in technology and cost structures are key uncertainties.

4.3 Aggregate Demand and Production

The key uncertainty with respect to aggregate energy demand is its relationship with economic growth. Nakićenović, Grübler, and McDonald (1998: 6) suggest that the historic pattern is for annual declines of 1% in the growth of energy demand relative to GDP and use a range of 0.8% to 1.4% for forecasts. Shell (2001: 60) forecasts of growth in primary energy demand in their two scenarios similarly fall below economic growth (at PPP) by 0.7%-1.4% between 2000-2025 and 0.4%-1.2% from 2025-2050.

The IEA's 2002 *World Energy Outlook* forecast that global primary energy demand would grow at a 1.7% rate from 2000 through 2030. It is unclear what the assumptions were about global economic growth, but given global economic growth averaging 3% from 1973 through 1998, it appears that the IEA expects energy demand to grow by approximately 1.3% less than the economy. They further expect 60% of demand growth to be in developing countries, taking their share of global demand from 30% to 43% and reducing OECD share from 58% to 47%. The share of the transition economies is expected to fall slightly to 10%.

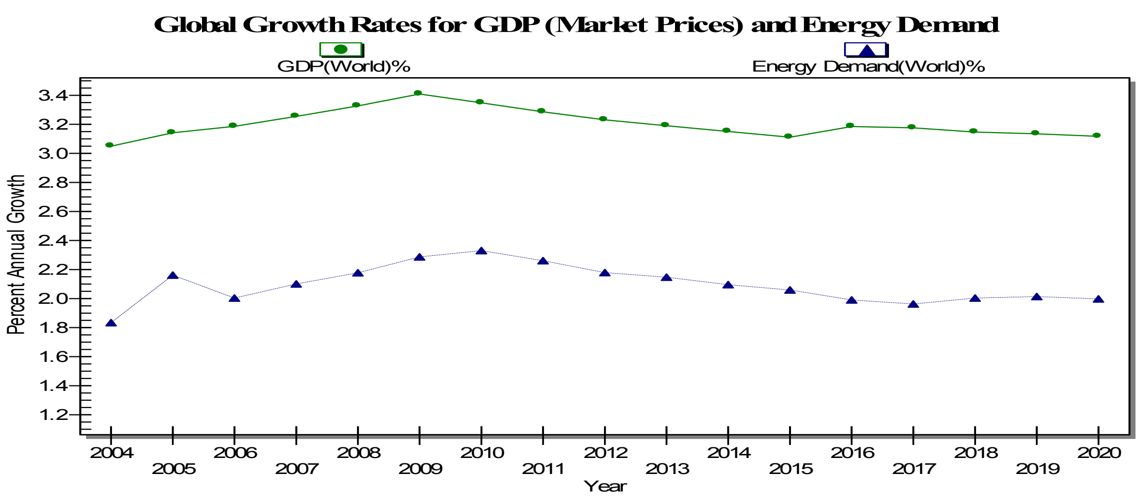
The IEA further disaggregates demand growth by usage category, noting that transport demand will grow most rapidly, at 2.1% per year, residential and commercial use at 1.7%, and industrial use at 1.5%. IFs does not forecast usage by category.

The IEA's Sustainable Development Scenario (in its *Energy to 2050* report) assumes that energy demand will grow by 1.5% annually less than GDP through 2050, with carbon intensity falling by 2.5% each year (2003: 137). This is, of course, a greater decoupling of economic and energy demand growth rates than most analyses anticipate.

The U.S. Department of *Energy's International Energy Outlook 2003* foresees global demand growth between 2000 and 2020 of 1.9% in their reference case (down from 2.2% in the 2002 study), 1.3% in the low case and 2.6% in the high case. These spreads suggest a wide range of uncertainty. The economic growth assumption of the IEA is 3.1% annually (with a rate of 6.2% for China), so the decoupling of economic and energy demand tends to be on the low end of other forecasts. An annual rise in oil prices of 0.7% (to a level of $26.57 in 2001 dollars) is also tied to this forecast.

Although the range of forecasts cited above is significant, the reference, base-case, or mid-range estimate tends to exhibit substantial consensus (or much mutual consideration) among energy forecasters around 1% decoupling or slightly more. Still another example is the European Commission's 2003 study, which assumed 3.1% global economic growth through 2030 and 1.8% energy demand growth, a difference of 1.3%.

The IFs base case is built on an assumption that energy demand will grow 1% slower than GDP if prices are stable. But because energy prices rise in the base case (to be discussed below), the gap between economic and energy demand growth rates somewhat exceeds 1%. In short, IFs is very close to other forecasts in this area.



4.4 Energy Supply by Type

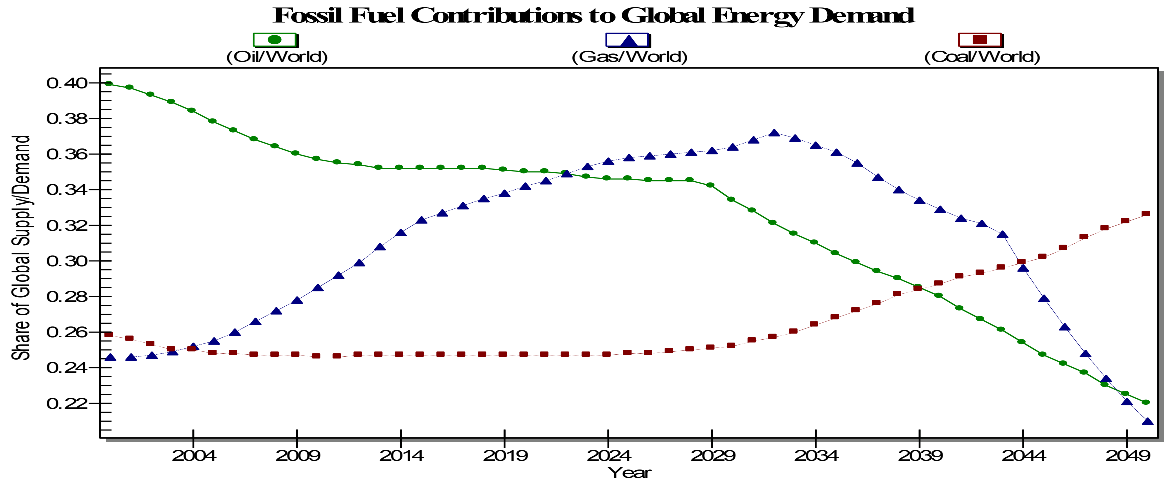
The IEA's 2002 *World Energy Outlook* forecasts that 1.7% growth in global energy demand through 2030 will be met by 1.6% annual growth in oil supply, keeping oil's share of supply relatively constant. Natural gas will grow in share, rising from 23% of total energy to 28%. Coal supply will grow more slowly than total energy demand. Nuclear power's share of global energy will stay at 7% until 2010 then fall to 5% by 2030. Hydropower will keep its share. Supply of non-hydro renewables, especially wind and biomass, will grow at 3.3% annually, but those rates will not appreciably increase their contribution towards demand.

Similarly, the U.S. Department of *Energy's International Energy Outlook 2003* foresees global demand growth between 2000 and 2025 of 1.9% with oil demand/supply increasing by 1.8% annually. The natural gas share of global energy will increase from 23% of the total to 28% (exactly the forecast of the IEA 2002), passing the coal share by 2005. Coal use will rise by 1.5%, with a share falling from 24% to 22%. The coal share declines will be especially rapid in Western Europe and the Transition Economies, with China and India accounting for 75% of global increase in coal use. Nuclear power's share of electricity generation will fall from 19% to 12% globally. Hydropower and other renewables will grow at 1.9%, implying a constant share.

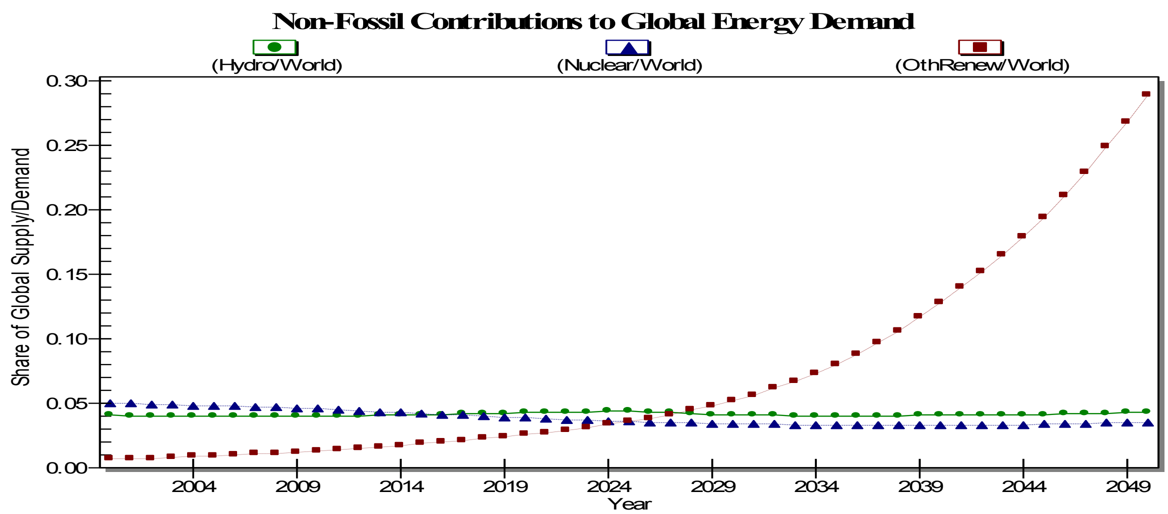
Although the European Commission's 2003 study has much in common with the IEA and US DOE, including a presumed 1.8% increase in energy demand through 2030, there are differences. The EC sees coal production growing at 2.3% and thereby increasing its global share, with 4.5% growth in Africa and 3% in Asia. Otherwise similarities are more common. World oil production is expected to rise by 65% by 2030 (an implicit annual growth rate of nearly 1.7%) and gas production will double (a growth rate of 2.3%). The EC expects electricity from biomass, solar, wind, and small hydro to grow at 4% and wind and solar to grow at 11% (considerably above IEA or DOE forecasts), still only increasing the non-hydro renewable share of total electricity to less than 3% of the total.

The two graphs below show the contributions of various energy forms to satisfying total global demand/supply in the IFs base case.[34] Like the forecasts summarized above, IFs shows a decreasing share for oil and an increasing share for natural gas, but the shift is somewhat faster in IFs. The graph extends beyond the 2025-2030 forecast horizons reviewed above and shows a decline in gas share as well as for oil, late in the period. The IFs base case indicates a slight drop in the coal share and then relative stability for a couple of decades, before a rebound, presumably using coal in cleaner ways than is currently the norm.

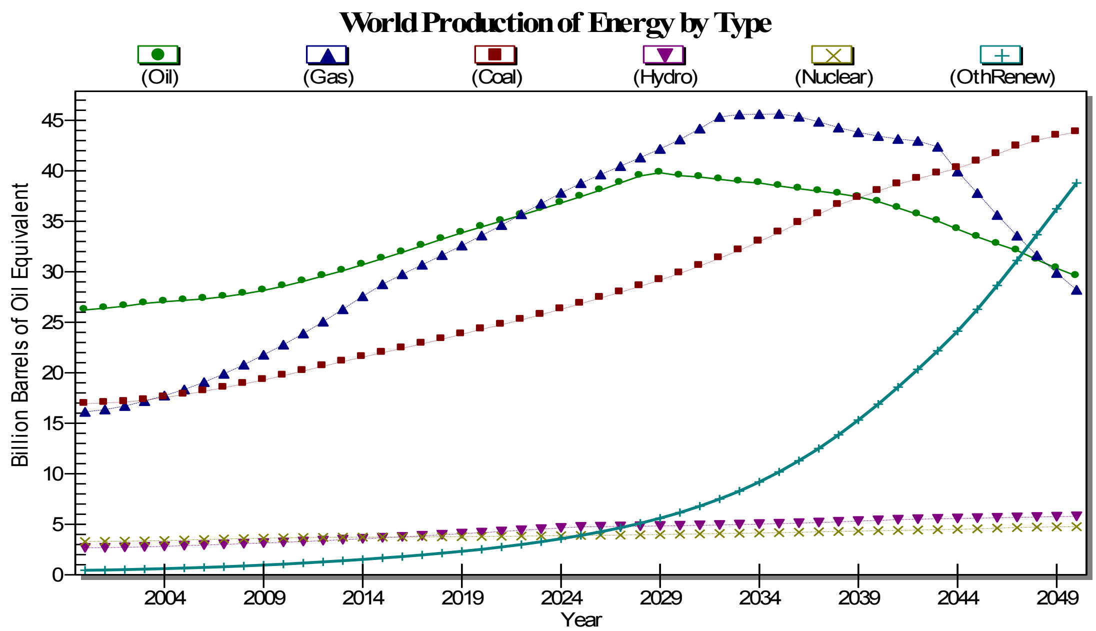
[34] The variable in IFs is world energy production by type (WENP, Oil…) divided by world energy demand (ENDEM).



The second in this series of graphs shows the contribution of non-fossil energy forms to total global demand, recognizing that some would classify nuclear as a fossil form. As in the forecasts summarized earlier, both hydro and nuclear energy contributions decline slowly. And as in the EU forecasts, production of other renewables, including all other forms such as wind, photovoltaic, and geothermal, grows at a quite rapid rate, which still fails to boost its total contribution to global demand significantly by 2030. A continuation of fairly rapid growth beyond that year, however, results in approximately the 30% share of Shell's "Dynamics as Usual" scenario by 2050.



What are the total magnitudes of energy supply by type to which these shares give rise? The graph below, although cluttered, gives an integrated answer to that question. The IFs base case currently suggests that both growing coal and other renewable energy supplies could pass declining oil and natural gas production before 2050. It should be obvious that the level of uncertainty in such a forecast is exceptionally great. Energy supply forecasts have much less solid foundation than do demographic forecasts or even aggregate economic ones. This chapter returns later to the "great debates" that frame some of the key uncertainties.

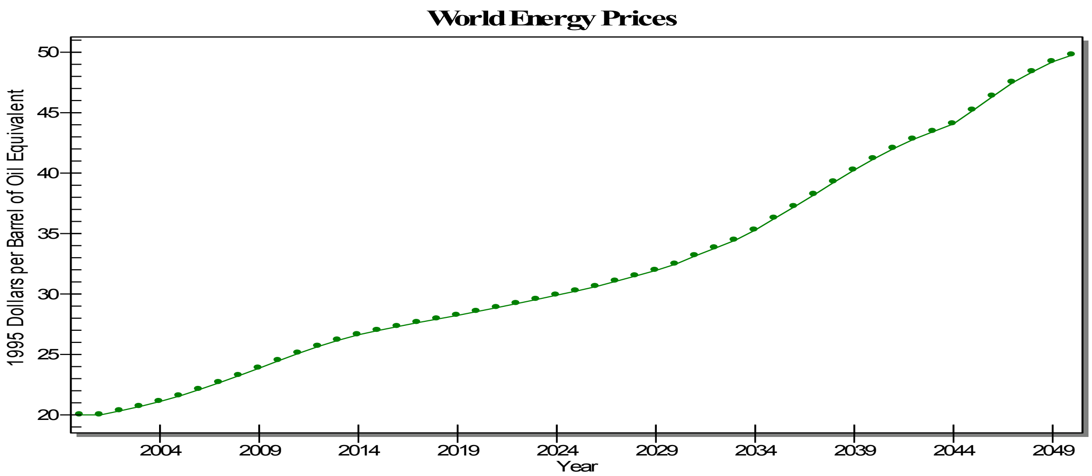


4.5 Trade and Pricing Patterns

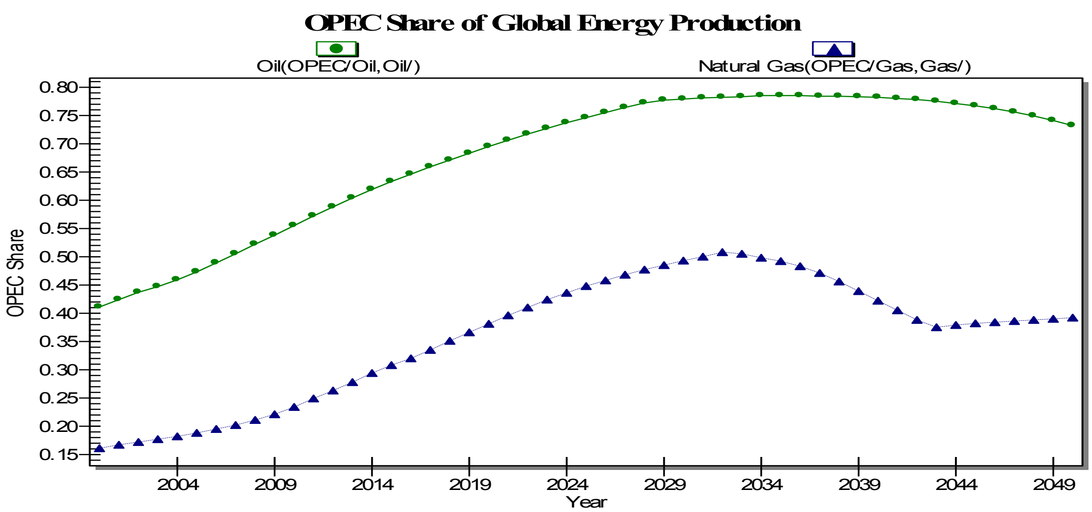
The U.S. Department of *Energy's International Energy Outlook 2003* presents three scenarios for oil prices. In the reference case they rise by 0.7% annually through 2025. In the low price case they fall to \$19.04 by 2009 in 2001 dollars and then level out. In the high price case they rise to \$32.95 by 2015 and then level out.[35] The graph below shows the trend of energy prices in the base case of IFs. It shows an annual growth rate of nearly 2% through mid-century.

Sometimes there appears to be a schizophrenia in the energy forecasting literature. One personality of the literature points to the rising pressure that China and other developing countries will put on the global energy market and to the great complications involved in making an energy transition to renewables as substantial as that described above. Another personality forecasts little or no upward pressure on energy prices. One of the larger unknowns within IFs is the pattern of long-term decrease in renewable energy costs with technological advance. IFs now uses a possibly conservative 1% annual rate of decrease for the renewable category as a whole. This is an area of sufficient importance to merit continued attention and review.

[35] It has been a challenge to determine what the appropriate starting point for energy prices should be within IFs, because oil prices obviously fluctuate by \$5-10 per barrel quite often. Whenever a new value is put in, changes in real-world prices can make it look unreasonable in a very short time. The starting point for prices in IFs should thus be treated more as an index level than an actual price. The variations over time relative to the starting point are of considerably greater importance that the absolute level.



Where will the oil come from? The graph below suggests that the OPEC shares of global oil and gas production will steadily rise over the next several decades. Some extent of rise seems almost certain and will also affect the price patterns discussed above as well as the possibility of constraint-induced price shocks.



4.6 The Great Debates

Whereas the first portion of this chapter showed substantial apparent consensus in near-term energy supply and demand forecasts across major organizations, the last section began to indicate the great debate and uncertainty just below the surface, especially for forecasts beyond 2020. The two primary areas of uncertainty are around ultimate fossil fuel resources and the possible rate of introduction of renewable energy (including the rate of decline in the costs of producing renewables).

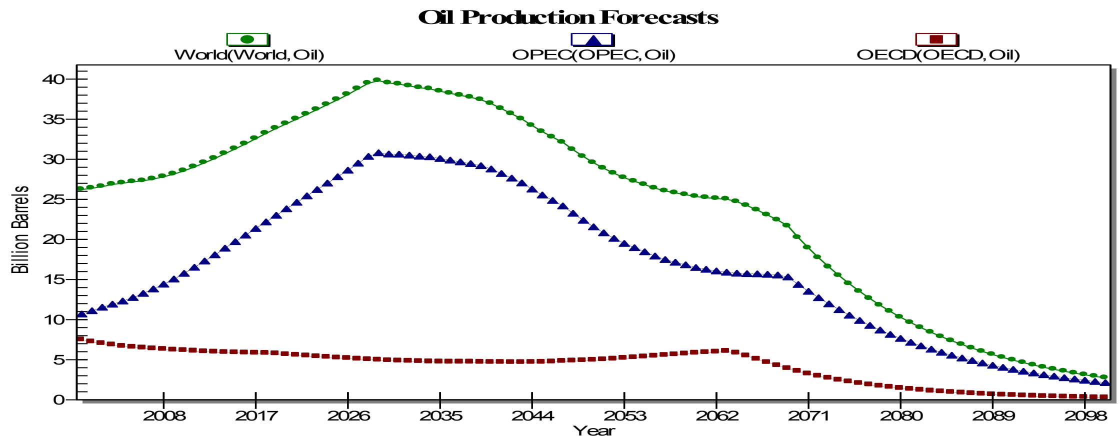
With respect to fossil resources, there is a substantial community that believes ultimate global oil resources to be much lower than those used in the estimates by the organizations that produce most forecasts. Rifkin (2002, Chapter 2) reviews some of the research/arguments, including those of Campbell and Laherrère (1998). Like those analysts, members of the Association for the Study of Peak Oil (ASPO) and the Oil Depletion Analysis Centre (ODAC) argue that global oil production is likely to peak quite soon, possibly as early as 2010. They base their forecasts on analysis using Hubbert's Curve, the same technique that allowed M. King Hubbert in 1956 to correctly forecast the peak of U.S. oil production about 1970. The argument of the pessimists is that the world has already produced and consumed about half of all oil that will ever be recovered. If they are right, the forecasts described above would be dramatically wrong and the global price of oil could rise very sharply in the coming decade and more.

In sharp contrast to that argument, other analysts such as Morris Adelman or Hans-Holger Rogner (2000) argue that oil resources are much greater and that, at least for the 21st century, pose no constraint on production and use of fossil fuels.

The U.S. Geological Survey (USGS) is somewhere in the middle, but seen as a bit on the optimistic side (Charpentier 2003). In its "World Petroleum Assessment 2000," the USGS estimates that known oil and natural gas liquid reserves can be supplemented by expected reserve expansion of 612 billion barrels and 42 BBOE, respectively, as well as by 649 billion barrels and 207 BBOE of undiscovered resources. The total of 1510 BBOE augments about a trillion barrels of known reserves, for a total of about 2.5 trillion barrels of oil yet to be produced. Similarly, the USGS estimates that known natural gas reserves of about 1 trillion barrels of oil equivalent can be augmented by 551 BBOE of expected reserve growth in known fields and another 779 BBOE of new discoveries. That is, ultimate gas resources are not much less than those of oil. On top of this are unconventional resources such as tar sands. For instance, based on analysis by the U.S. Geological Survey, the U.S. Department of *Energy's International Energy Outlook 2003* added tar sands to dramatically increase the oil resource assumptions for Canada to 1.7 trillion barrels of oil (255 billion recoverable with capital costs of $5-9 per barrel and operating costs of $8-12 per barrel). Debate about the recoverability costs for unconventional oil such as tar sands and oil shale adds much of the uncertainty in this area.

The resource assessments of the USGS have increased with each world assessment since 1981. The IFs base case uses global resource volumes comparable to those of the USGS (adjusting WEC numbers to reach them).[36] The figure below shows the kind of global production pattern (Hubbert's curve) that results from use of those estimates; the peak of global production comes near 2030 with increasing reliance on OPEC up to and beyond that time.

[36] IFs will be switching to USGS numbers before long.



The second issue of great debate is the rate of introduction of renewables. Such introduction could occur because of shortages in fossil fuels (push factors), but might also occur because of pressures for more environmentally-friendly energy. Reductions in the costs for renewable energy will be important to the pace of such transformation. As many point out, the stone age did not end because of depletion of stones and the oil age may not end with depletion of oil. Instead, better alternatives may become technologically feasible and economically viable.

On this debate, renewable energy optimists such as Lester Brown, formerly of the Worldwatch Institute and now leading the Earth Policy Institute, and Jeremy Rifkin posit potential growth rates for renewables such as wind and photovoltaic that are much larger than the numbers generally used, basing those rates on continued rapid declines in costs. Shell's scenario group, known for producing scenarios that push limits, produced one already by 1995 that suggested renewables could meet 50% of global energy demand by 2050 (about the same as the most optimistic scenarios from the IPCC).

The 1999 costs of production of electricity with natural gas (4.2 cents per kilowatt-hour), nuclear (4.0 cents), and coal (3.9 cents) are benchmarks for the renewable technologies to approach or beat. In some analyses geothermal and wind power now have comparable capital and operating costs in select environments. Concentrated solar power is perhaps twice as expensive and photovoltaic power begins at 25 cents or considerably higher, but with some forecasts of costs bringing it down near 10 cents by 2010. See UNDP (2000: 15-16) for one analysis.

Therefore the near-term potential for growth is primarily with wind and the WEC says that global capacity has been doubling every 2-3 years, reaching 17.5 gigawatts in 2000 (over 2 gigawatts in Denmark, meeting 12% of electricity demand). Capacity per machine has reached 1-3 megawatts. The U.S. Department of Energy's Wind Powering Initiative suggests targets for the U.S. of 80 gigawatts installed capacity in 2020, up from 2.25 in 2000, a growth rate of nearly 20% annually. Even if the target is met, however, it would satisfy only 5% of U.S. electricity demand. A reasonable conclusion is that the share of new renewables will remain modest globally through 2020, with much more and very uncertain potential by 2050.

5. Food and Agriculture

5.1 Forecasters

There are three primary sources of longer-term forecasts with respect to food and agriculture:

1. The United Nations Food and Agriculture Organization (FAO) is the premier data-gathering institution in this issue area and also provides regular analysis and forecasting. It tends to build cautious optimism about global prospects on an understanding of the very considerably progress in food supplies around the world, excepting Africa, over several decades. In 2000 the FAO released *World Agriculture: Towards 2015/30*, which is an update of *World Agriculture: Toward 2010*, released in 1995.

2. The International Food Policy Research Institute (IFPRI). IFPRI is affiliated with the Consultative Group on International Agricultural Research (CGIAR) and provides extensive food policy research. Its 2020 Vision Initiative focuses on forecasts and alternative scenarios, drawing in part on its International Model for Policy Analysis of Agricultural Commodities (IMPACT). It tends to be a little less optimistic than the FAO, especially for Africa. Among important reports are:

- Pinstrup-Andersen, Pandya-Lorch, and Rosegrant 1999. *World Food Prospects: Critical Issue for the Twenty-First Century*.
- Rosegrant, Paisner, Jeijer, and Witcover. 2001a. *2020 Global Food Outlook: Trends, Alternatives, and Choices*.
- Rosegrant, Paisner, Jeijer, and Witcover. 2001b. *Global Food Projections to 2020: Emerging Trends and Alternative Futures*.

IFPRI has also begun making longer-term forecasts, including some to 2050. See von Braun with others (2003), "Overview of the World Food Situation," a brief prepared for CGIAR in Nairobi.

3. The Worldwatch Institute. Worldwatch is at the far end of the optimism/pessimism scale from the FAO. Building on environmental and systems analysis perspectives, rather than trade-based and economic foundations, its analyses of land and soil availability/fertility and of water and energy resources have led it to produce since 1974 regular forecasts of increased environmental degradation and lowered production capacity.[37] See, in particular, the chapters on food and agriculture in its annual State of the World series and assorted Worldwatch Papers. One analysis that raised a great deal of discussion was Brown (1995), *Who Will Feed China? Wake-Up Call for a Small Planet.*

[37] See www.worldwatch.org; January 10, 2004.

The Organization for Economic Development and Cooperation (OECD) has also produced useful, but generally shorter-horizon reports. See, for example, OECD (1998b), *The Future of Food: Long-Term Prospects for the Agro-Food Sector.*

5.2 Key Concepts/Variables

Human nutrition is perhaps the key concept in this area. The most common measure of nutrition is calories available per capita per day. The FAO estimates that an individual needs between 1720 and 1960 kilocalories (kcal) for basal metabolism and light activity. Within countries the distribution of calories is always uneven, so a country average of 2200 kcal per day indicates very low levels of consumption and levels between 2600 and 2950 are needed to assure adequate nutrition for almost all of a population. Children require less than adults, so aging populations need somewhat more.

Related closely to the availability of calories is the prevalence of malnutrition, generally assessed for children in terms of weight or size relative to age-based averages. The World Food Summit in 1996 set a target of reducing the numbers of malnourished in the world from 830-840 million in 1990-92 to 410 million in 2015.

Also on the consumption/nutrition side of agriculture and food, poverty and income levels are essential concepts. There has come to be quite wide-spread acceptance of the proposition that malnutrition results primarily from poverty, not inability of the world to produce sufficient food.

On the supply side, crop and meat production are critical concepts, as are the necessary inputs for them: land and its yield rates, water, fertilizer, etc.

In addition, pricing and trade are key concepts/variables, helping equilibrate food demand and supply across countries and across time. Countries have, of course, intervened heavily in agricultural markets, within both the developed and developing worlds.

5.3 Calorie Availability and Malnutrition

The FAO 2015/30 report forecasts that daily calorie consumption globally will climb from 2,803 at the end of the twentieth century to 2,940 in 2015 and 3,050 in 2030, with levels in developing countries rising from 2,681 to 2,850 and 2,980 in the forecast years, (in the interim version of this report in 2000 the developing world forecast for 2030 was 3020 calories, suggesting some recent reduction in optimism).

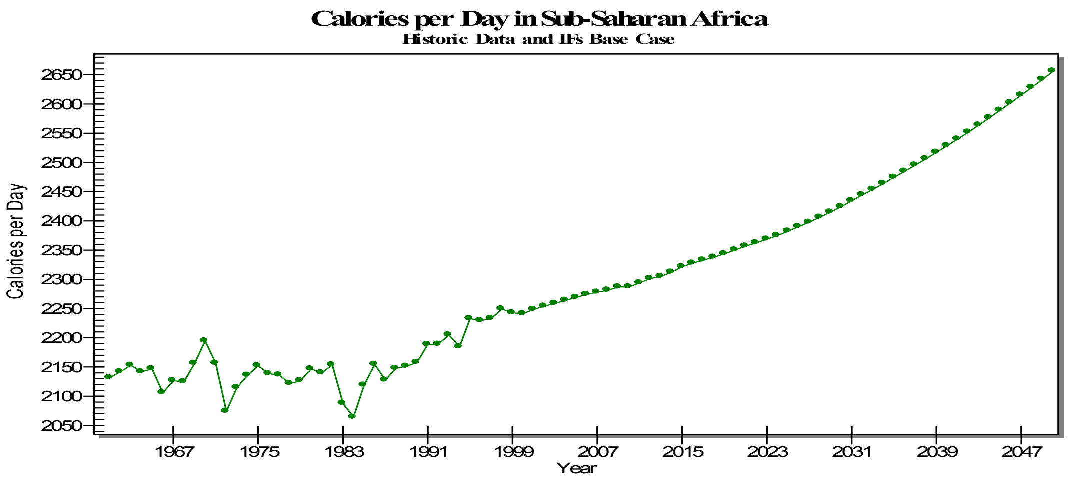
The FAO further forecasts a rise to about 2,600 kcal per day for Sub-Saharan Africa in 2030. The IFPRI (2001a) forecasts that calories in Sub-Saharan Africa will grow only to 2,442 per day by 2020, relative to about 2,200 in 1997.

Although the IFs base case forecasts for caloric growth in the world as a whole and for the developing world are very similar to those of the FAO, the forecast for Sub-Saharan

Africa is considerably lower, only about 2,420 in 2030 rather than 2,600. Thus the IFs base case suggests even slower caloric growth in the region than does IFPRI (to about 2,350 in the year 2020 versus IFPRI's 2,442), which is in turn more pessimistic than the FAO.

	CLPC[0]	CLPC[0]	CLPC[0]	CLPC[0]
	World	OECD	non-OECD	Afr-SubSahar
Year	Per Cap/Day	Per Cap/Day	Per Cap/Day	Per Cap/Day
2000	2,803	3,392	2,668	2,241
2005	2,842	3,416	2,714	2,269
2010	2,881	3,437	2,762	2,287
2015	2,920	3,454	2,811	2,321
2020	2,963	3,475	2,861	2,350
2025	3,008	3,494	2,915	2,383
2030	3,054	3,509	2,970	2,424
2035	3,101	3,522	3,026	2,475
2040	3,148	3,534	3,082	2,528
2045	3,199	3,548	3,140	2,589
2050	3,250	3,562	3,200	2,656

Looking at historic data in Africa, it is difficult to be as optimistic as the FAO. The figure below shows actual calories available per day per capita in Sub-Saharan Africa from 1961 through 2000, with the IFs base case forecast extending the series until mid-century. That region had almost stable consumption patterns until 1991, at which point it experienced a decade of considerable growth in calorie availability. Growth of availability in the IFs base case falls somewhat short of the historic pattern in the 1990s, but is highly optimistic relative to the longer term pattern. It must be remembered that Africa has entered the 21st century with great challenges demographically and relatively low expectations for economic growth. And again, the IFs base case for long-term forecasts tends to build on longer-term historic foundations, not just on the most recent decade.



Turning from calories to malnutrition, IFPRI (2001a) forecasts in their base case that the number of globally malnourished children will decline from 166 million in 1997 to 132 million in 2020. In their optimistic and pessimistic scenarios the numbers in 2020 are 94 and 178 million, respectively. In the base case of IFs, the initial numbers for globally malnourished children differ from IFPRI. There are two widely-used measures, one based on weight and the other on height, so IFs and IFPRI may use different measures. To compare forecasts, we should look at percentage change. Whereas IFPRI expects a 20% reduction in numbers by 2020, the IFs base case anticipates a 30% reduction. Sub-Saharan Africa remains a problem even with a 30% global improvement.

In the IFPRI (2003) analysis to 2050 the authors sketch a scenario of "progressive policy actions" that brings global per capita levels above 3,500 per day and child malnutrition numbers to about 40 million (about 16 million in Sub-Saharan Africa). But in two alternative "failure" scenarios, they see global child malnutrition numbers closer to 140 million with perhaps 45 million in Sub-Saharan Africa. The IFs base case global numbers are closer to the optimistic scenario, but the Sub-Saharan Africa scenarios are closer to the pessimistic ones.

	MALNCHIL[0]	MALNCHIL[0]	MALNCHIL[0]
	World	non-OECD	Afr-SubSahar
Year	Mil People	Mil People	Mil People
2000	219.0573	212.3347	67.03
2005	179.5687	175.1313	68.58
2010	171.3038	167.3283	72.05
2015	162.7605	159.1878	74.32
2020	152.5419	149.3928	76.21
2025	139.2332	136.3260	76.77
2030	122.8375	120.1970	74.54
2035	105.9824	103.5773	70.64
2040	89.5580	87.4260	65.75
2045	73.4312	71.6113	59.51
2050	60.4027	58.9189	51.82

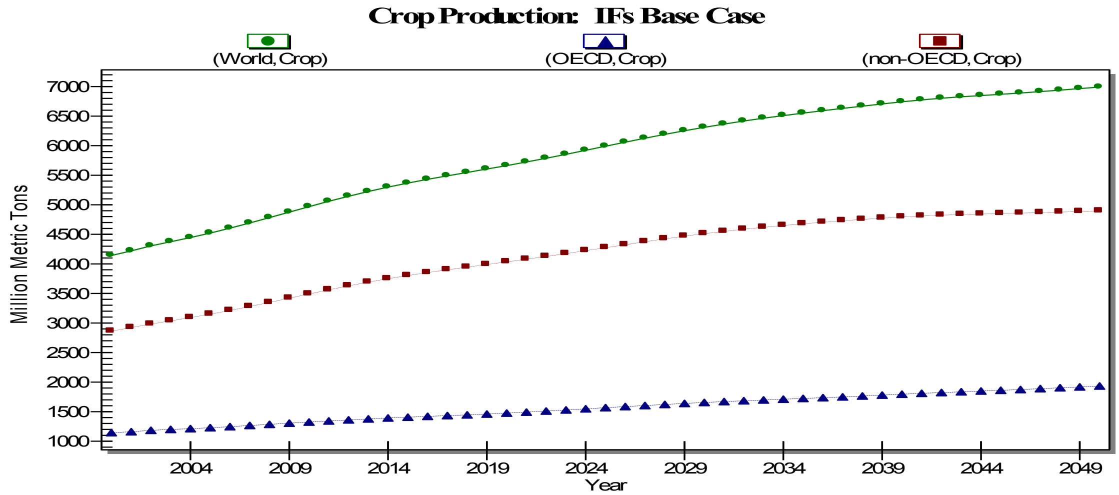
This report will return to the issue of malnutrition when it looks at forecasts around the Millennium Development Goals in the chapter on socio-political futures.

5.4 Production Patterns

Nutrition is ultimately a function of production, trade, and pricing patterns. We begin with production. Cereal production is at the foundation of most forecasts.

The FAO foresees global cereal production growing from 1,889 million tons in 1997-99 to 2,387 in 2015 and 2,838 in 2030. For developing countries the numbers are 1,027 in 1997-99, 1,354 in 2015, and 1,652 in 2030. IFs does not separate cereal production from broader crop production. Thus the figure below cannot be directly compared with the FAO forecasts. [38]

[38] Although the IFs food/agriculture submodel has some strengths, it is one of the least developed submodels in the overall system.



It is more nearly possible to compare the IFs base case with such forecasts if we turn to growth rates in production, rather than absolute numbers. FAO cereal production forecasts for the world suggest annual growth of 1.4% from 1997-99 through 2015 and 1.2% thereafter (compared to 1.4% from 1979-1999 but only 1% from 1989 to 1999). For developing countries the forecasted growth rate from 1997-99 to 2015 is 1.4% and that thereafter is 1.3%, compared to 2.5% from 1979-1999.

IFPRI forecasts global cereal production to grow from 1997 to 2020 at a rate of 1.26%, slightly below their forecast of demand growth at 1.32%. IFPRI forecasts, like those of the FAO, exceed the likely growth rate in global population (which had dropped to 1.2% by 2003).

It is, unfortunately, still not possible to do a direct comparison with IFs forecasts, because crop production in IFs includes vegetables and oil crops, both of which are growing at a considerably higher rate than cereals. What the table below does show is a pattern of longer-term decline in growth rates similar to the forecasts of the FAO and IFPRI.

Year	AGP[0] World Crop % Change	AGP[0] OECD Crop % Change	AGP[0] non-OECD Crop % Change
2000	1.892	1.325	2.162
2005	1.716	1.359	1.872
2010	1.891	1.468	2.088
2015	1.283	1.036	1.425
2020	1.042	1.048	1.105
2025	1.161	1.228	1.199
2030	.924	.973	.947
2035	.643	.743	.611
2040	.531	.862	.409
2045	.301	.66	.154
2050	.362	.777	.189

Worldwatch has repeatedly pointed in publications to the fact that cereal production increases in the 1990s fell below the rate of population increase, suggesting the passing of a global peak in cereal production per capita and a significant risk of nutritional impact. The FAO 2015/30 report notes the phenomenon but attributes it to not very clearly explained “exceptional and largely transient factors” (in the chapter on “Prospects by Major Sector: Crop Production,” p. 1). At the same time, the FAO points to very rapid growth in oil-crop production over the last two decades of the 20th century as one of the primary contributors to improved calorie levels.

Global meat consumption has been rising, especially in the developing world. IFPRI forecasts growth in global demand by 57% from 208 million tons in 1997 to 326 million in 2020 (IFPRI 2001b: 65). They foresee growth of demand in developing countries of 92% (an additional 102 million tons).

In the table below from the IFs base case, the growth in meat production globally from 2000 through 2020 is 63% and the growth in non-OECD countries is 85%, quite similar to IFPRI forecasts.

Table Display

Continue Refresh Graph Print Save Percent Filter Display Run Horizon

	AGP[0]	AGP[0]	AGP[0]
	World	OECD	non-OECD
	Meat	Meat	Meat
Year	Mil Met Tons	Mil Met Tons	Mil Met Tons
2000	242.0	101.1	137.4
2005	275.8	110.5	161.9
2010	318.2	121.2	193.7
2015	355.8	129.5	223.4
2020	393.5	136.7	254.2
2025	438.1	148.8	287.1
2030	479.7	161.3	316.4
2035	517.5	173.9	342.1
2040	550.7	187.0	362.6
2045	572.3	197.3	374.4
2050	606.1	217.7	388.4

The FAO forecasts that the use of grain for animal feed will grow globally at 1.9% from 1997-2015 (3.5% in developing countries) and 1.5% from 2015 to 2030 (2.5% in developing countries). The table below from IFs suggests considerably more rapid growth in feed demand and suggests that this area of the model requires review.

Table Display

Continue Refresh Graph Print Save Whole Filter Display Run Horizon

	FEDDEM[0]	FEDDEM[0]	FEDDEM[0]
	World	OECD	non-OECD
Year	% Change	% Change	% Change
2000	3.046	1.325	6.744
2005	4.492	2.687	7.693
2010	3.485	1.496	6.158
2015	2.00	.243	3.929
2020	2.334	.70	3.827
2025	2.50	1.489	3.339
2030	1.672	.928	2.246

5.5 Production Inputs

Land. IFPRI relies heavily on FAO land data and analysis. They foresee global expansion of cereal cropland from 738 million hectares in 1997 by 6% (46 million hectares) through 2020, almost all in developing countries (IFPRI, 2001b: 77). Total global cropland in 1997 was 1500 million hectares.

Most cereal and other agricultural production growth is dependent globally on increased yields per hectare of land. In Sub-Saharan Africa and Latin America, however, IFPRI (2001b: 61-62) foresees 27% and 15% growth in land for cereal production between 1997 and 2020 (only 9% in the developing world as a whole).

In the table from IFs global crop land expands by 9% through 2020, but contraction begins in the third decade of the century (an issue to which the next chapter returns), so that the expansion by 2050 is only a total of 12%. Expansion through 2020 in Latin America is 13%, but that in Africa is considerably below IFPRI forecasts.[39]

	LD[0]	LD[0]	LD[0]	LD[0]	LD[0]
	World	OECD	non-OECD	Afr-SubSahar	Latin America
	Crop	Crop	Crop	Crop	Crop
Year	Mil Hectare	Mil Hectare	Mil Hectare	Mil Hectare	Mil Hectare
2000	1,509	449.6	926.7	156.3	156.1
2005	1,541	455.3	945.8	160.1	162.0
2010	1,584	465.5	972.7	162.3	168.0
2015	1,626	477.5	999.2	164.2	173.1
2020	1,650	484.1	1,015	165.6	176.2
2025	1,670	489.1	1,029	167.5	179.5
2030	1,693	494.1	1,046	171.0	183.3
2035	1,707	497.4	1,058	174.4	185.7
2040	1,712	499.5	1,063	177.0	186.5
2045	1,708	500.3	1,062	178.6	186.0
2050	1,697	499.2	1,056	180.0	184.3

What about the arguments of Worldwatch that land degradation, land use for urbanization and roads, shortages of water, higher energy prices and/or other factors will undercut the global production capability? The FAO explicitly decided not to consider land degradation in making its forecasts, because it decided that quality was too difficult to quantify and also because it sees some factors reducing degradation.

IFPRI foresees a loss of land to urbanization in developing countries of only 14 million hectares through 2020. In the IFs base case the loss is about 40 million hectares (almost certainly too high).

[39] The land use formulations of IFs are not very sophisticated; this area of the model has not been one given great attention. Users of the model should be wary.

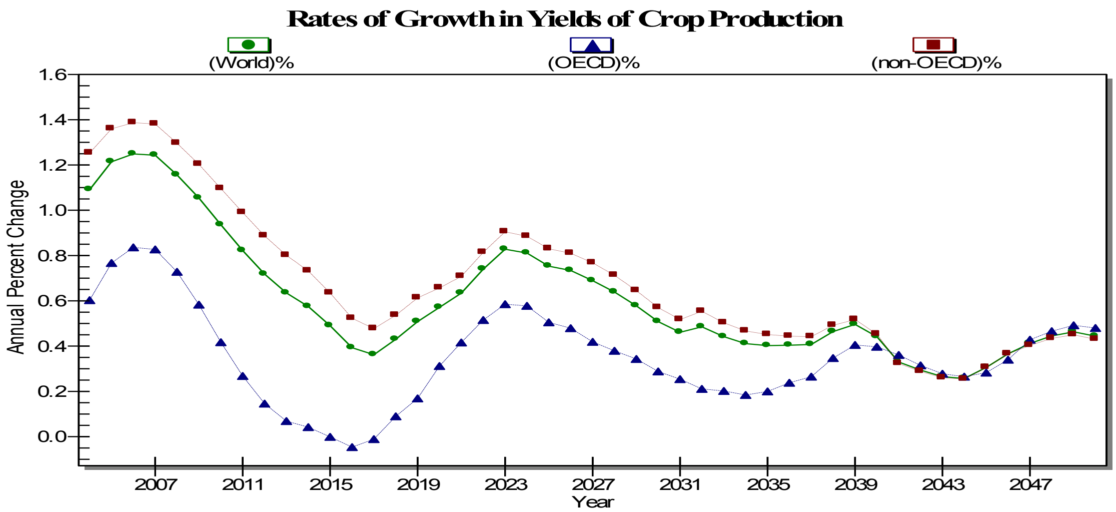
	LD[0]	LD[0]	LD[0]
	World	OECD	non-OECD
	Urban	Urban	Urban
Year	Mil Hectare	Mil Hectare	Mil Hectare
2000	259.6	131.9	89.19
2005	273.9	137.7	97.09
2010	292.8	145.1	107.5
2015	313.0	152.0	119.3
2020	332.5	158.5	131.1
2025	352.1	164.7	143.6
2030	371.8	170.5	156.6
2035	391.3	175.8	170.0
2040	411.0	180.3	184.2
2045	430.5	184.1	199.3
2050	448.6	187.5	214.1

With respect to water, the FAO foresees expansion of irrigated land in developing countries from 202 million hectares in 1997-99 to 242 million in 2030 (noting that the pace of expansion in the 1990s was 0.3% per year). It estimates the maximum potential at 402 hectares. IFPRI notes that irrigation accounts for 72% of water withdrawals and 90% in low-income developing countries (IFPRI 2001b: 80). Their baseline scenario allows irrigated areas to grow to 248 million hectares in 2020.

IFs does not represent irrigated land.

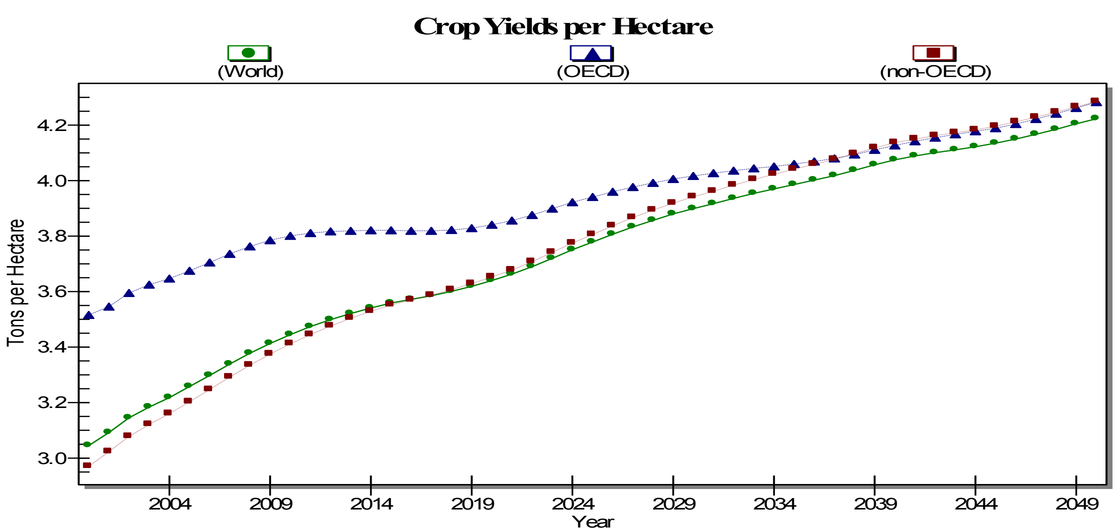
Most production growth is dependent on yield increases. The FAO calculates that 70% of production increases by 2030 in developing countries will come from yield and the portion is presumably higher in developed countries. They see wheat yields rising at 1.2% per year over the next 30 years, compared to 3.8% from 1961 through 1989 and 2% from 1989 to 1999. Rice yield growth rates fell from 2.3% to 1.1% over the historic period. The FAO suggests that forecasted yield increases are possible even without significant advances in biotechnology, but that those could provide useful boosts to production.

The graph from IFs below global yield increases in this decade near to the forecasts of the FAO, but shows gradual decline over a 30-year period and longer.



Still another argument raised by Worldwatch and others is that yields may be reaching theoretical maximums (as, for instance, determined by photosynthetic capability. IFPRI (2001b: 79) reviews some estimates of biophysical potential that do not suggest that yield is approaching limits, with some exceptions such as northern India, southern China, and the North American plains.

The figure below from IFs shows a significant total increase in yields through mid-century, but not one that would seem to bump against physical or technological limits. One possible area of challenge to the pattern would be the closing of the gap between yields in developing countries and those in developed countries. Tropical soils exist primarily in the developing world and are considerably less productive. At the same time, non-tropical soils in the developing world are often cultivatable more intensively than in the developed world. So the aggregate pattern may be reasonable.

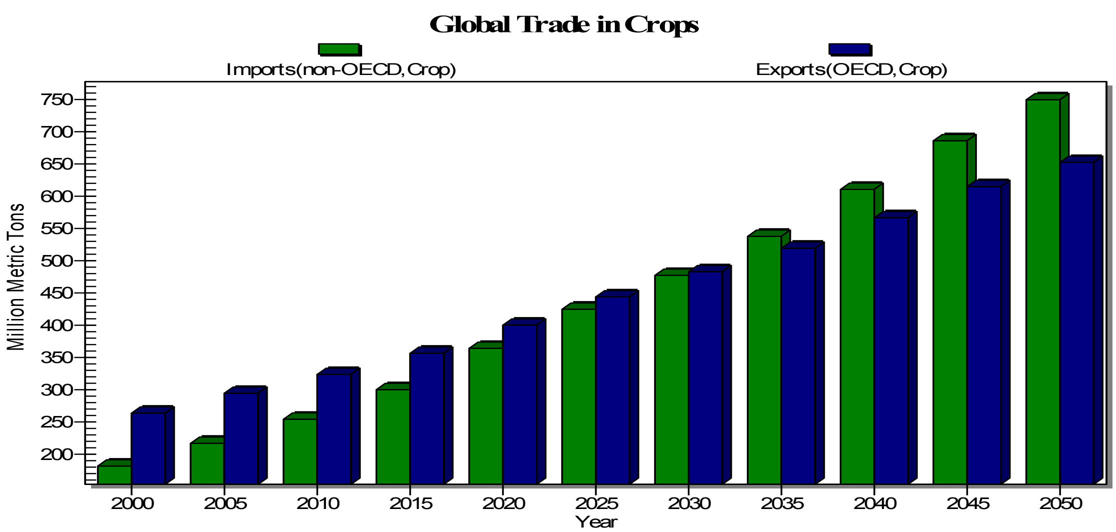


5.6 Trade and Pricing Patterns

Worldwatch (1995) has expressed great concern that a richer China, turning to a diet heavier in meat, even while cropland was shrinking from overuse, would need to import massive amounts of grain. Specifically (1995: 98), the analysis produced a scenario of steady growth towards 280 million metric tons of grain imports in 2030, placing great strain and upward price pressure on global markets. With faster growth in India beginning in the 1990s, the same concern has been raised for it.

In contrast, the FAO points out that China was an importer of grains for most years until 1991, but that even with rapid growth in consumption it exported grain for six of the years between 1992 and 1999. Similarly, South Asia imported 11% of its consumption in the mid-1960s, but even after a doubling of per capita consumption by 1999 it was importing only 2%. Notwithstanding this historic pattern, the FAO foresees OECD grain exports rising to about 245 million metric tons by 2030, while grain imports of developing countries climb steadily to about 275 million metric tons.[40]

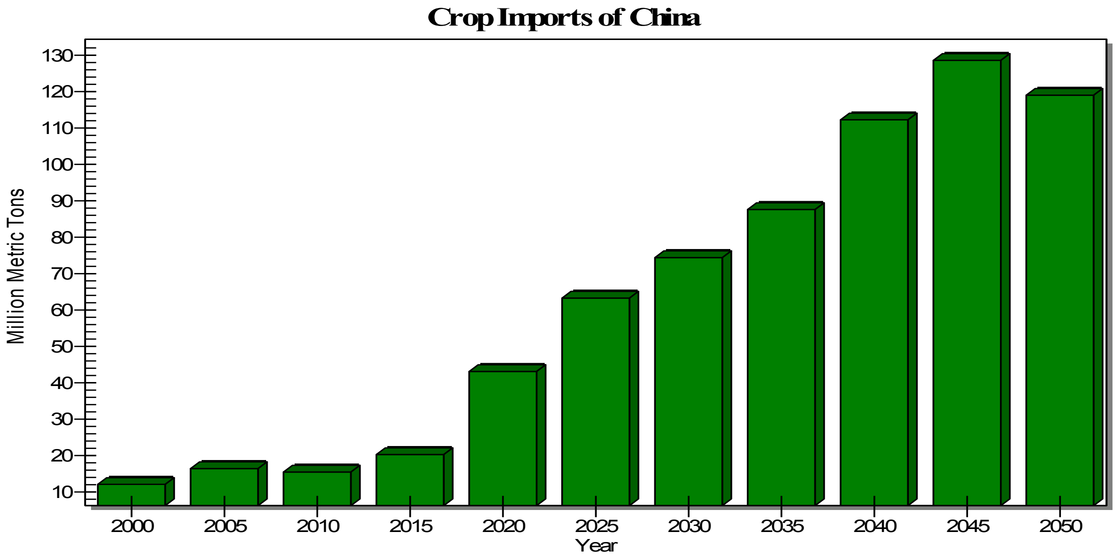
Once again, the representation of aggregate crops, rather than of cereal, makes difficult the comparison of these forecast with the IFs base case. The figure below shows steady, but not extraordinary growth in agricultural imports of non-OECD countries and of exports by OECD countries (they are not equal, of course, because there is also trade within those two sets of countries).



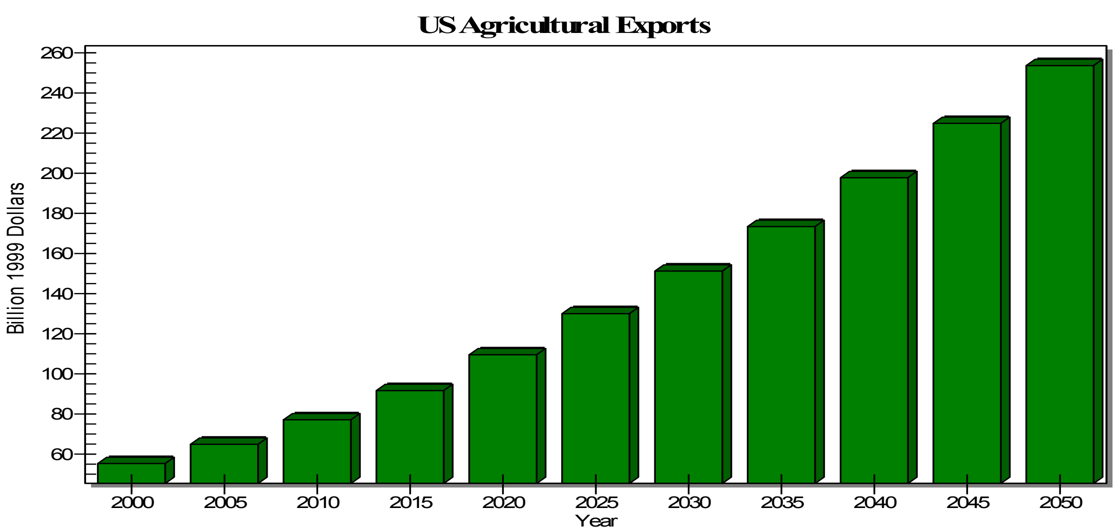
Turning specifically to China, the growth in food imports is substantial, especially after 2015, but not as dramatic even for total crops as the Worldwatch study suggested for

[40] The FAO (chapter on the “Prospects by Major Sector,” p. 7) also anticipates growth in exports from developing countries of food commodities in which production is growing especially rapidly (including sugar and vegetable oils).

cereals alone. And, obviously, the import of food by China has many drivers within IFs, not least of which is the increasing wealth and foreign exchange of the country as a result of exports of manufactures. That is, imports are not necessarily driven only by domestic production constraints.



In value terms, IFPRI foresees net cereal exports from the U.S. rising only from $10.1 billion to $13.3 billion between 1997 and 2020, with Chinese imports growing from $1.9 billion to $4.9 billion (IFPRI 2001b: 66). The graph of US exports below is gross value of all food, including meat, so is not comparable to the IFPRI forecast.



In addition to steadily increased calorie availability, one of the strongest arguments that food has become more plentiful over time almost everywhere in the world is the long-term relative decrease in world food prices. Julian Simon made this argument repeatedly and forecast that prices would continue to decline relative to the prices of other goods. In contrast, Worldwatch has frequently argued that declines in food inventories and constraints on production would lead to higher prices.

The IFPRI model (IMPACT) produces price forecasts. Through 2020 they see alternative scenarios for wheat prices that vary from decreases of 29% to increases of about 26%. Similarly, their scenarios for rice, other grain, and meat prices include both rises and falls, although the meat prices are less variable across them (IFPRI 2001b: 104-105).

In their 2003 study out to 2050 they produced a wide range of food prices across three different scenarios. In the case of "progressive policy action" they forecast maize prices to fall from about $105 per ton in 1997 to about $100 in 2030 below $90 in 2050. But in the case of "Technology and Resource Management Failure," the prices would rise to nearly $170 a ton in 2030 and fall little by 2050 (von Braun 2003: 2). Similarly, beef prices could rise or fall about 10% or rise about 20% through 2030, depending on the scenario.

The graph below shows food prices in IFs through 2050. The forecast shows a very, very small increase in prices over the next two decades and a very small decrease thereafter. The decrease accelerates a little towards mid-century as the impact of an increasingly stable world population, increasingly well fed with calories, brings growth in aggregate food demand to low levels. The primary conclusion from the graph, however, has to be that the base case shows little change in food prices over a long period of time.

6. Environment

6.1 Forecasters

The United Nations Environmental Programme (UNEP 2002) produces the *Global Environment Outlook,* the single most comprehensive set of environmental forecasts with a global scope. Responding to mandates growing from Agenda 21, the report first appeared in 1997 and GEO-3 appeared in 2002.

More specialized environmental forecasting exercises exist at the country or regional level and for specific environmental issue areas at the global level. Among the most significant of those with a global scope are:

- The work of the Intergovernmental Panel on Climate Change (IPCC), sponsored by the World Meteorological Organization (WMO) and UNEP. Established in 1988, the IPCC (2001) released *Climate Change 2001* as its third large-scale assessment report. Like the GEO project, IPCC relies on an extensive global network of scientists for report compilation.

- Publications of the World Water Council. These include *Making Water Everybody's Business* (the Vision Report 2000) and *A Water Secure World: Vision for Water, Life and the Environment* (Commission Report 2000).

There has been considerable additional forecasting associated with multi-component, largely environmental models, many of which have supported the IPCC efforts. Among the best known are scenario analyses using (1) IMAGE (Integrated Model to Assess the Greenhouse Effect), see, for example, Alcamo, Leemans, and Kreileman (1998) or (2) TARGETS (Tool to Assess Regional and Global Environment and health Targets for Sustainability), see Rotmans and de Vries (1997). See Janssen (1998) for a good review of such integrated assessment models. These systems tend to be used as scenario analysis tools rather than for the development of specific forecasts.

6.2 Key Concepts/Variables

Environmental forecasts can focus either on inputs to other systems (such as water, timber, or fossil fuels) or on outputs from other systems (such as carbon emissions). In the first case, the concern is usually depletion of a nonrenewable resource or overuse of a renewable one. In the second case the concern is usually growing accumulations of the output in air, water, or land systems. In either case, the environmental forecasts tend to be driven heavily by the other systems, especially agricultural and energy systems, but more fully also by demographic and economic systems.

6.3 Key Inputs

The World Water Council (Vision Report) begins forecasting analysis by noting that, given population growth, the average annual renewable water resources available per human will fall from 6,600 cubic metres to 4,800 cubic meters between 2000 and 2025. A common indicator of water stress is availability of less than 1,700 cubic meters, with severe stress at 1,000, and they forecast that 3 billion people will live in countries subject to stress. Forecasts come from the WaterGAP model.

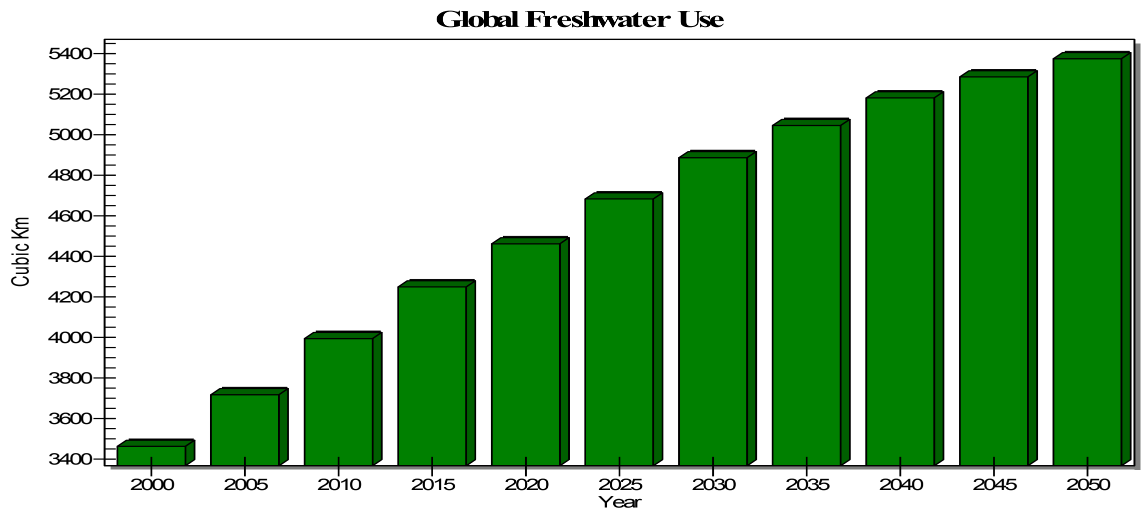
The Council provides two alternative, generally extrapolative, and unattractive scenarios for global water futures (expanding irrigation and stable irrigation) as well as their own vision scenario. That the two base scenarios both center on irrigation is due to the fact that agriculture, especially irrigated food production, accounted for withdrawals of 2,500 cubic kilometers of water in 1995 of a global total of 3,800 cubic kilometers. Industry and municipalities took another 750 and 350 cubic kilometers, respectively.

Both of the two irrigation scenarios look to the FAO and IFPRI for underlying analysis (see the earlier chapter on agricultural/food forecasting). **Expanding Irrigation** increases irrigated area by 30% between 1995 and 2025 and results in total withdrawals of 5,200 cubic kilometers, of which 3,200 is for agriculture, 1,200 for industry, and 600 for municipalities. **Stable Irrigation** holds increased area to 5-10% and still results in withdrawal growth to 4,300 cubic kilometers in 2025, of which 2,300 are used in agriculture.

The stable scenario is, however, costly in terms of food availability. Hence the Council provides a **Vision Scenario** that uses water considerably more productively (a more normative or "road map" and less extrapolative or exploratory scenario). That scenario still increases food production by 40% between 1995 and 2025, but holds net increase in irrigated area to 5-10% and water withdrawals to 4,200 cubic kilometers, of which 2,650 is for agriculture, 800 for industry, and 500 for municipalities, and none of which comes from groundwater.

The IFs base case forecasts water use globally that begins a bit lower than the World Water Council numbers, just short of 3500 cubic kilometres (using data from the WRI Earth Trends). The growth pattern falls generally between the two exploratory scenarios of the Council, and above its more normative one.[41]

[41] The formulation for water forecasting in IFs is directly tied to agricultural production and is a very simple one. It is included in IFs for illustration, not because of its analytic power. The variable is WATUSE.



Beyond water and energy, forecasts of other inputs are more difficult to find, in part because those two inputs are so critical, and in part because of high levels of uncertainty among those who study others. For example, with respect to forests, the FAO produces a volume on *The State of the World's Forests* every two years (2003). Their 2001 study estimated that global rates of loss in the 1990s were 0.22% per year, the difference between gross loss of 0.38% and reversions to forest (2003: Part 1: page 2). Rates of loss in Africa were 0.8%. Probably building on FAO analysis, the GEO-3 report estimates that deforestation in tropical forests was about 1% annually (GEO3 Synthesis: 2) and that 21.4% of world land remained in forests at the turn of century.

The FAO thus has a basis for forecasting in its regular analyses, at least via simple extrapolation. For instance, it concluded in the 2003 report that the rate of net deforestation had declined to 9 million hectares annually, about 20% lower than the rate reported in 1995.[42] Forest area in Europe and North America is increasing. The FAO sees the future of net deforestation directly linked to the expansion or contraction of agricultural land, with the former now occurring in more locations than the latter. Although the FAO presumably has made longer term forecasts of forest loss, they must be somewhat rare because this research has not identified them

We can turn again, however, to work of the IPCC, which draws upon FAO data, and which says about its scenarios:

> In most scenarios, global forest area continues to decrease for some decades, primarily because of increasing population and income growth. This current trend is eventually reversed in most scenarios with the greatest eventual increase in forest area by 2100 in the B1 and B2 scenario families, as compared to 1990. (*IPCC Special Emissions Report: Emissions Scenarios Summary For Policy Makers*, p. 6)

[42] Reported at http://www.afrol.com/Categories/Environment/env055_fao_deforestation.htm; January 29, 2004).

Somewhat surprisingly, in most of the IPCC marker scenarios, net global deforestation ends and net reforestation beings before 2040. In the B1 IMAGE scenario, forest area begins at 4,277 million hectares in 1990, declines to 4,179 million hectares in 2010, begins climbing by 2020 and ends the century at 5,543 million hectares.[43]

As noted earlier, the IFs land-use submodel is not at all sophisticated. Yet it produces roughly the same rate of global deforestation that the FAO finds early in the 21st century, with a definite slowing of loss beginning before 2020.

Table Display

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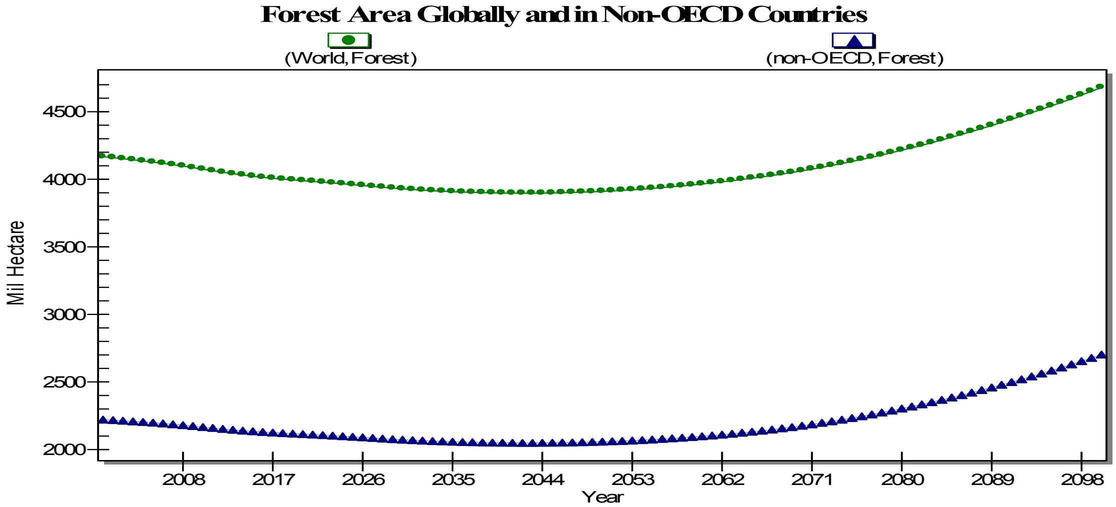
	LD[0]
	World
	Forest
Year	Mil Hectare
2000	4,165.9980
2001	4,159.8910
2002	4,151.7340
2003	4,143.3890
2004	4,135.3350
2005	4,126.7490
2006	4,117.7020
2007	4,107.8300
2008	4,097.1920
2009	4,085.9710
2010	4,074.4340
2011	4,062.8700
2012	4,051.5970
2013	4,040.9510
2014	4,031.1670
2015	4,022.3120
2016	4,014.3990
2017	4,007.3140
2018	4,000.8760
2019	3,994.9110
2020	3,989.2330

In the longer-term, the base case and other forecasts with IFs suggest that global deforestation may begin to be reversed by 2040, with substantial global reversal by the end of the century, ending somewhat in the middle of the IPCC forecasts. It is possible that the century could end with as much forest, or more, than that with which it began. Such forecasts are, of course, as the FAO argues, intimately tied to those of land use in agriculture. As crude as they may be within IFs, they are least provide a foundation for a base-case analysis of the contribution of forests to the carbon cycle, an issue to be taken up below.

[43] The land use forecasts for all scenarios are at http://sres.ciesin.org/final_data.html; February 12, 2004.



Before turning to environmental outputs, especially carbon dioxide, it is useful to comment on species loss, like land not strictly an issue of input or output, but an environment impact area as a result of both exploitation and collateral damage. Because only a small share of total estimated species have been identified, species loss estimates tend to focus on larger and more visible ones such as mammals, birds, and fish. We will not review the estimates of numbers at risk in this century because IFs does not forecast species numbers.

IFs does, however, use exogenously specified assumptions about the availability of wild global marine catch and has turned to some of the literature for the grounding of those assumptions. Estimates of the number of fisheries that are being exploited unsustainably are fairly common, with global marine catch estimated to have stabilized in the 1990s at around 90 million tons. Forecasts cannot easily be found. In IFs, the exogenous future specification for marine fish catch is set at 90 million metric tons annually throughout runs of the base case. Such a base case forecast/assumption is quite possibly too high, however, given that most analyses of present patterns suggest that humans are using stocks at unsustainable levels. In contrast, however, the forecast/assumption for global aquaculture, which is also exogenous in IFs, is set at a constant 65 million metric tons. Because that has been growing rapidly, the forecast must be too low and it, together with wild marine catch, may be reasonable. Again with wild fish catch and aquaculture, forecasts from other sources are difficult to attain.

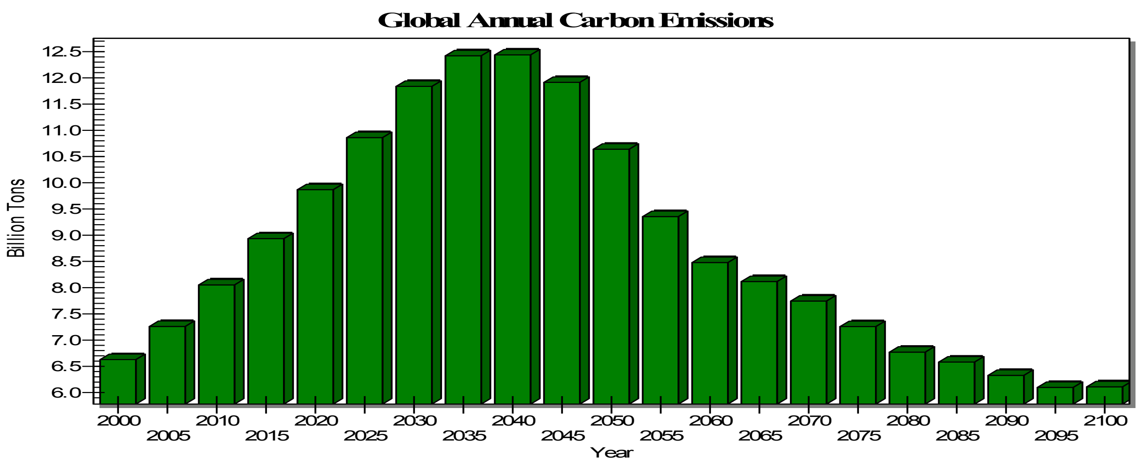
6.4 Key Outputs and Their Impacts

The IPCC (Special Report, *Emissions Scenarios: Summary for Policymakers*) provides forecasts in 2020, 2050, and 2100 of carbon dioxide emissions, as well as those of sulfur dioxide, methane and other greenhouse gases. Each forecast is given for multiple scenarios in four families (A1, A2, A3, and A4), with demographic and economic underpinnings that range widely across the families.

With respect to sulfur dioxide, global emissions in 1990 were 70.9 million tons. In 2050 forecasts range from 40 to 105 million tons, and in 2100 they range from 20 to 60. Methane emissions in 1990 were 310 million tons and in 2100 forecasts range from 236 to 889. IFs forecasts neither of these.

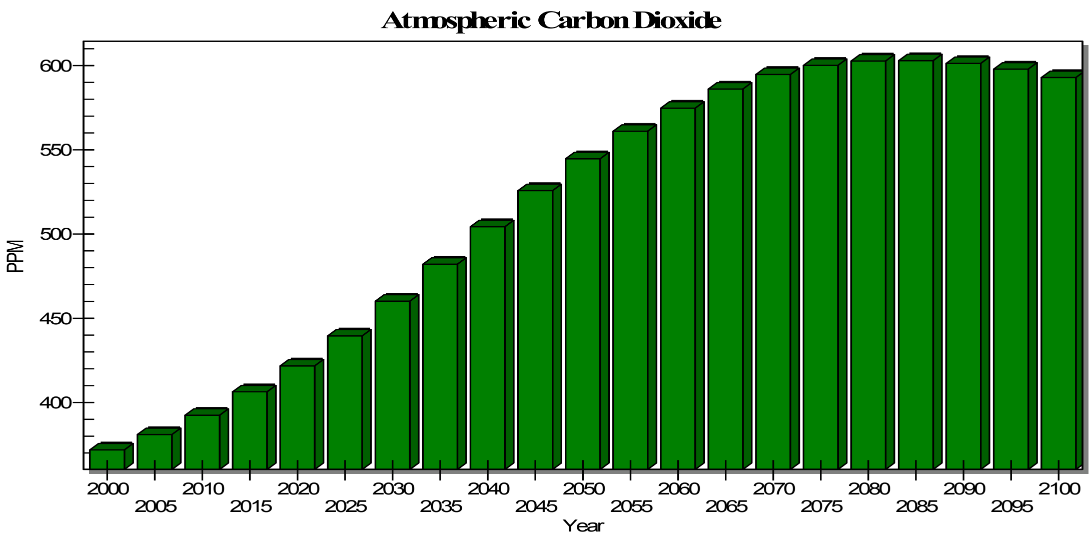
Carbon emissions are, of course, the big greenhouse gas. In 1990 those emissions were 6 gigatons (billion tons) of carbon per year. The IPCC forecasts in 2020 range from 9 to 12.1 gigatons and those for 2050 range from 11.2 to 23.1 gigatons. By 2100 the forecast range is huge because especially of the uncertainties around future energy systems; in the IPCC scenarios they run from 4.3 to 30.3 gigatons. Cumulative carbon dioxide emissions over the 1990-2100 period range from 983 to 2189 gigatons.

The IFs base case is shown below. It tends to track the middle of the IPCC forecasts through 2020, but then begin to fall back towards the lower end of IPCC ranges. Key reasons for this have already been discussed in the energy chapter of this report and consist of a combination of increasing constraints on availability of some fossil fuels (although not as a result of particularly conservative estimates within IFs of resource bases) and the increasing attractiveness of renewables. Note that the right-hand tail on the curve is rather extended. The base case is certainly not assuming exhaustion of fossil fuels, particularly not for either coal or various non-traditional oil and gas sources.

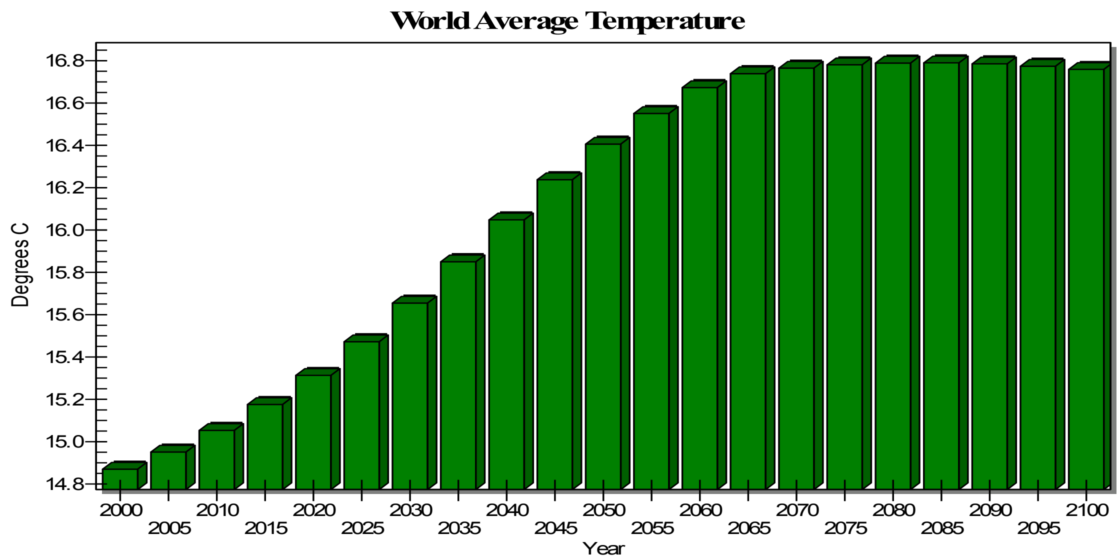


The IPPC Climate Change *Synthesis Report: Summary for Policymakers* draws some of the consequences of carbon emissions from the supporting models of the IPCC. Whereas the atmospheric concentration of carbon dioxide in the pre-industrial era was 280 parts per million (ppm), growing to 368 ppm in 2000, the forecasts for the year 2100 range from 540 to 970 ppm (p. 8).

Given carbon emissions above, it is not surprising that the IFs base case produces a pattern of growth in atmospheric carbon that is again near the middle of the IPCC scenarios early on, but very much towards the low end of the IPCC scenario set in the long term. In fact, the forecast begins to exhibit a small decline before the end of the century. In addition to the importance of declining fossil fuel use in explaining this, a major part of the explanation lies in the reversal of deforestation, as discussed earlier in the chapter. Instead of changes in forest patterns being net contributors to the atmosphere of 1-2 gigatons of carbon annually, they become new removers of a somewhat larger amount by the end of the century. To the degree that forest patterns are important in the graph below, however, the atmospheric carbon pattern in the IFs base case is somewhat questionable on two grounds. First, as noted earlier, future forest patterns are highly uncertain. Second, it is likely that reforestation near the end of the century will still emphasize temperate rather than tropical forests. IFs does not distinguish between the two in its computation of net carbon release or absorption, and presumably reforestation of temperate forests cannot fully offset deforestation of equal amounts of tropical forests with respect to net carbon flows. Thus the curve below is very likely somewhat too low, even if the underlying fossil fuel use and reforestation assumptions were correct. By way of contrast, it is important to note that, even in the lowest IPCC emissions scenarios, which bring carbon emissions down to 4.3 gigatons in 2100, the growth in atmospheric concentrations only begins to level by 2100, not to decline.



The IPCC Third Assessment forecasts for increase in globally-averaged surface temperatures range from 1.4 to 5.8 degrees centigrade from 1990 to 2100. Sea level increases range from 0.09 to .88 meters between 1990 and 2100 (p. 9), but run much higher as the models work out new equilibria for global temperatures over centuries and sea levels over several millennia. IFs has a representation of temperature increase that is too simplistic to include the lag effects that the IPCC documents. Thus temperatures in the figure below level out too soon. And IFs includes no representation of sea levels.



6.5 The Big Debates

As indicated above, the key drivers of assumptions about carbon build up are land use and fossil fuel use (emissions from fossil fuel use are usually packaged with emissions from cement production in most forecasts and discussions). Fossil fuel use in the long term is heavily linked to ultimate resource base, but obviously also influenced by the price of alternative energy forms. As was discussed in the energy chapter, the IFs base case begins with an assumption of about 2.5 trillion barrels of oil remaining in 2000, with a bit less natural gas, and 10 times as much coal. Given forecasts of their use, it is fairly easy for any model to calculate the carbon released by the use of these energy forms over time. The spread of energy forecasts discussed earlier is fairly well understood.

The discussion above suggests, however, that perhaps even more complicated with respect to forecasting of atmospheric carbon levels is land use. IFs has looked to the representations of carbon cycles portrayed by the Woods Hole Research Center and by John Grace.[44] Such representations show global net primary production and respiration from vegetation as a current sink for 1.4 (Woods Hole and Schimel) or 2-3 (Grace) gigatons per year, on top of the ocean sink, estimated at about 2 gigatons annually by both Woods Hole/Schimel and Grace). Deforestation and other changes of land use are estimated as net sources by Woods Hole/Schimel of 1.1 gigatons and 1-1.5 by Grace. Although there is thus important variation in these representations, it may be less important than the variations in the deforestation/reforestation scenarios. Those look to be quite important.

[44] Woods Hole, like many others, references Schimel, et al 1995, "CO2 and the Carbon Cycle," in *Climate Change* (1994) Cambridge UK: Cambridge University Press. See the Woods Hole Research Center web site at www.whrc.org/science/carbon/content.htm. In a teaching presentation in Power Point called World Forests and Global Change, John Grace presents a very similar portrayal of the global carbon cycle at http://www.ierm.ed.ac.uk/ierm/teaching/slides.pdf.

For the above reasons and many more, forecasts concerning environmental change are recognized to be subject to a wide range of uncertainty. Most forecasting groups therefore rely heavily upon scenarios to present some of the alternatives. The IPCC has even been criticized for providing such a wide range of quantitative forecasts. The GEO project has relied heavily on four scenarios in GEO3: Markets First, Policy First, Security First, and Sustainability First. Even then, it has looked out only from 2002 to 2032 and presented a relatively small selection of quantitative forecasts, preferring to sketch the broad qualitative scenarios and use only selective quantitative support (around water, carbon dioxide, global temperature change, percent of land built up by human activities, soil degradation, and a few other of the usual suspects).

There has been a tendency for some organizations to present primarily more negative scenarios, in part as a conscious spur to policy action. Worldwatch Institute certainly has done this over many years. Whether or not such scenarios have been unduly pessimistic and alarmist, they have elicited a reaction from those who reject the scenarios and/or the policy prescriptions. Julian Simon (*The Ultimate Resource*, Princeton: Princeton University Press, 1981) is a good early example. Bjørn Lomborg, *The Skeptical Environmentalist: Measuring the Real State of the World*, Cambridge: Cambridge University Press 2001) follows in the tradition, opening his book with a quote from Simon, and, in direct contrast to Worldwatch, emphasizing the more optimistic scenarios of the IPCC and largely dismissing the more pessimistic ones.

On the input side of the equation, Simon and others have noted that prices of key inputs, including energy, have fallen in the long run relative to other prices and especially relative to income levels. Simon boldly forecast a continuation of such declines with respect to nearly all raw materials, thereby arguing that human ingenuity and technological advance will essentially make even non-renewable energy sources more plentiful relative to demand. To date he has been mostly right.

On the output side, Simon pointed to increasing life expectancy as a key measure of things improving in the aggregate. Simon, Lomborg and others point frequently to progress in air and water quality in many parts of the world, often in the face of citable forecasts to the contrary, as evidence that when a problem is identified, humans can and will act to fix it.

Probably the greatest and most important focal points of such optimist/pessimist debates is the build up of carbon dioxide and the global warming from greenhouse effect. It is hard to argue with at least near-term continuation of increased atmospheric levels of greenhouse gases, and Lomborg and most other optimists do not. The arguments instead are normally that such build-ups are unlikely to persist (due to rapid change in energy systems), are not as historically unusual as the IPCC claims, and, most commonly, that the affects on temperature are really not known, are overestimated by the IPCC and others, or are not significant with respect to the resources for coping of a rich world. Lomborg primarily takes the very last approach, arguing that costs calculated at $5 trillion (estimates from William Nordhaus are most often used) are not significant relative to the economic growth benefit of $107 trillion from continued fossil fuel use (Lomborg

2001: 317-318). The Lomborg challenge generated a heated exchange in *Scientific American* on January 2, 2002.

Of important note, however, is the near absence of alternative forecasts by most of the critics. Also of importance are the large number of scientists and the seriousness of the work that have supported forecasting of the IPCC. Unless the critics do provide alternative and, in turn, reviewable forecasts, we must most often look to work by the IPCC and others as the best range of guesses we have about the future.

7. Socio-Political Systems

7.1 Forecasters

Almost all social scientists are potential forecasters, because they deal in theoretical structures that provide bases for making clear if-then statements. Somewhat surprisingly, however, relatively few social scientists build on that potential. Moreover, when they do use their foundational theories to weave pictures of the future, and with rather narrowly-focused exceptions like forecasters of election outcomes, those portraits are likely to be general statements of social patterns and interactions, largely free of dates and details. For instance, Marx and Engels provided a clear forecast of the transformation of capitalism into socialism, but did not presume to provide a temporal map, in part because they were helping to create one. In the contemporary era, Manuel Castells writes in the same sweeping sociological fashion, but he closes his impressive trilogy with a short chapter on "Making Sense of Our World" that gives us remarkably little to hang our hat on with respect to the next 20-30 years.

It is presumably the complexity of human socio-political structures and processes that primarily explains this phenomenon. Moreover, as with environmental forecasting, it is impossible to lay out broader socio-political forecasts without also laying out a portrait of the driving forces in technological change, demographic developments, economic growth patterns, and, in fact, also the human-environment linkage.

Thus it may not be surprising, again in parallel to environmental forecasting, that most socio-political forecasting with some degree of richness has been done by groups and that, in light of large numbers of uncertainties, those groups have used multiple scenarios to paint possible futures. Examples include the Global Scenario Group, the Hart-Rudman Commission and the National Intelligence Council.

Although it is important to examine such integrated forecasts, and the next chapter turns to integrated scenarios, it is also useful to attempt somewhat sharper focus on the socio-political elements of global futures – again in comparison with the base case of IFs. An approach to doing so is to attempt identification of some of the key components of socio-political systems and to look at the literature on those components, especially those pieces that provide some basis for thinking about future developments.

7.2 Key Concepts/Variables

The socio-political system that we want to forecast has at least the following four key elements:

1. Human values, beliefs, and behavioural orientations. Broadly speaking, these are cultural foundations that change slowly, but that do change, especially in interaction with other cultures.

2. The life conditions of individuals. Literacy rates and life expectancy illustrate such conditions and are among the most important.

3. Social and political structures, both informal and formal. The informal side includes the extent and character of elements ranging from family structure to civil society, while the formal side includes the governance structures and character, including the level of democratization.

4. Social and political processes, both domestic and international. The extent and character of conflict and cooperation are central here.

The above elements of the social fabric are highly interactive.[45] They may be difficult to define and measure, and the theories with respect to their dynamics and interactions may be highly contentious, but they provide some basis for thinking about socio-political futures.

7.3 Values and Culture

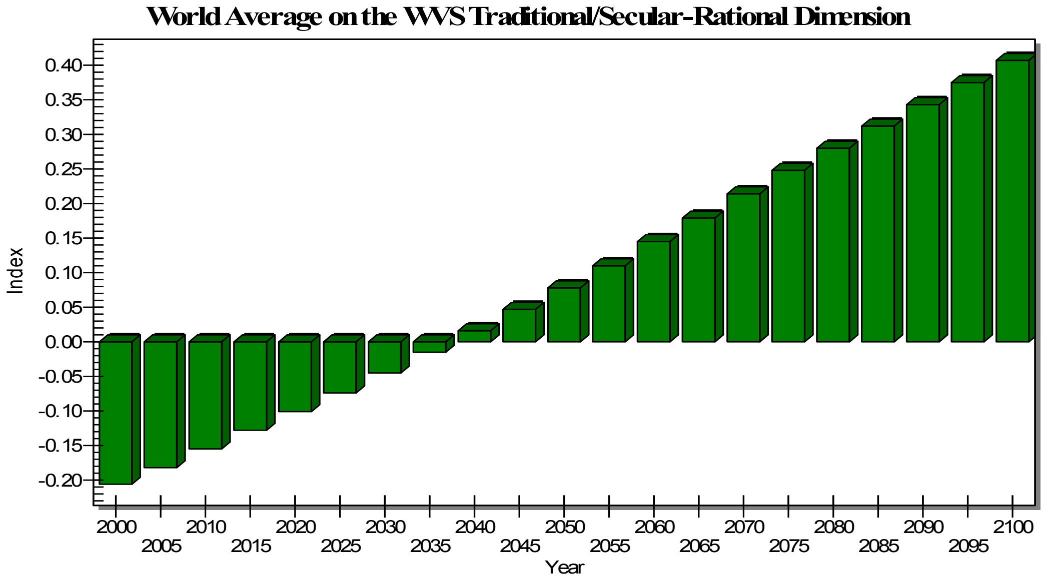
Ronald Inglehart and the World Value Survey (WVS) have provided a very useful typology with which to think about values and culture (Inglehart 1997). Undertaking and then analyzing surveys from four waves and across more than 60 societies, that project has identified two unrelated (orthogonal) dimensions of values that seem to organize a large portion of human values around socio-political phenomena. The first is traditionalism/secular-rationalism and the second is survival/self-expression. Humans seem to move across these values structures with economic and broader development, moving first to modernism and then to a post-modern value structure. There has been little explicit forecasting in the WVS project (although some involving IFs). Yet the implications of the analysis are clear: if societies continue to develop economically, on the average their value structures will become more secular-rational and more oriented towards self-expression. At the same time, however, the WVS project recognizes that changes in values are strongly path-dependent, with starting points rooted in cultural traditions and history.

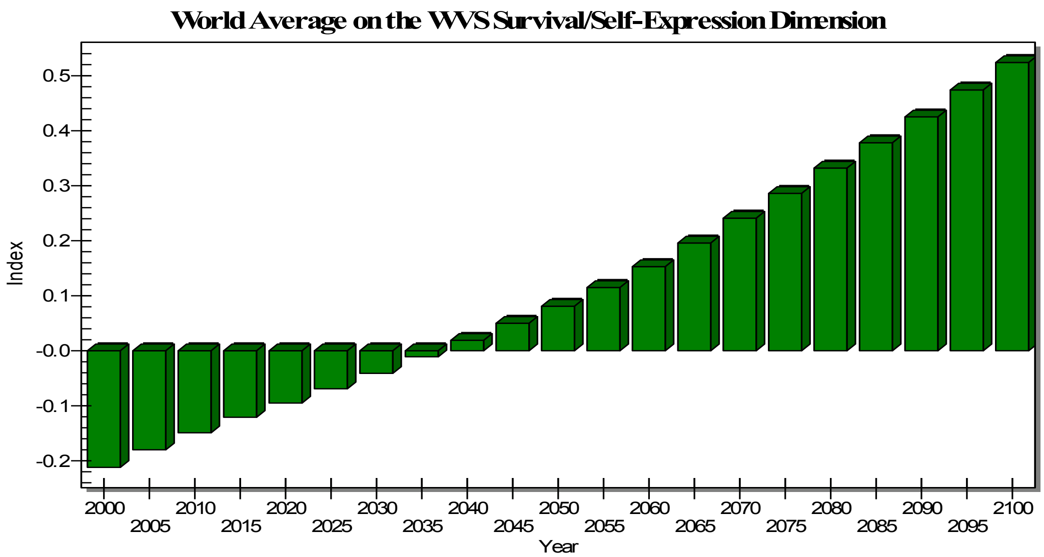
Also with respect to forecasts, there are important forward-linkages from value change. For instance, secular-rational orientations correlate with and seem to precede lower fertility, while self-expression seems similarly to support movement towards democracy.

The graphs below show the IFs base case forecasts for global movement on the two scales. Each scale runs from -2 to 2, and the forecasts both suggest more than a half point (or half a standard deviation) of movement globally on each over the course of the

[45] The late Robert Pestel was the first to introduce me to the intriguing concept of "social fabric" and I have been trying ever since to figure out how to conceptualize and operationalize that.

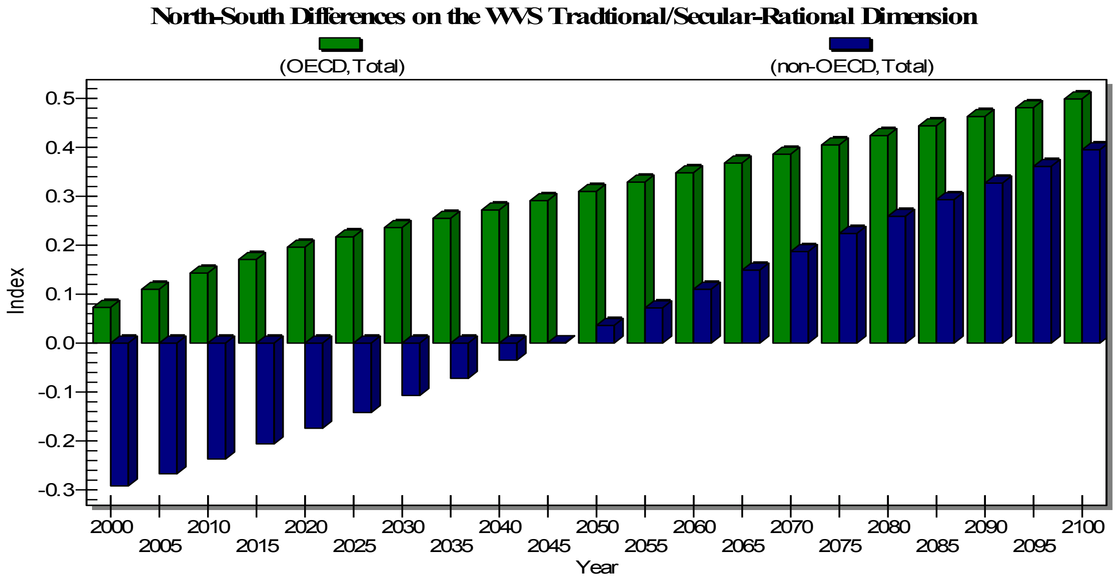
century, with a bit greater change on Survival/Self-Expression dimension.[46] Again, this recognizes the slowness of cultural and value change under most conditions.



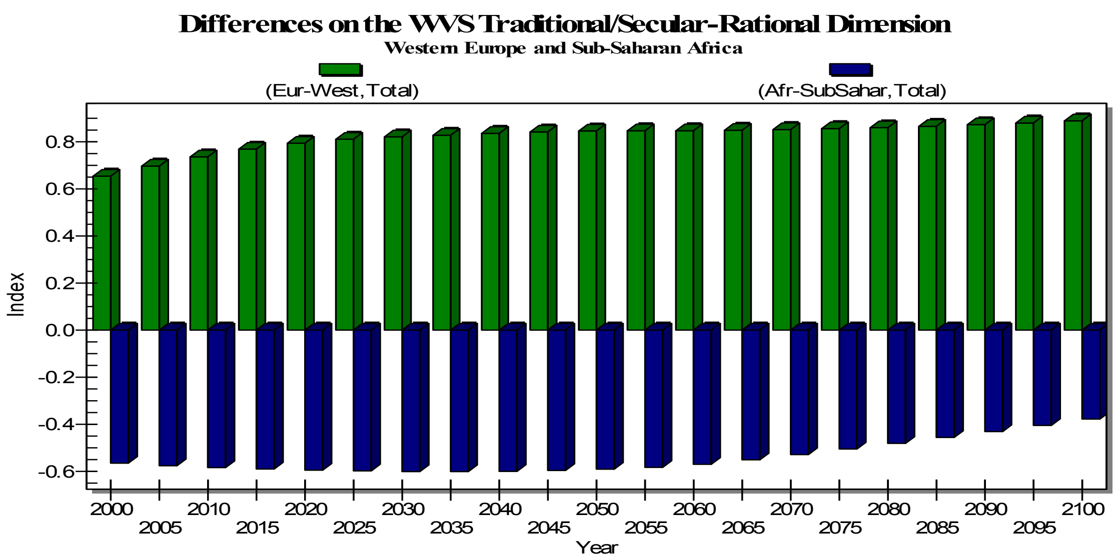


Although there is no alternative forecast with which to compare it, it is also interesting to look below at the differences that currently characterize the OECD countries versus the non-OECD countries and hold they might change over time.

[46] Because the index values are factor scores, it is likely that a country-weighted initial calculation would be closer to zero than the -0.2 shown. IFs uses a population-weighted average across countries of the world and adds estimates for non-surveyed countries, most of which are less developed.



And, of course, some regions are much further apart than others with respect to value orientations. With respect to the Traditional/Secular-Rational dimension, the gap between Western Europe and Sub-Saharan Africa is among the greatest, even larger than that between Western Europe and North Africa/Middle East.

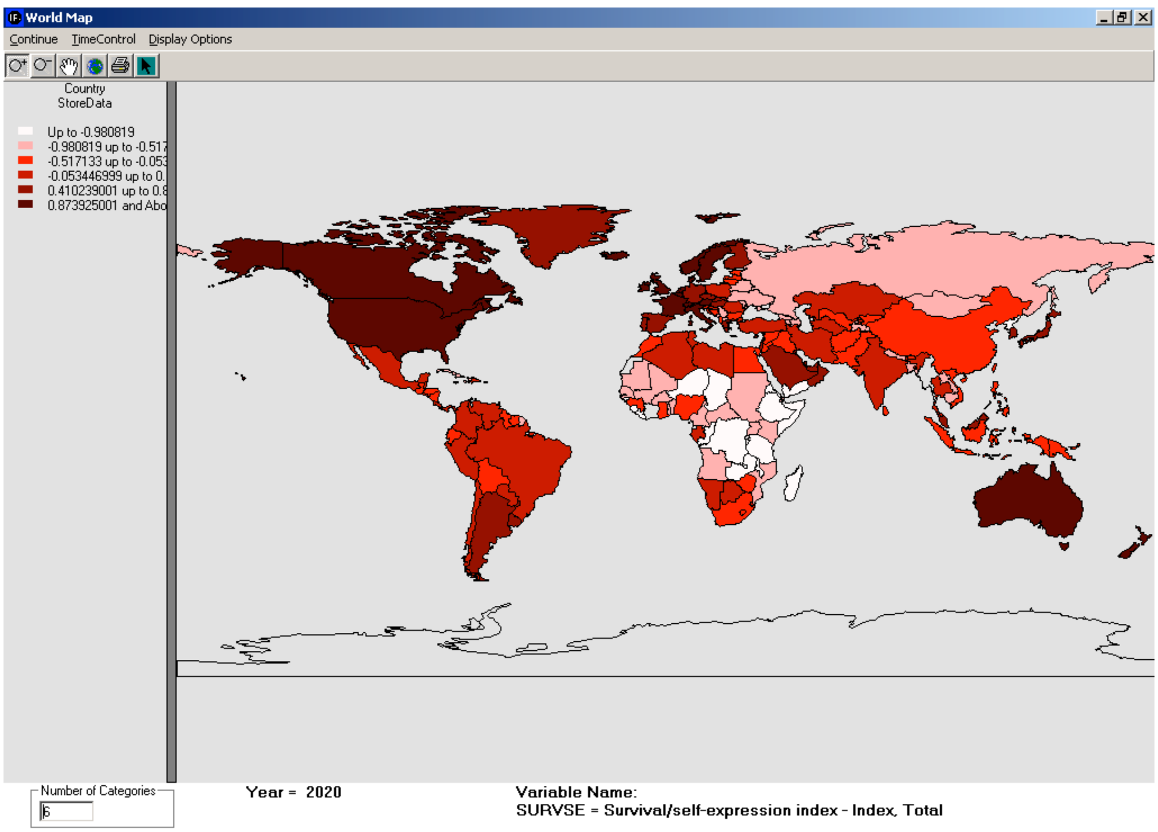


There is also a literature on the "Clash of Civilizations" that has looked at cultural orientations across societies and argued that such belief systems have now become and will for some time remain the major basis for global cleavages (Huntington 1993). The WVS has, in fact, verified the existence of groupings of societies that correspond generally to the groupings that Huntington and others have identified. Huntington's view of civilizational interaction differs in one important way, however, from the portrait of the WVS. He sees the possibility of coaliltion-like groupings of civilizations (for instance, "the West versus the Rest" and "the Confucian-Islamic Connection") that have more to do with an overlay of power balancing than with the dimensions of values that the WVS sees differentiating and gradually transforming the rough country groupings.

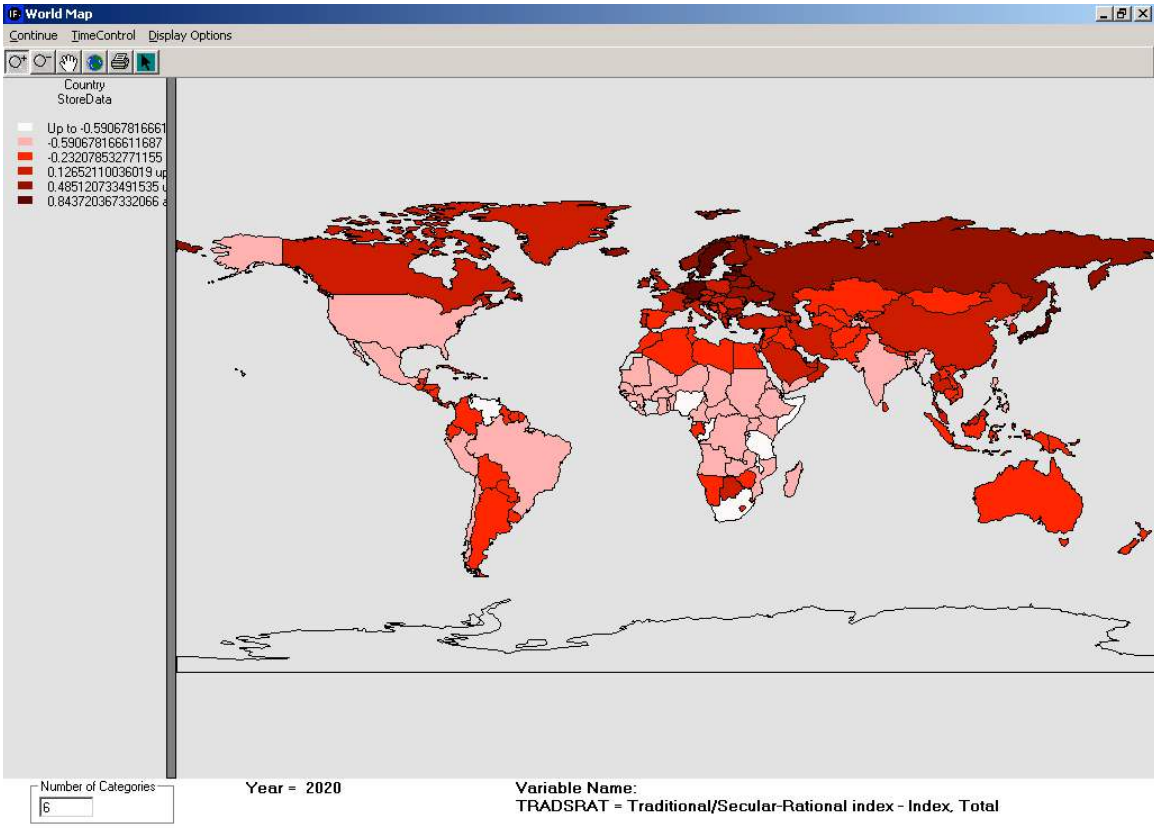
Again, however, the civilization-based literature is short on forecasting relative to elaboration of possibilities, lacking even a general statement as to whether such value differences are likely to become more or less pronounced over the coming decades (IFs suggests that they will become less pronounced over the long run).[47]

The two maps below show base case forecasts for 2020 from IFs with respect to the two WVS dimensions, in order to hint at the kind of regional groupings that could constitute the civilizational regions of Huntington.

With respect to survival/self-expression, there is an obviously strong relationship with likely levels of economic well-being. With respect to traditionalism/secular-rationalism, however, the role of historic cultural and religious traditions begins to be even more obvious.

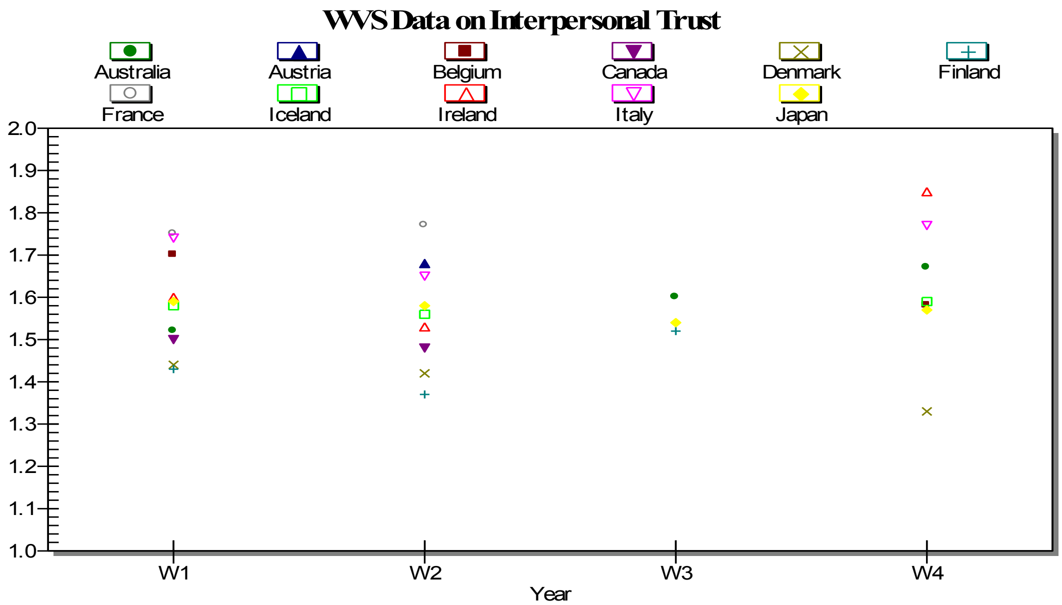


[47] IFs is still using only a subset of the data from the fourth wave of the WVS. And discussions have begun with members of the WVS project around enhancements in the forecasting capability of IFs with respect to global values. Ron Inglehart has suggested some general direction for enhancement of the forecasting formulation. One productive avenue for exploration will be the relationship between openness to globalization of societies and the rate of value change within them.



There is also remarkably little widely-accepted empirical analysis upon which to base forecasting, either within the WVS project or elsewhere, about the important dynamics of value structures across subpopulations within societies. For instance, the prospects of intensified cultural conflict or "culture wars" within societies as rapid development reshapes them is a fairly common theme or hypothesis (e.g. Hunter 1991). Arnold Toynbee suggested that such dynamics were critical to the possible toppling of civilizations and their related cultures: when ruling minorities fail to deal creatively with external challenges (varying as widely as other civilizations or environmental degradation), a majority population can withdraw its support, leading to a loss of social unity and either large-scale re-orientations of cultures or the collapse of their civilizations.

Variables for forecasting of value differences and their consequences within states do not exist within IFs. Nonetheless, it might be interesting to explore parts of the IFs database that come from WVS with respect to such questions. Below is a figure across the four survey waves (early 1980s to early 2000s), showing the average level of trust within selected countries (an arbitrary, low-alphabet set of the OECD countries). The question provided two alternatives: most people can be trusted (coded 1) and you can't be too careful (coded 2). Putnam (1995) and Fukuyama (1999) have both argued that there has since the 1960s been a breakdown in social capital, measured especially for Fukuyama by such interpersonal trust. Unfortunately, the WVS data do not go back far enough to provide a baseline in the 1950s or 1960s before the posited disruption of social capital. The WVS data do not, however, show any significant average change across the OECD societies during this period (Fukuyama suggested an ongoing deterioration across much of it, with some possible rebuilding of social capital emerging near the end of it). Instead, what we see is the rather persistently low level of trust in Italy, consistent especially with studies by Banfield and Putnam of its South, an increase in trust over time within Denmark and a deterioration of trust in an economically-booming and immigrant-absorbing Ireland.

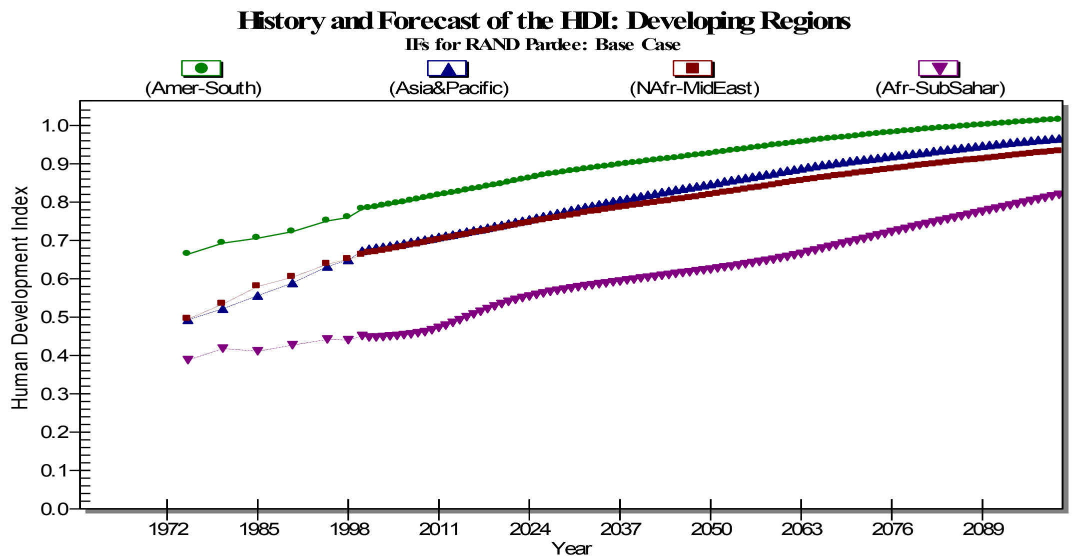


The discussion of social and political structures will return later to the intra-societal theme, but through the lens of state failure.

7.4 Life Conditions and Human Development

Change in life conditions and levels of human development have been measured with increasing carefulness and extensiveness in recent decades. Moreover, elements of life condition such as fertility rates, life expectancy, or literacy tend to change relatively smoothly over time, making forecasts of them based simply on trends rather easy compared to forecasts of values and beliefs.

In the IFs project we have even begun to attempt the forecasting of the key composite measure of life condition, the Human Development Index (HDI) of the United Nations Development Program (Hughes 2004). The figure below shows the historic values of the HDI for four developing regions, extended by the base case forecast of IFs.

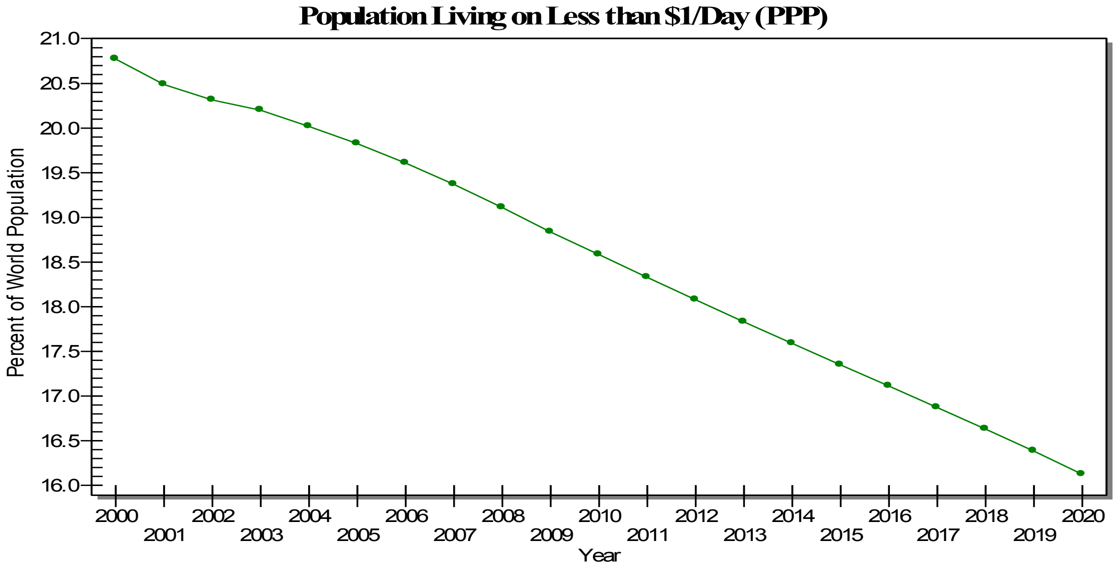


In addition, there has been a growing movement, exemplified by the Millennium Development Goals (MDG), to set goals for such indicators, most often with time horizons in the 2015-2020 range. The goals could, but should not themselves be considered forecasts. Many will not be met on schedule and a few may be met early. In 2000 the IMF, OECD, UN, and World Bank assessment of progress towards the goals (see IMF 2000, *A Better World for All*) suggested areas in which the world is already falling short of the MDGs, and the UN *Human Development Reports* (e.g. 2003) have continued such analysis.

The first Millennium Development Goal is to eradicate extreme poverty and hunger. The first target with respect to the goal is, between 1990 and 2015, to halve the proportion of people who receive income of less than $1 per day (at PPP). That would reduce the percentage from 30% to 15%. By 1999 a level of 23% had already been achieved, suggesting by extrapolation that the goal would be met globally before 2015, in spite of failures in regions such as Latin America, Sub-Saharan Africa, and the transition societies (UNDP 2003: 33). Like the UNDP, the World Bank (2004) is optimistic about meeting the poverty goal, estimating that the global percentage of those living on less than $1/day will have fallen from 28.3% in 1990 to 12.5% in 2015, driven heavily by falls from 31.5% to 3% in China and from 41.5% to 16.4% in South Asia (Chapter 1, Table 1.6, page 46). The assessment in *Global Economic Prospects 2004* was actually a little more optimistic than that in the 2003 volume.

The base case of IFs is less optimistic than the UNDP and the World Bank. In spite of the fact that the percentage in poverty in 2000 shown in IFs is slightly less than that of UNDP figures,[48] the goal is not quite attained by 2020, much less exceeded by 2015.

[48] Because IFs uses the UNDP data for those in poverty, it is surprising that the 2000 figure is not identical to that from the UNDP assessment.



In general, IFs suggests that progress towards the goal of poverty reduction will become steadily more difficult as the numbers decline. In particular, much of the contribution of China is already behind us, and even as rather rapid growth rates in South Asia begin to work some magic, the speed of poverty reduction associated with the economic growth patterns forecast in Chapter 3 is not enough to reach the goal.

The table below shows regional patterns as well as the global forecast.

Table Display

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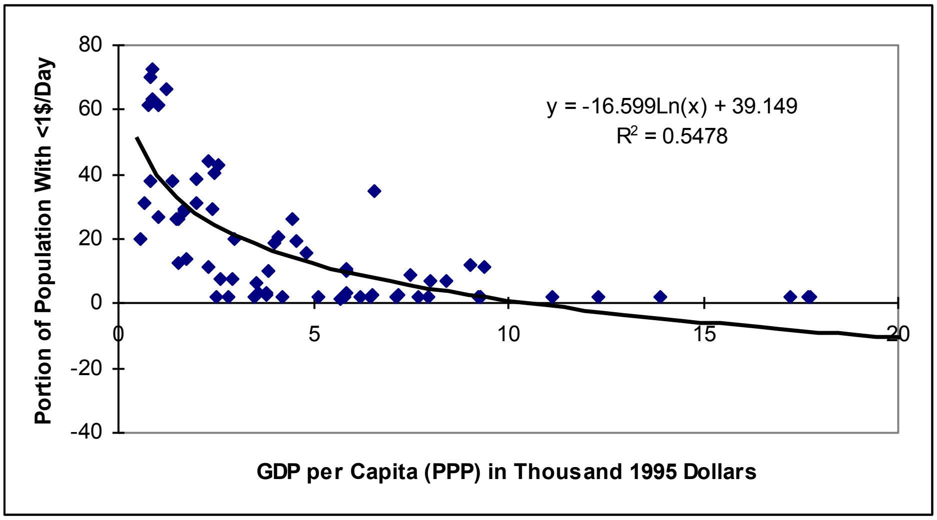
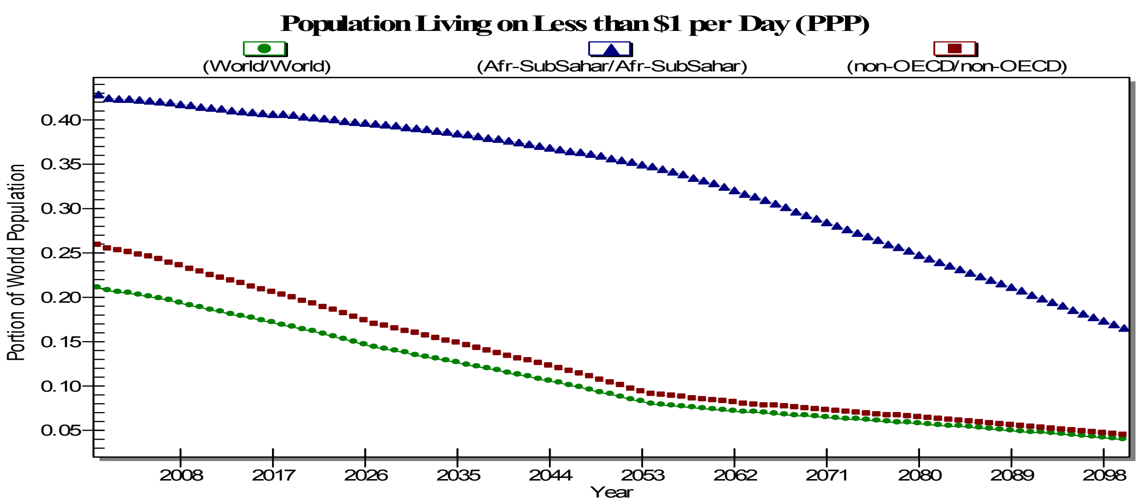
	INCOMELT1[0]/	INCOMELT1[0]/	INCOMELT1[0]/	INCOMELT1[0]/
	World/World	China/China	Asia-SoCent/As	Afr-SubSahar/A
Year	Mil People/Mil F	Mil People/Mil F	Mil People/Mil F	Mil People/Mil F
2000	.2077	.1850	.3785	.4265
2005	.1983	.1538	.3628	.4190
2010	.1858	.1176	.3400	.4123
2015	.1735	.0828	.3156	.4057
2020	.1612	.0502	.2890	.4014

Obviously, forecasts of the portion of humanity living on less than $1 per day are, like all forecasts, dependent on the formulations used, as well as on the demographic and economic drivers discussed earlier. Below is a scatterplot of countries for which there are data on which to build such a formulation. The logarithmic curve fit to that data suggests that as countries reach about $10,000 per capita at PPP, absolute poverty essentially disappears. This formulation is important in generating the forecasts of IFs. It should be noted, however, that an exponential curve can be fit to the same data with approximately the same R-squared, but which exhibits slower decline and has a much longer tail of non-zero poverty. When it is substituted within IFs, the forecasts for reduction are even less positive. Another factor, however, is that IFs adds a distributional term (based on Gini indices) to the average income term in the formulation. With rapid economic growth, distribution often weakens somewhat, as it has in China, further complicating the reduction of poverty.



Even with the more optimistic logarithmic formulation, it is important to understand that great poverty would by no means disappear as a problem with the meeting of the Millennium Goal, whether by 2015 or 2020. The figure below shows possible patterns across the century. Although Sub-Saharan Africa begins to make more progress further into the century, the world as a whole begins to show decreasing rates of progress against residual poverty pockets.



The second target associated with the first MDG is to reduce the *proportion* of people who suffer from hunger, again by half between 1990 and 2015. In analysis of the global food system and calorie availability, the FAO (2000) concluded that the earlier World Food Summit target of reducing the *numbers* of globally malnourished by 50% before

2015 will not be reached and may still not be accomplished in 2030. Instead, they forecast 610 million malnourished in 2015 and 443 million in 2030. Similarly, the UNDP (2003: 33) concluded that, without acceleration in progress, the goal of one-half reduction *proportionally* will not be met before 2020.[49]

The IFs base case may even be very slightly less optimistic than the FAO with respect to reducing the numbers of people malnourished – it is difficult to be definitive, because the FAO did not provide a specific forecast. However, the earlier chapter of this report on food provided less sanguine forecasts of calorie availability than the FAO, especially for Sub-Saharan Africa, and calories are the foundation of malnutrition forecasts. The table below shows the reduction by 50% in *numbers* of globally malnourished to be achieved by about 2040.

Table Display

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	Malnourished	MALNPOPP[0]
	World	World
	Millions	
Year		Percent
2000	868.0524	14.1859
2005	737.0221	11.3352
2010	720.3373	10.4735
2015	693.1114	9.5616
2020	662.5074	8.7119
2025	623.3300	7.8603
2030	568.3319	6.9137
2035	500.7402	5.9071
2040	425.0208	4.8826
2045	354.0145	3.9774
2050	303.7367	3.3536

Nonetheless, quite rapid progress is forecast towards the Millennium Development Goal of a 50% *proportional* reduction. Like the UNDP, IFs does not anticipate that the goal will be met by 2015, but the table above agrees that it may well be met by about 2020.

The IFs base case (below) further suggests the possibility of essentially eliminating malnutrition by the end of the century.

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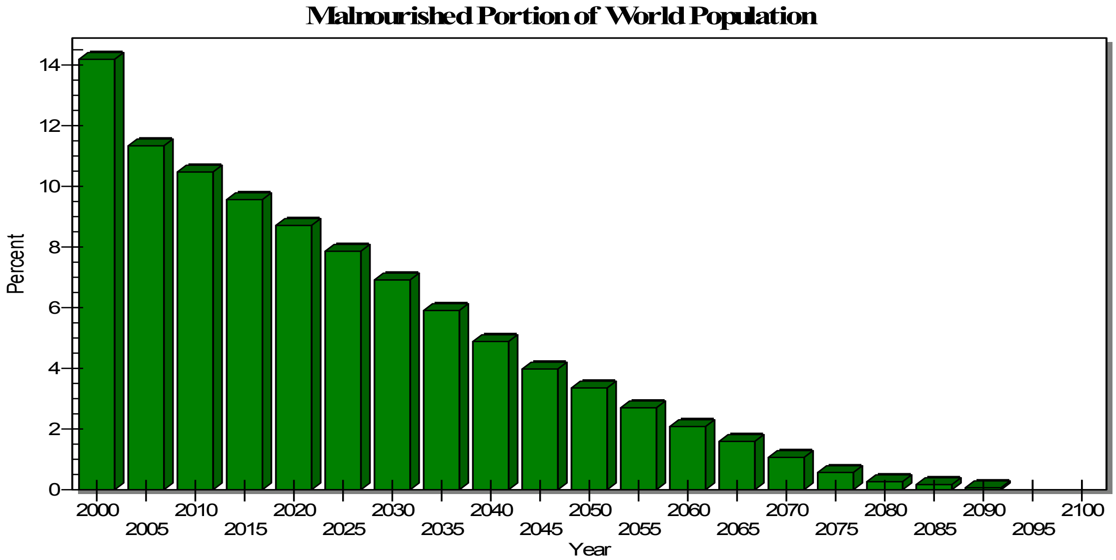
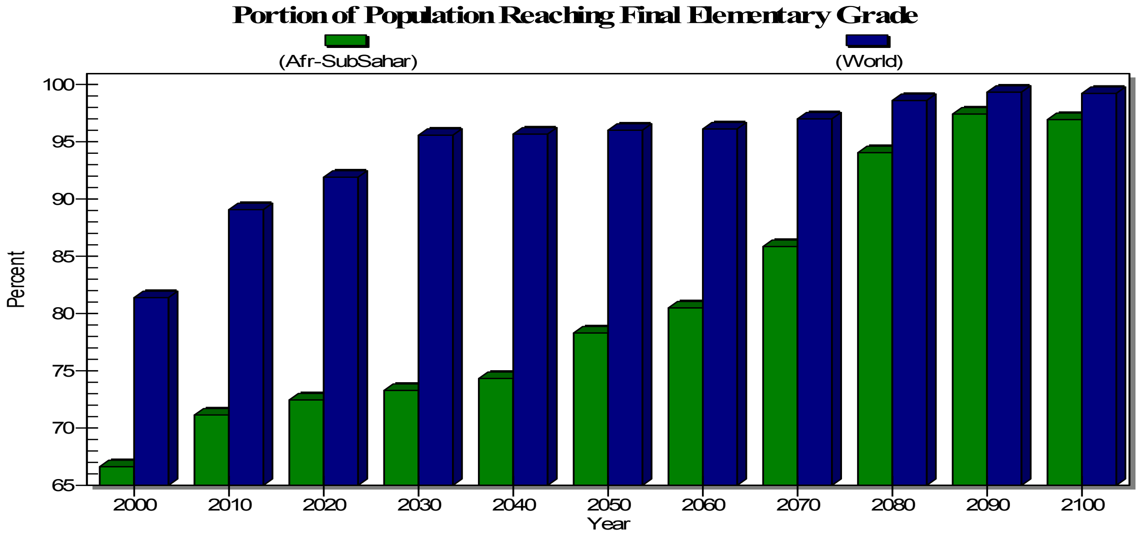
[49] The fact that 22 countries lack data about malnutrition (UNDP 2003: 35) and 100 have no trend data significantly complicates out ability to assess progress and to make forecasts. The variable within IFs is MALNPOPP.



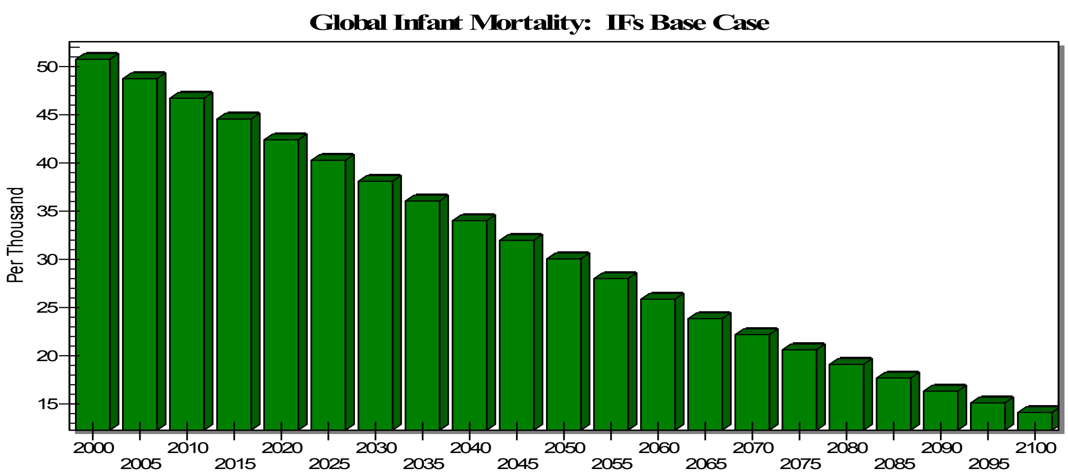
The second MDG is achievement of universal primary education. The third specific target is associated with that goal, and it calls for both boys and girls to meet the target by 2015. The UNDP (2003: 33) concludes that without intensification of effort this goal will not be met before 2050, with South-Asia, Arab States, and Sub-Saharan Africa being the most challenging regions.

Mohammod T. Irfan is developing an education module for IFs that, although it is still very much a work in progress, has begun to produce forecasts for primary, secondary, and tertiary education. At this point the forecasts for South Asia and the Arab States appear considerably too optimistic, with climbs of both to universal primary education by 2035 (South Asian levels approximated 65% at the beginning of the century). Nonetheless, early base case forecasts for Sub-Saharan Africa and the world as a whole, shown below, suggest that the UNDP is right in concluding that 2015 is considerably too optimistic for the goal of universality.[50]

[50] The IFs variable portrayed is EDPRISUR and represents the proportion of the school-aged population reaching the 5th grade.



The fourth MDG is to reduce child mortality, with the specific target being to reduce the under-five mortality rate by two-thirds between 1990 and 2015. The UNDP (2003: 33) again suggests that the world is NOT on track to meet this goal by 2015, but in the absence of quite substantial intervention is more likely to do so between 2020 and 2050. Although the demographic module of IFs tracks mortality by cohort and does internally compute the rate for children under 5, that variable is not now externally available for display. Most mortality under 5 is, however, infant mortality. The graph from the IFs base case below shows infant mortality and suggests the same general conclusion reached by the UNDP.



There are a total of eight MDGs with 12 targets. One of those is to combat HIV/AIDs, malaria and other major diseases, with a specific sub-target of halting and reversing the spread of HIV/AIDS by 2015. As was discussed in the chapter on demographic forecasts, the UN AIDS forecasts now build in a peaking of the infection rate by about that year and IFs, using UN AIDS assumptions, does the same. It was also noted earlier, however, that rates of infection growth in China, India, and Russia might well put those assumptions at risk.

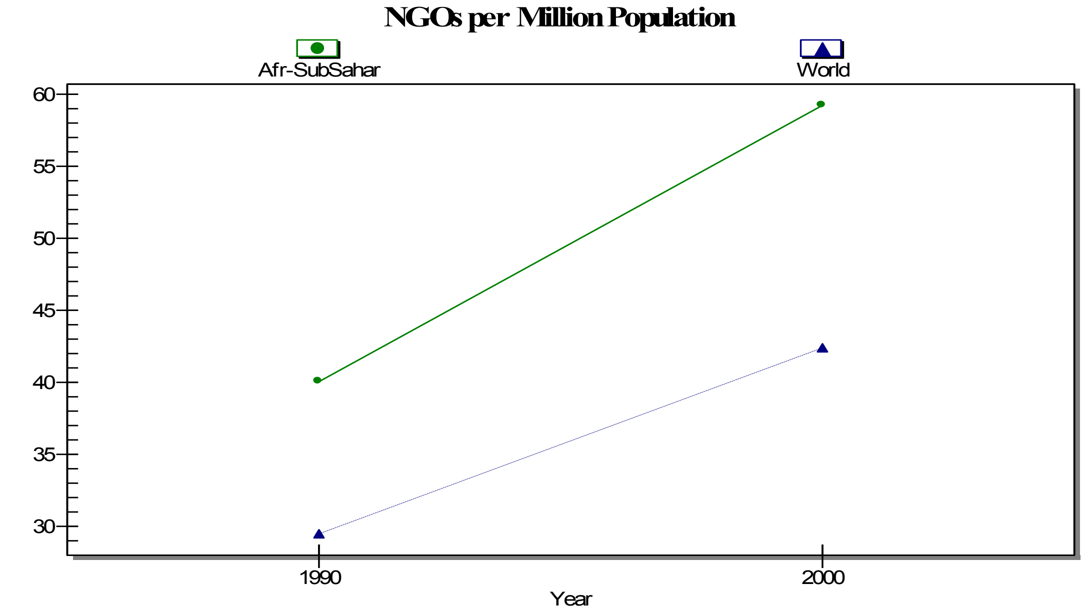
IFs does not currently include and forecast other variables identified in the Millennium Development Goals. The possibility of a global compact, for instance, can be introduced into IFs on a scenario basis, but the base case includes no such intensification of North-South interaction to meet the MDGs.

7.5 Social and Political Structures

Turning to informal and formal socio-political structures, we again find that available forecasts become much fuzzier. Consider something as seemingly simple as the role of civil society in the United States. Putnam (1995) has decried the loss of social capital in recent years. Fukuyama (1999) has similarly pointed to a Great Disruption in social structures, not just in the U.S. but across the developed, Western societies. Both see, however, the possibility, and in the case of Fukuyama the probability of ultimate restructuring of social capital. Yet such forecasts may be both too non-specific and too contentious to give us much purchase on the future. We looked earlier at domestic data on trust, but IFs includes no such variable in its forecasts.

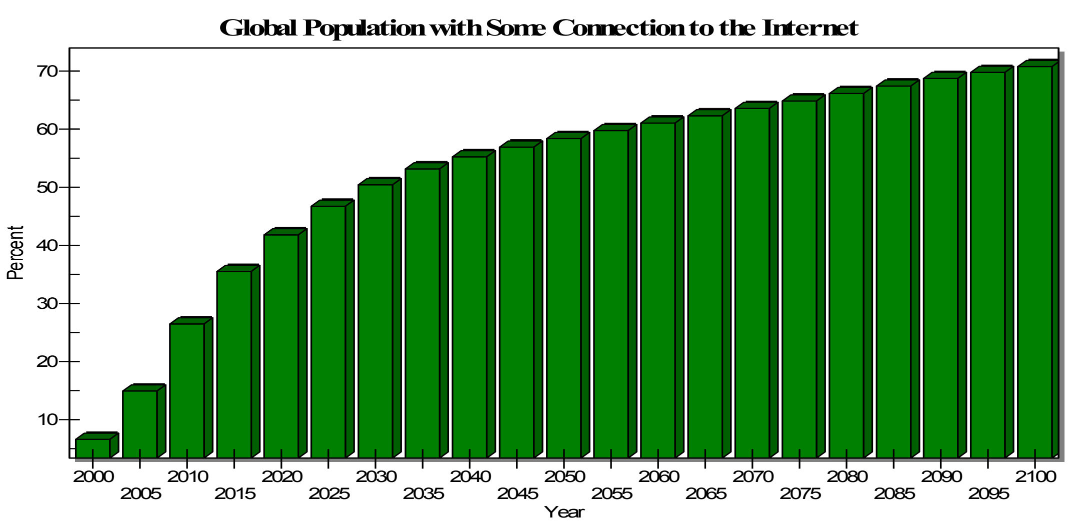
More generally, IFs does not include variables representing social capital or civil society. It would be especially desirable to have some representation of the strength of what is loosely called civil society. Even data, however, much less formulations, are mostly lacking. In addition to interpersonal trust, one possible cut into the question of trends for civil society is to look at the number of NGOs, a variable on which data has begun to be collected.[51] The graph below is from the IFs database, and it is not a forecast. It does show a growth in NGO numbers consistent with arguments that civil society is strengthening around the world. Disconcertingly and improbably, however, it also indicates that NGO numbers per million population are higher in Sub-Saharan Africa than in the world as a whole. Forecasters beware.

[51] The IFs data come from the Center for the Study of Global Governance, are published by the Union of International Associations, and come to IFs via the WRI Earthtrends database.



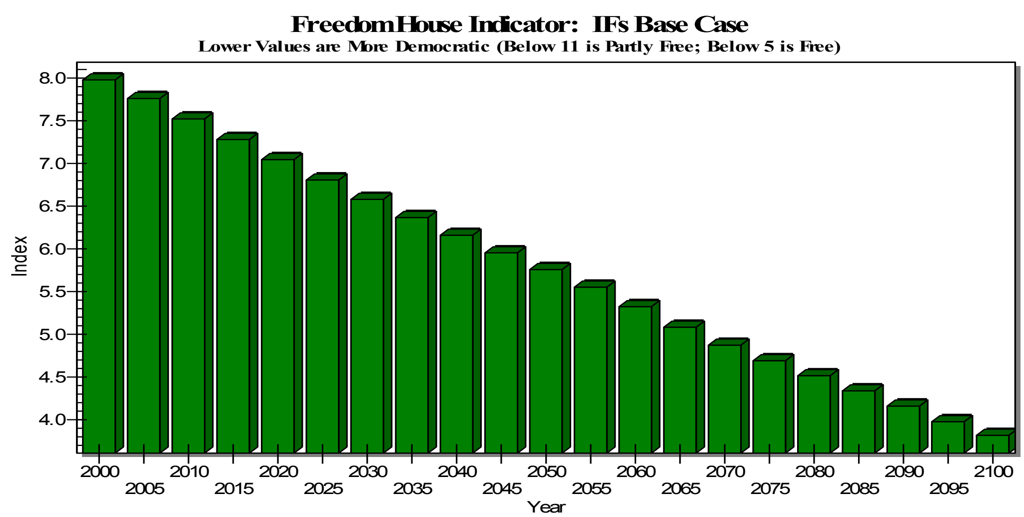
Like Fukuyama, Manuel Castells (2000, 2000, and 2004) and others have pointed to the growth of networking, not just electronic but social, as a key informal socio-political change with multifold consequences.   Castells has spun out the story of the unfolding of the information-based era and networking more fully than many, pointing to the growth of "resistance" identities, their challenge to "legitimizing" identities, and the possible rise of "project" identities. As intriguing as the broad story is, even Castells struggles with the forecasting side of it.

IFs offers one very narrow path into this arena, however, by providing a roughly-based forecast of the numbers and proportions of people connected to the web. The numbers globally in 2002 were already about 10% of the world's population, an incredible growth from essentially nothing 10 years earlier. The annual growth rates of users at the beginning of the century were still about 20%. The graph below looks perhaps somewhat optimistic, but reflect growth rate decline to 10% by 2010 and under 4% by 2020.

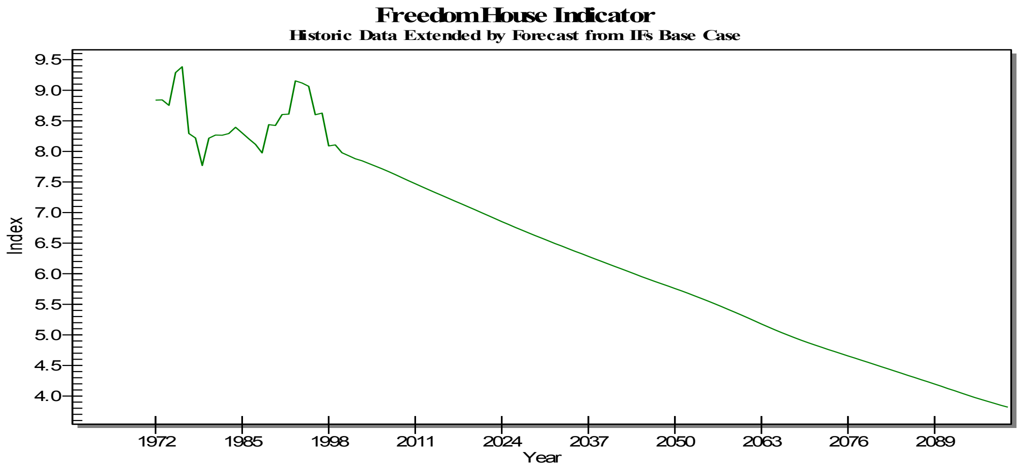


Moving to formal institutions, one of the key socio-political trends is almost certainly the global spread of democracy. Huntington has, however, argued that global democratization has wave-like, rather than persistently progressive character of that spread, and such wave character has become conventional wisdom. He concluded (1991: 315) his discussion of "Whither" the most recent or third wave may take us with the rather non-specific forecast that it "will not last forever" and that "it may be followed by a new surge of authoritarianism constituting a third reverse wave." The conventional wisdom of the literature is nonetheless that, in spite of such possible and likely temporary reversals, democratization will continue its global spread. Specific forecasts, however, were not found for this review and may not exist.

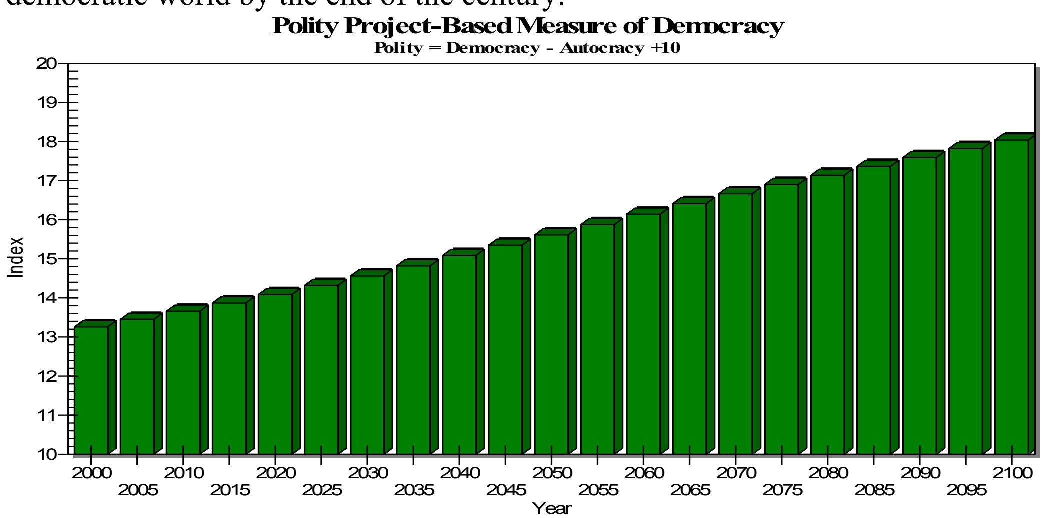
IFs produces forecasts that are associated with two different indices of democratization. The first index is the Freedom House measure of freedom, which uses two separate scales, one for political rights and the other for civil liberties. Each scale runs from 7 (least free) through 1 (most free). Freedom House itself averages the scales into one before assigning rough categories based on them: 1-2.5 for Free, 3-5.5 for Partly Free, and 5.5-7 for Not Free. Like many other users of the index, the IFs project sums rather than averages, thereby attaining an aggregate index running from 14 through 2 (most free). Doubling the cut-off points for the Freedom House categories suggests that the world is, using a population-weighted average of country scores, already well into the Partly Free category. A value of 5 would indicate Free status and the IFs base case suggests below that a global level of "Free" could well be reached before the end of the century.



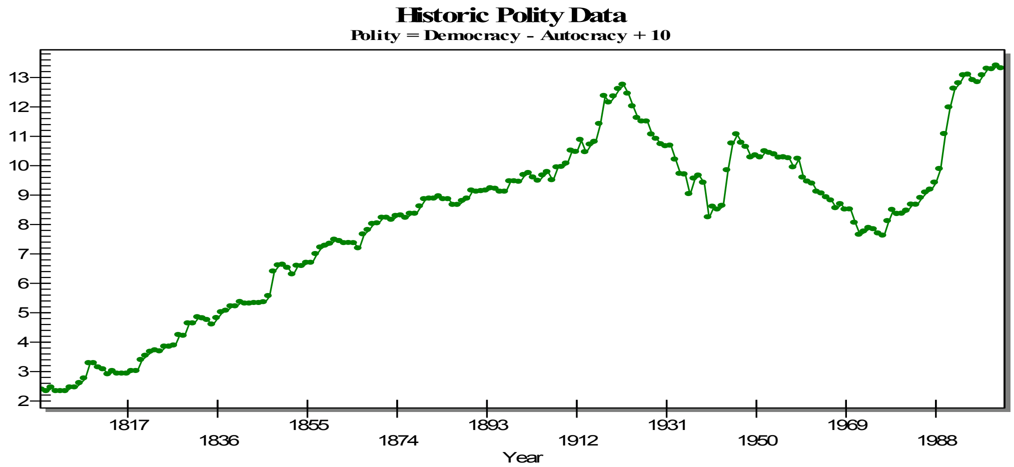
Again, there are not forecasts against which to readily compare the base case of IFs. One way of assessing the IFs forecast is to extend the relatively short (Freedom House numbers exist since 1972) historical series available with the IFs forecast. The figure below does so, but the historic series is too short to provide a very convincing base for such a long forecast.



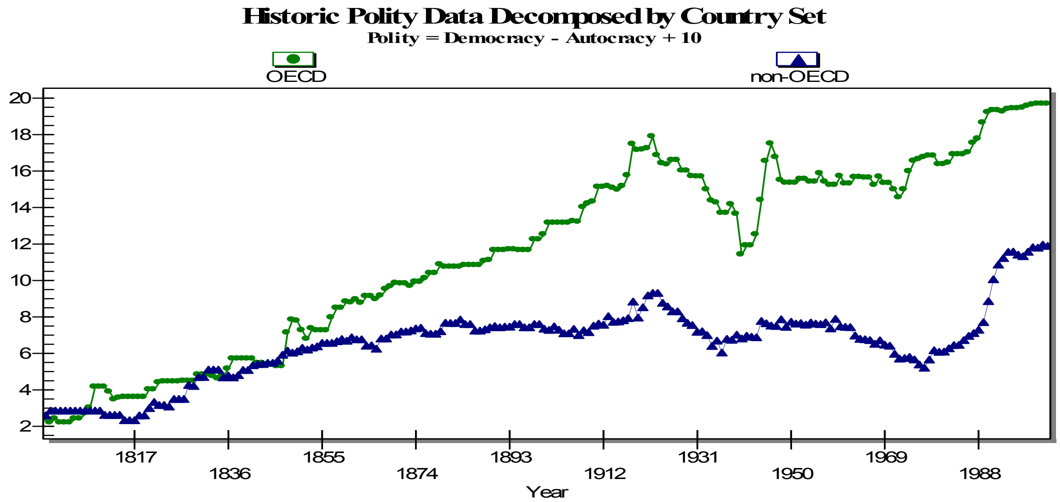
The Polity project provides an alternative set of indicators for democracy, including 10-point scales of democracy and autocracy. It is common to join those scales into a single 21-point Polity or Polity Democracy scale by subtracting autocracy from democracy and adding 10. The IFs project has developed a formulation for forecasting that aggregated measure, as indicated below. Again the base case suggests the possibility of a largely democratic world by the end of the century.



For the Polity measure, there is a much longer historic base, in fact one that extends nearly two centuries. That base is shown below. The three waves of democracy that Huntington (1991) and others have identified appear evident and although the pattern of growth in the 19th century is obvious, that is not true in the 20th. This might lead one to conclude that global growth in democracy largely ended as the 20th began, to be replaced by a pattern of surges and reversals.



Such a conclusion would be unjustified. The last 200 years was a period in which the empirically-assessed global system grew from the handful of European core states that partially democratized in the 19th century into the global system of today. The figure below decomposes that historic world of growing size into today's OECD members and all other countries. What it seems to show is that the democratization of the OECD members, which was only a bit beyond the half-way or partially democratic level at the beginning of the 20th century went on to become essentially complete at the end of the century, in spite of the reversals after World War I and through the Great Depression. The rest of the world also appears to have made some substantial strides towards democracy across both centuries. The number of states in the rest of the world increased dramatically over time, however, much more rapidly than the number in the contemporary OECD set. The population-weighted average of the two sets (or nearly any other form of average), makes the global figure above look as if democracy stalled in the 20th century. The figure below shows that to have been far from the reality. Moreover, the growth of democracy outside of the OECD appears to have accelerated in the last two decades, a fact that would be consistent with many developing countries moving toward the \$5,000-\$7,000 per capita range in which democracy seems often to be consolidated. On average, developing countries are beginning the 21st century with of level of democracy very close to that with which OECD countries began the 20th century.

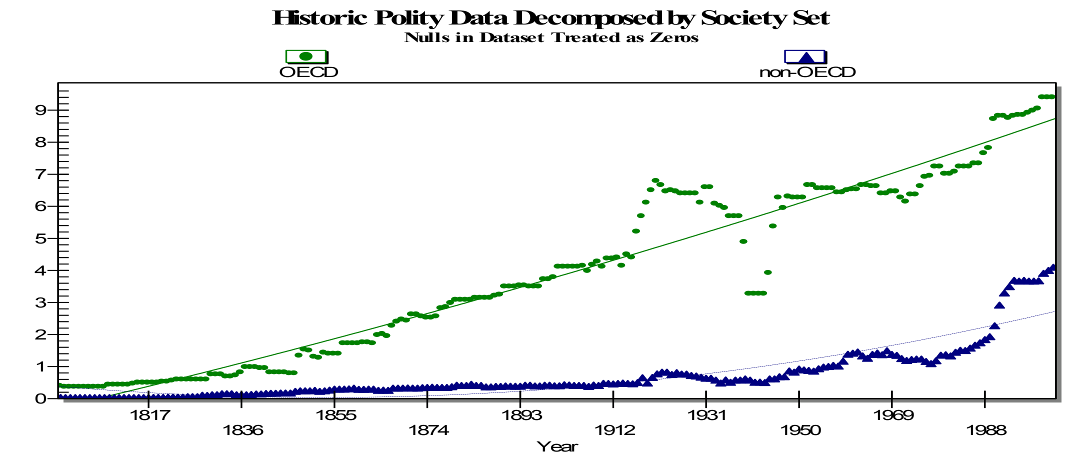


The graph above, however, still presents a distorted image of democratization historically. The problem is that the country set in the above two graphs, and in almost all of the research that shows historic waves of democratization, changes quite dramatically over time. At the beginning of the 1800s, there were very few countries in the dataset, mostly European ones. With waves of decolonization and state formation, the country set grew, bringing in developing countries, most of which were not very democratic. The graph below conceptualizes the world in terms of "societies" rather than "countries." By converting nulls to zeros it assumes that colonized societies were non-democratic, but still existed as societies in the world and deserve to be counted.

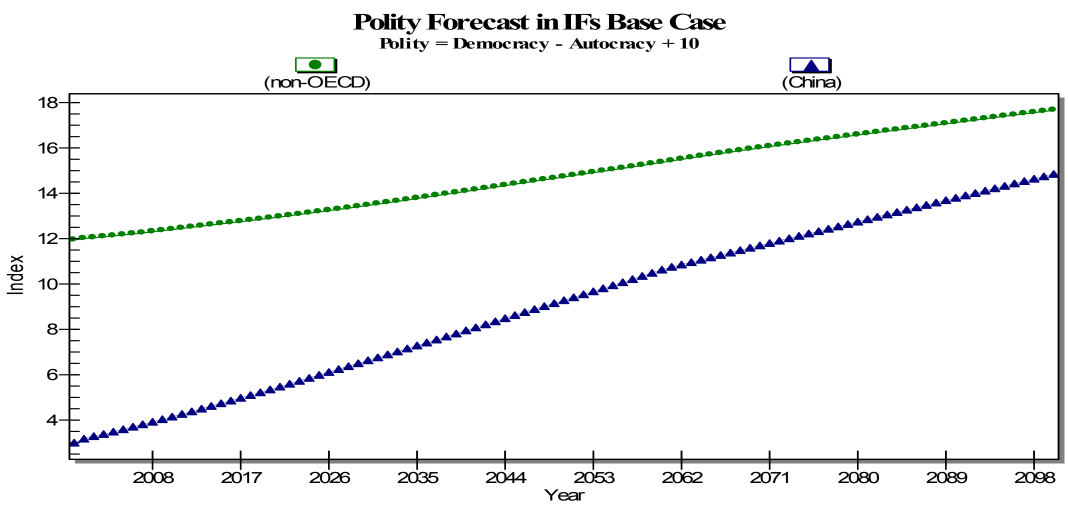
The resulting graph shows that the current OECD societies underwent a rather steady democratization process over the last 200 years, except for one substantial surge above the trend-line (premature democratization in the war to make the world safe for democracy?) and one major reversal following the surge. The non-OECD societies, often as colonies historically, have been mostly non-democratic, but in the last century have begun to demonstrate accelerated democratization.

What happens to the three waves of democratization in the figure below? One remains as a surge and reversal, rather than the end of a century-long wave, as it is usually portrayed. The second reversal described by Huntington is shown to have really been an expansion of the country set in the 1960s to add newly independent colonies. The addition of them made the global total appear to have a reversal that did not really occur, if the entire world is the true subject of our study both historically and in the future.

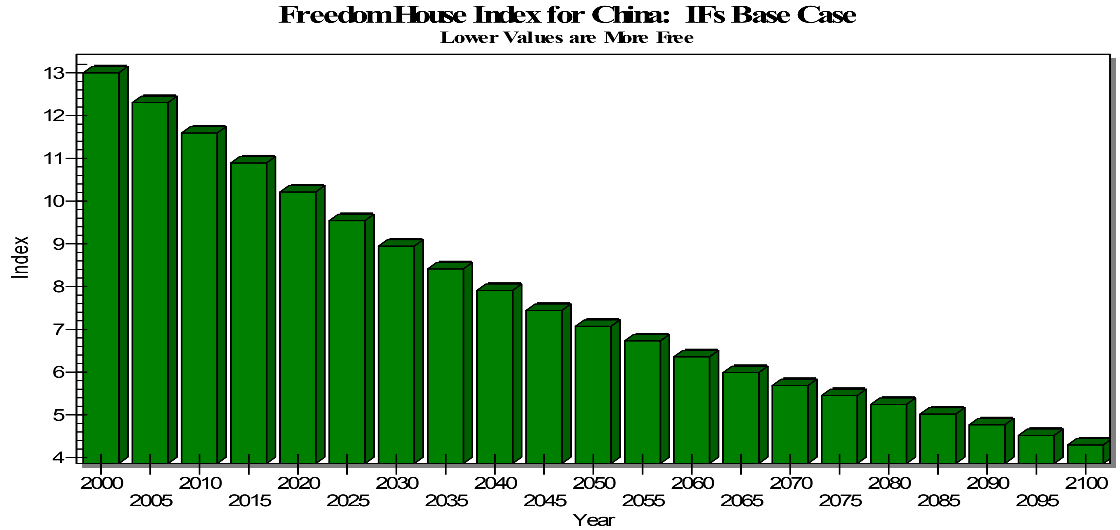
It is especially interesting in the graph below that we can now fit trend lines to the two sets of societies. The trends suggest that democratization growth may be quite related to economic growth, which is a relationship that cross-sectional relationships persistently show. The IFs project has found that a formulation involving GDP per capita (PPP) and the WVS dimension of survival/self-expression provides very strong explanatory power with historic data, as well as a very useful basis for forecasting.



What about the future for non-OECD countries generally, and particularly for China? Going back to the more general measure of Polity (Democracy – Autocracy + 10), the figure below provides the IFs base case forecast. As with other indices that saturate, growth inevitably slows down. But perhaps the most important conclusion from the graph is that China, if it follows historic patterns of other states, may move fairly rapidly towards democracy, but could also well be a non-democratic state or a non-consolidated democracy through the entire first half of the century.



The Freedom House measure in IFs suggests a similarly rapid rate of potential transformation in China. Using their cut-offs for category groups, China might be expected to move into the Partly Free category by about 2015, yet not into the Free category until late in the century. Thus forecasts using both measures suggest a potentially very long period of political uncertainty for China. The State Failure Project, to be discussed below, and other analysts suggest that unconsolidated democracies are the least stable of political forms and the most subject to internal violence. Of course, the reality could well be very different than our crude contemporary look ahead.



7.6 Domestic Politics

Turning to domestic and world political processes, especially the prospects for changes in levels of conflict and cooperation, one striking characteristic of social science literature is again the prevalence of general analysis and rather non-specific statements (sometimes with use of alternative scenarios), rather than the availability of specific forecasts. Clearly uncertainty levels must be exceptionally high in this area, and IFs enters with specific forecasts that must be treated with great caution.

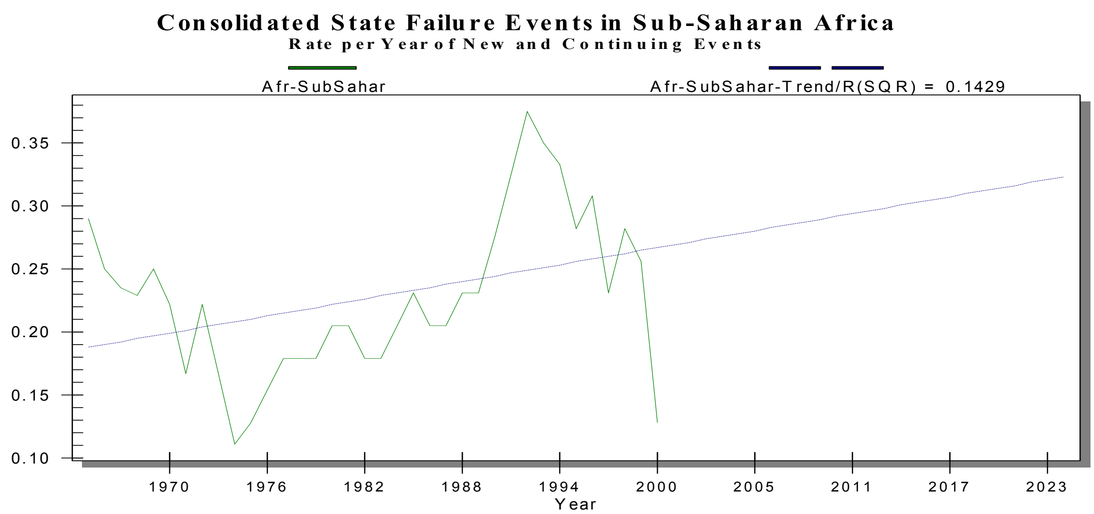
Are there forecasts of potential utility with which to compare those of IFs? For instance, the Stockholm International Peace Research Institute (SIPRI) annually produces an extensive description of contemporary capabilities and conflicts. A useful appendix to the chapter on conflict has in recent years noted the shift of most systemic conflict from interstate to intrastate. The authors further review changes in regional patterns, apparent foundations for conflicts, and intensity. Yet they do not tend to provide forecasts.

The State Failure Project has similarly built an incredibly impressive database and undertaken very extensive analysis to build models that explain state failure historically, both globally and within specific geographic regions. There has been again, however, a reluctance to use the models for forecasts of state failure in future years. And such reluctance appears fairly deeply rooted among social scientists with respect to socio-political change. For instance, looking at the results of that project, King and Zeng (2001) wrote an article titled "Improving Forecasts of State Failure." They divided the historic data into periods, and used one period to develop a model that provided improved forecasts of another historic period. Scientifically, this makes great sense. For policy analysts it is frustrating, because their analysis did not provide future-oriented forecasts.

Absent forecasts of state failure against which to test the IFs base case, one approach is to generate simple forecasts ourselves via simple extrapolation on the database built by the State Failure Project. To do so we must understand that the project's conceptualization recognizes four types of state failure: adverse or abrupt regime changes, revolutionary wars, ethnic wars, and genocides/politicides. Following the lead of the State Failure Project, it is also possible to consolidate all types into a single concept of consolidated state failure episodes.

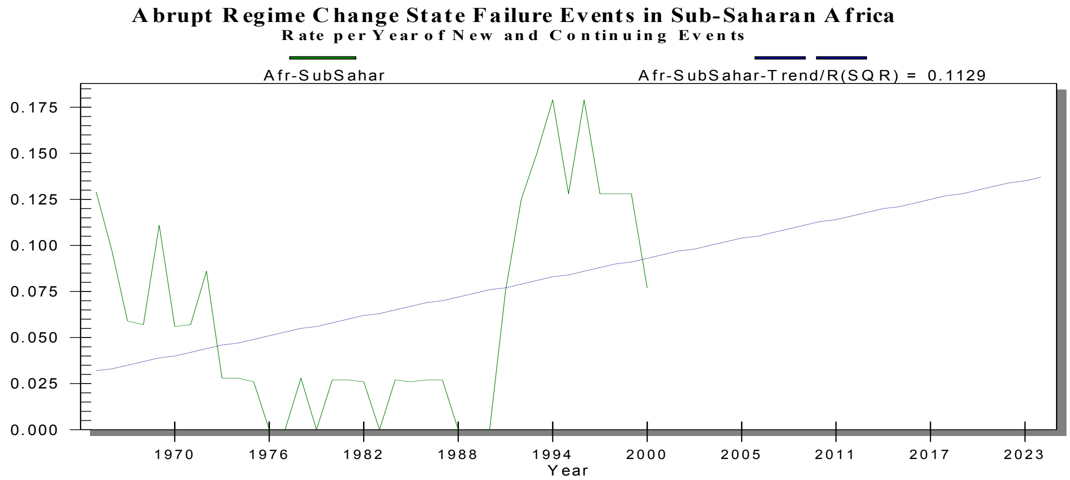
For the purposes of extrapolation here, it is useful to focus only on Sub-Saharan Africa, where the rate of past failure and concerns about future failure are especially high. For extrapolation we use the database only since 1965 by which time most Sub-Saharan African countries had gained independence; that allows us to focus on a relatively consistent set of states over time, avoiding the problem of changing country sets that was shown above to have plagued many analyses of democratization.

The first figure below shows consolidated events since 1965, either initial ones or continuations, with linear trend extrapolation through 2025. There is a clear upward trend overall, but there are really two peaks, one in the early years of independence and the second at about the time that democratization within Africa surged in the 1990s. There is also a large drop at the end of the decade that makes it more difficult to be sure that an upward movement will continue.[52]

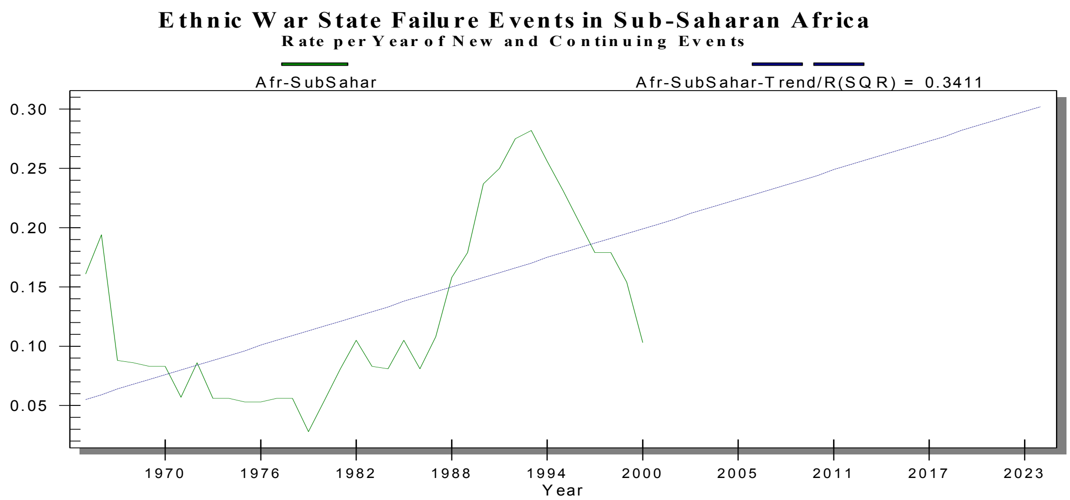


The data and extrapolation on abrupt regime change are similar in general pattern, including both the two surges and the upward trend.

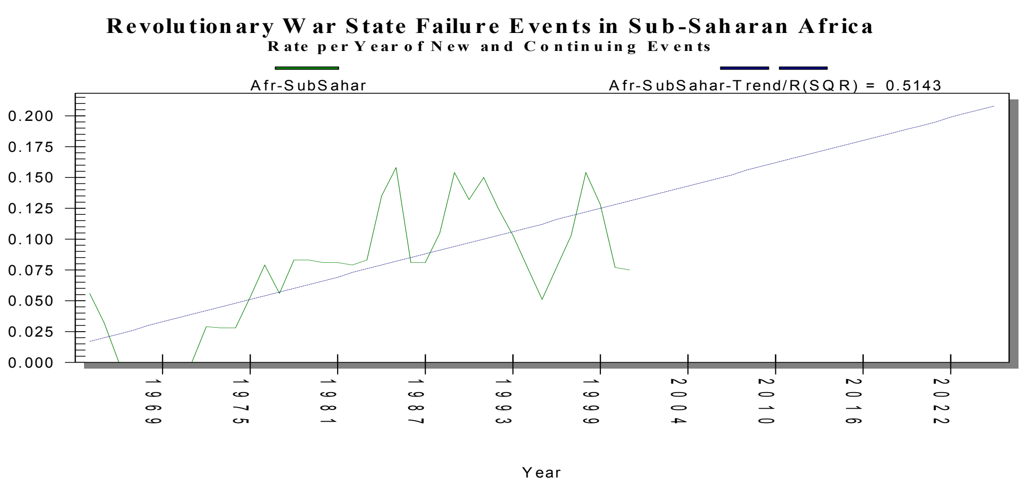
[52] Although the State Failure project has now generated data through at least 2001, the IFs database does not yet contain data beyond 2000.



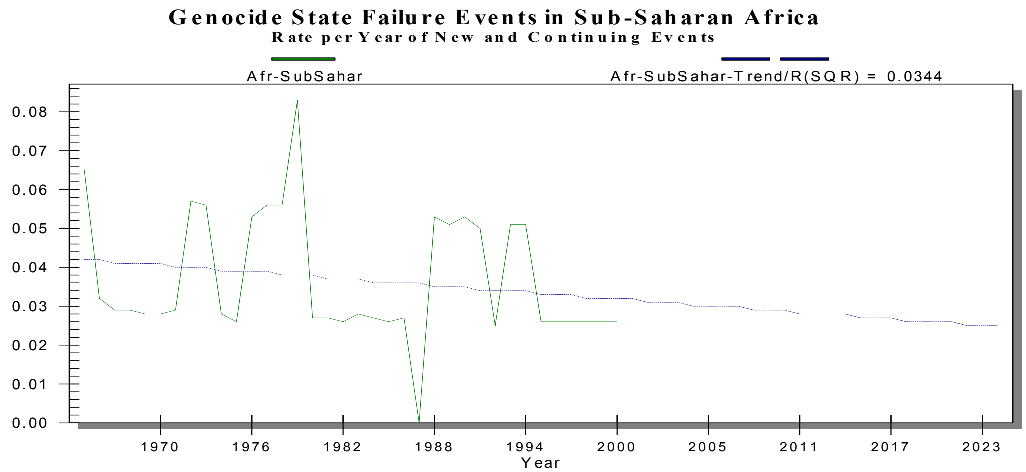
Moving to ethnic war, the type of state failure that has the highest peak incidence, the pattern is again roughly similar.



Revolutionary war exhibits a different pattern for the first time, without an initial peak (perhaps after independence revolutionary wars are less likely), but again with an upward trend over the 35-year period, if not so obviously in the last 20 years .



Genocide and politicide are, blessedly, the least common of the state failure forms and there is slight evidence of a decreasing trend over time.



Moving from this simple mode of forecasting (using data in the IFs database and the extrapolation tools in the IFs system) to the base case of IFs, it must first be said that it has proven exceptionally difficult to build a forecasting formulation for the model in this area. That might seem improbable, given the extent of work that the State Failure Project has done in fitting formulations to the past, but the difficulty lies in the driver variables that the project has identified.

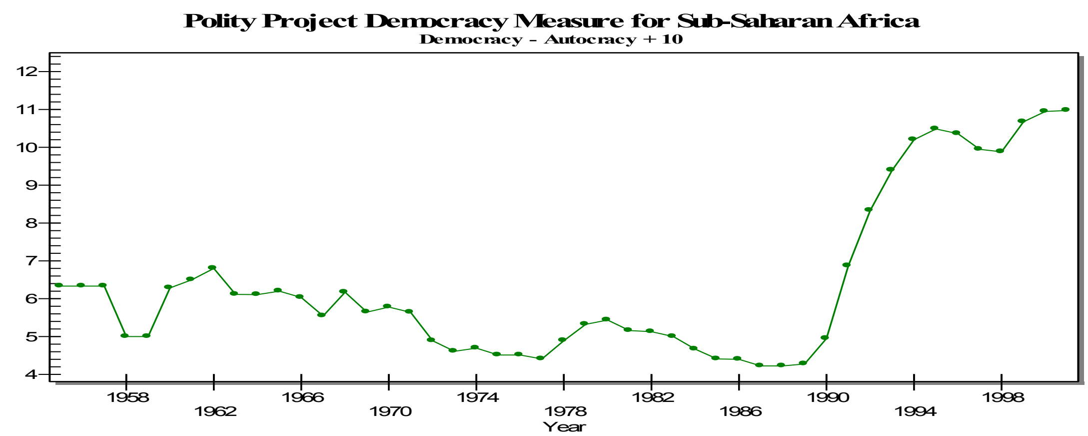
The global model created by the project has a small number of important variables (Goldstone, et al., 2000: vi-vii). Analysis found that partial democracies are seven times as likely to fail as autocracies or democracies. It found that low levels of material well-being (measured by normed infant mortality) doubled the incidence of failure, as did low levels of trade openness (exports plus imports over GDP), and as did major civil conflicts in two or more neighboring states. The African-specific analysis found that almost all partial democracies failed and that democracies were five times as likely to fail as autocracies. It found that failure increased two-to-five times with low trade openness, ethnic discrimination, new or entrenched leaders (versus those in office for a more intermediate period of five to 14 years), and unbalanced growth (defined as high urbanization and low GDP/capita levels).

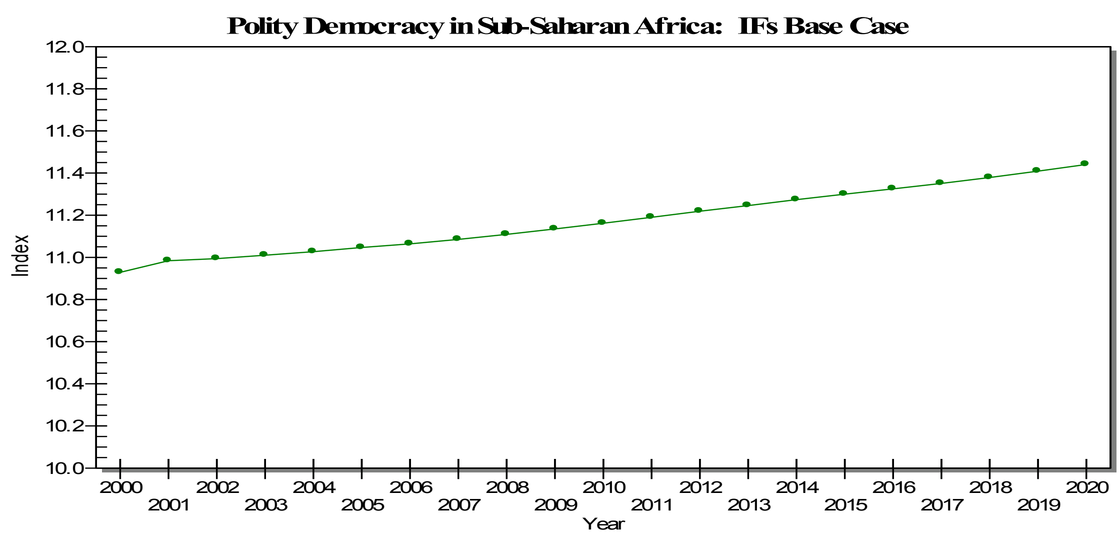
The problem of building these findings into a computer forecasting system is two-fold. First, most of the drivers change quite slowly– this would suggest small shifts in probabilities of events over time, whereas the historic data above obviously suggest rather rapid year-to-year changes.

Second, most drivers are changing in a direction that would suggest lower or unchanging frequency of state failure over time in Sub-Saharan Africa, while the data above and simple extrapolations suggest increasing frequency. Consider three pairs of graphs that each first show historic patterns and then show IFs base case forecasts for some of the key drivers identified by the State Failure Project.

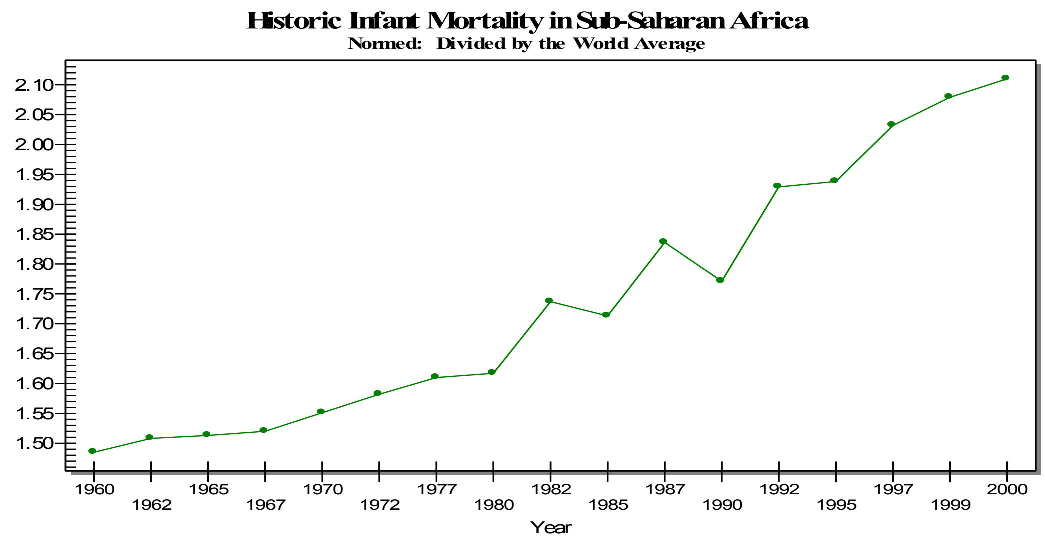
The first pair of figures looks at democracy, using the Polity database and creating an integrated measure of democracy from the component concepts measured in that project. The integrated measure that was used earlier in the discussion of democracy is the value of the democracy component, minus the autocracy component, plus 10. That formulation is common, has been used in the State Failure Project, and creates a scale that runs from 0 to 20, with partial or unconsolidated democracies being near the middle of the scale.

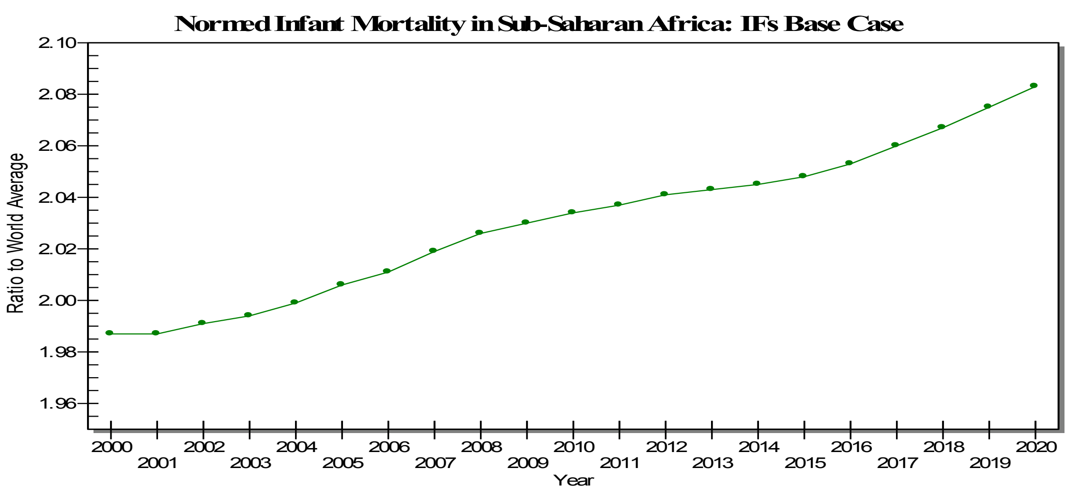
The historic graph shows a movement in the early 1990s within Sub-Saharan Africa as a whole from the preponderance of autocracy to partial democracy. As indicated above, that movement corresponds roughly with the second spike of state failures in the continent and it is therefore not surprising that partial democracy correlates very highly with state failure. The forecast graph, from the IFs base case, suggests that the average democracy level in the region may move slightly further towards democracy in the next two decades, but is unlikely to lead to widespread, consolidated democracy. Overall this would suggest that the rate of state failure in Africa might change little.



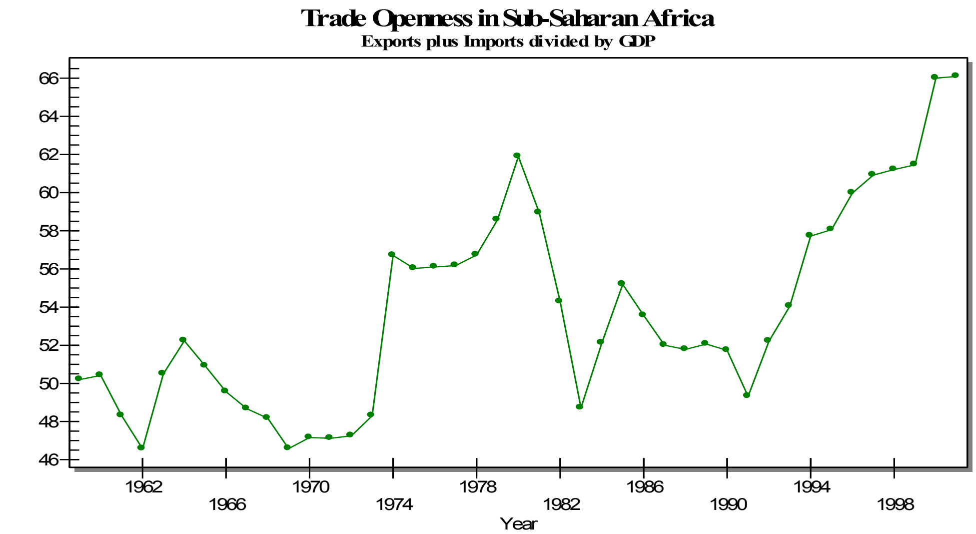


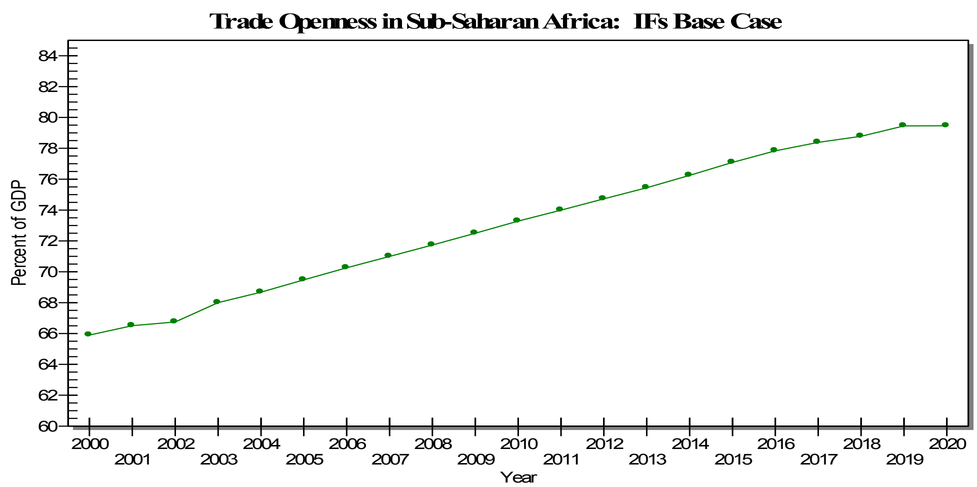
The second pair of graphs turns to satisfaction of material needs, using the infant mortality measure emphasized by the State Failure Project. The project uses a logged and normed formulation, dividing infant mortality for states by the world median. IFs uses world averages instead of the median. To compute world and regional averages, the IFs system uses population weightings. The historic pattern shows a steady deterioration of African government ability to deliver improved infant mortality levels at the rate of the rest of the world (in absolute terms there is improvement almost everywhere, but it is considerably slower in Africa). Interestingly, the most rapid period of deterioration is from 1980 into the early 1990s, again leading into the second continental surge of state failure (the State Failure Project gives special attention to conditions two years before failure onset). There is a slowing of deterioration in the late 1990s, and the IFs base case forecast is of very slightly deteriorating, but essentially stable but continued high normed mortality over the next two decades. As with the democracy driver, this might again suggest relatively stable patterns of African state failure, rather than the increase suggested by simple extrapolation.





The third pair of graphs turns to trade openness. The historic graph shows a general trend toward more openness, but a slight reversal in the 1980s and early 1990s, again preceding the second surge of state failure. The IFs base case forecast for this variable shows a considerable further advance in openness over the next two decades. In contrast to the other two drivers, trade openness thus suggests the possibility for some reversal in the upward historic trend of state failure.



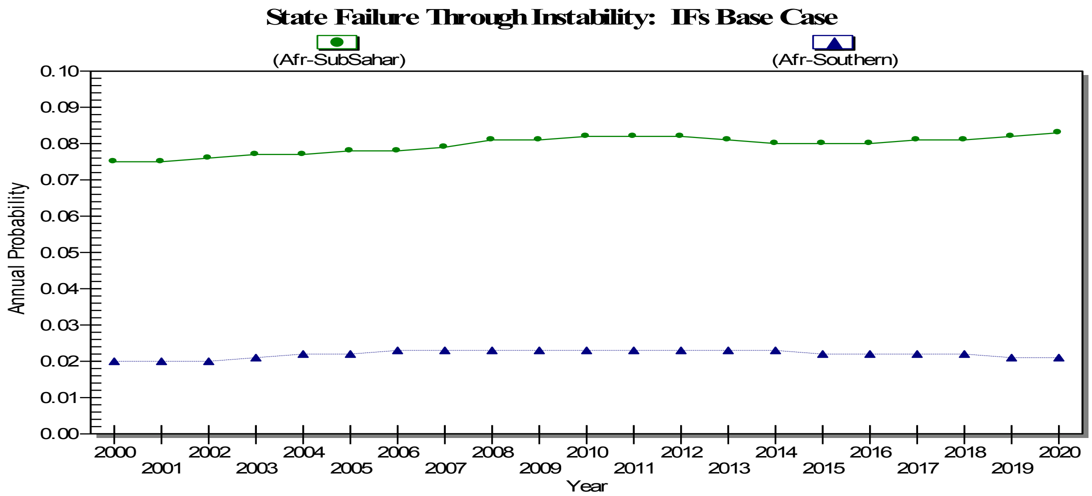


Given that simple extrapolation of historic trends would suggest increasing failure in Africa, but that forecasts of drivers would suggest stable or declining failure, what does the IFs base case generate for the future?

On the advice of Ted Robert Gurr, the primary developer of the conceptualization and force behind the event database, IFs collapses the four categories of state failure into two, identifying them as instability and internal war, respectively. The instability category contains abrupt regime change and the internal war category contains the other three event types: revolutionary wars, ethnic wars, and genocides and politicides.

The graph below is a forecast of instability or abrupt regime change probabilities for Sub-Saharan Africa as a whole and for the Southern tip of Africa separately. In both cases there is some limited increase in state failure probabilities, but a basically flat pattern.

The flat pattern is related to the driver discussion above, and is contrary to the increase of the simple extrapolation. The base case is showing a levelling of the probabilities at the high levels that tended to characterize the 1990s.



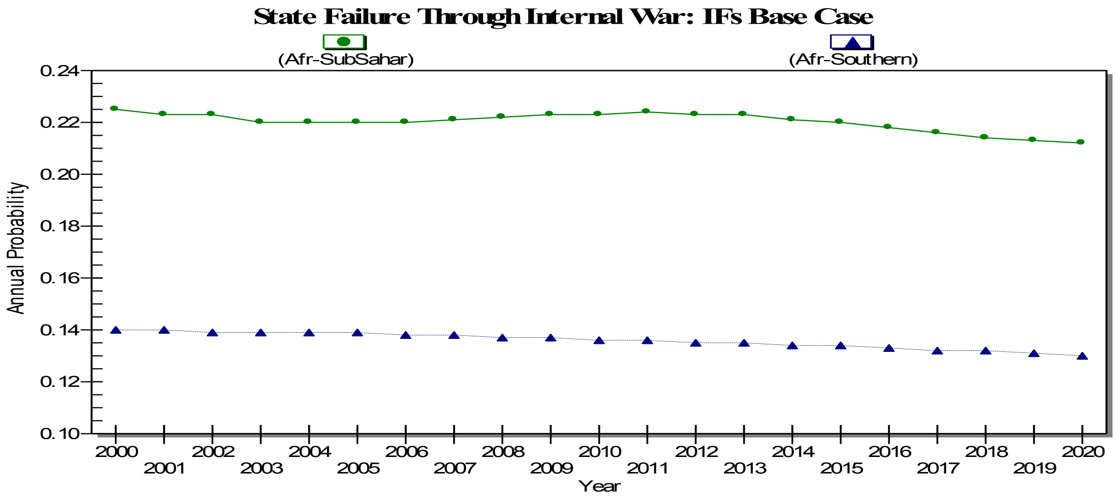
Such a forecast is, however, subject to very large caveats. As indicated earlier, developing a formulation for forecasting state failure is fraught with challenges and risks. The formulation now used within IFs actually only includes the infant mortality driver.[53] In the statistical analysis of the IFs project, which has been considerably less sophisticated than the large-scale and sharply focused State Failure Project, the other drivers discussed above did not prove statistically significant. It is also important to note that the IFs project found that average years of education of a population, a variable not earlier used by the State Failure project, nearly had a significance level for inclusion ($p<.05$). Were it added to the formulation, it would have led to a forecast of declining levels of state failure, because the continent is making progress on education. In short, the IFs project base case is indicating a less pessimistic forecast than does the simple extrapolation, but one in which failure probabilities stay quite high. A small formulation change would bend the curve of the forecast down. Thus the IFs project must re-iterate the high levels of forecasting uncertainty in this issue area.[54]

The formulation for internal war in IFs includes trade openness in addition to infant mortality, because it proved statistically significant. The base case forecast of internal war probability for Sub-Saharan Africa, either as an initial or continuing event, is very high (basically one chance in five for each country-year). That rate drops ever so slightly before rising again slightly into the peak years of the HIV/AIDS epidemic; it then begins

[53]Infant mortality itself correlates very highly with GDP per capita, and when GDP per capita is added to the formulation, normed infant mortality drops out. Normed infant mortality was retained instead of GDP per capita, because (a) it more easily and often shows deterioration and (b) it offers a point of policy leverage.

[54] Another issue is the foundational or base probability in 2000. IFs uses the recent historic period as a statistical "prior" for forecasts. Some analysts prefer an approach that calculates values without such a prior.

to fall again. The rates in Southern Africa are lower, but still very high (about one chance of failure in seven country-years).



To repeat, this area of forecasting is unusually difficult, and it is easy to understand why most analysts decline to make forecasts. IFs forecasts in this area should be treated with special caution. It is probably best for most purposes in assessing prospects for instability and state failure not to look at forecasts of probabilities like those above, but to look at a wide range of drivers, including those discussed here but adding factors such as youth bulges, AIDS death rates, etc. In short, a better approach is a watch list of danger signals like that provided in the Basic Report of the IFs system, coupled with judgment informed by area-specific expertise.

7.7 Global Politics

As with domestic politics, forecasters become appropriately reticent to make precise forecasts with respect to interstate conflict and cooperation, in spite of the great value that good forecasts would have.

Social science is actually more likely to generate socio-political forecasts within world views or paradigmatic perspectives than within its more scientific, ostensibly paradigm-free work.[55] Consider, for instance, the division between realist and liberal (sometimes called idealist) orientations. Liberals are likely to foresee the growth of role for non-state actors, such as NGOs and INGOs, as well as greater use of soft power and multilateralism rather than force and especially unilateral force by states. Realists more often foresee continuing roles for power and force by traditional states.

Both perspectives rather naturally give rise to forecasts, albeit highly general. Those of the realists may be somewhat sharper, however, because they rely on changing global

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[55] An exception is the GLOBUS project (Bremer 1987). That project created a world model heavily focused on socio-political dimensions. It had the capability of making forecasts, but did not tend to produce many (see Bremer and Hughes 1990 for a modest attempt).

power configurations and phenomena such as power transitions in global and regional leadership. We shall therefore explore forecasts of power with IFs and consider some of the implications that they might have for international conflict.

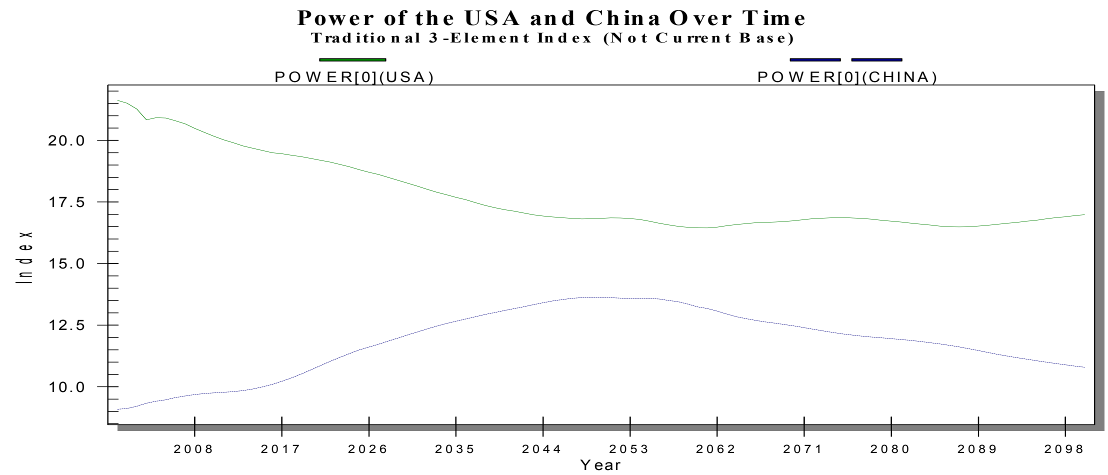
For instance, it has become common to foresee rise in Chinese power to a level that a power transition could occur in global leadership. Tammen, et al. (2000) suggested that such a transition could occur even before 2020 and, drawing upon power transition theory, argued that the dangerous period for global conflict would be during the movement of Chinese power from about 90 percent to about 110 percent of that of the United States.[56]

Comparing such a forecast with the base case of IFs requires an operational definition of power. The power measures from the Correlates of War project influence most operationalizations. COW efforts weight, most often equally, three dimensions of state power: demographics, economics, and military capabilities (Ray 1987). Power measures are traditionally expressed as a portion of systemic power, often restricting the system to a somewhat arbitrarily defined set of great powers.

IFs uses such a measure, but computes power for states as portions of the global total. For many years IFs operationalized demographics with total population, economics with GDP at exchange rates, and military capabilities with rather crude measures of military power (conventional and nuclear). But the appropriate components of the power index are highly contentious. For example, some argue that an equal weight on population overweights it, and that population should perhaps even be considered a burden. Others look to GDP at purchasing power instead of exchange rates. Evan Hillebrand (then of the CIA's Strategic Assessments Group) has argued that, in the modern era, technology is a critical element of power, and that GDP per capita (weighted by GDP) can serve as a rough proxy of technological sophistication. That is, a country with a large GDP spread across a large population is unlikely to have the technological sophistication of a country with the same GDP, but a higher GDP per capita.

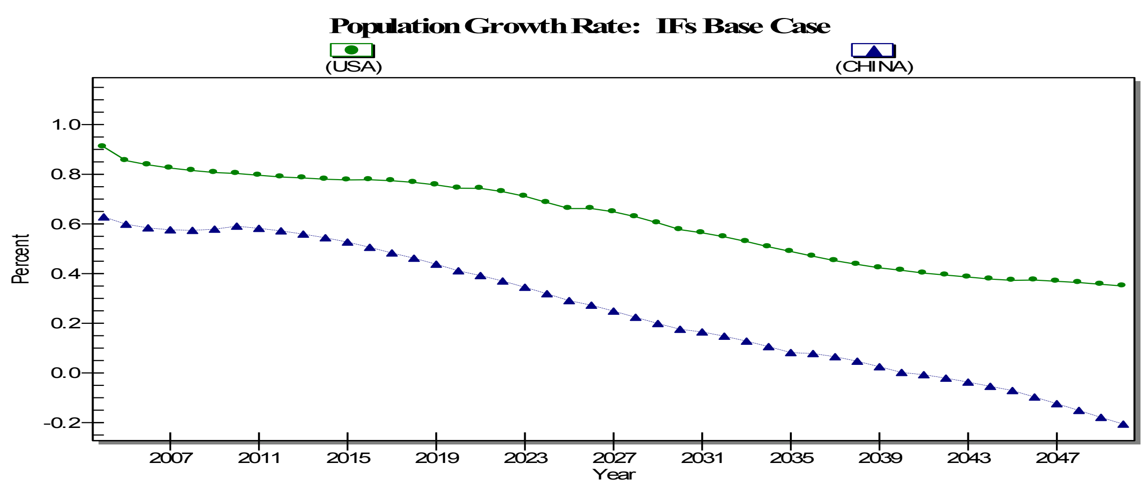
Were IFs to use the traditional three-component measure, with equal weighting and with military spending levels as a measure of military capability, the power of the U.S. and China in the base case would look like the following graph.

[56] Because of its importance, a very large number of studies on the future of the U.S.-China relationship, many with forecasts of the power balance, have been undertaken. A recent study of the future of international power balances done by Paul Herman within the Strategic Assessments Group would be a good place to begin. In addition, look-ahead studies for China alone, such as the World Bank's *China 2020* (1997) can be useful.

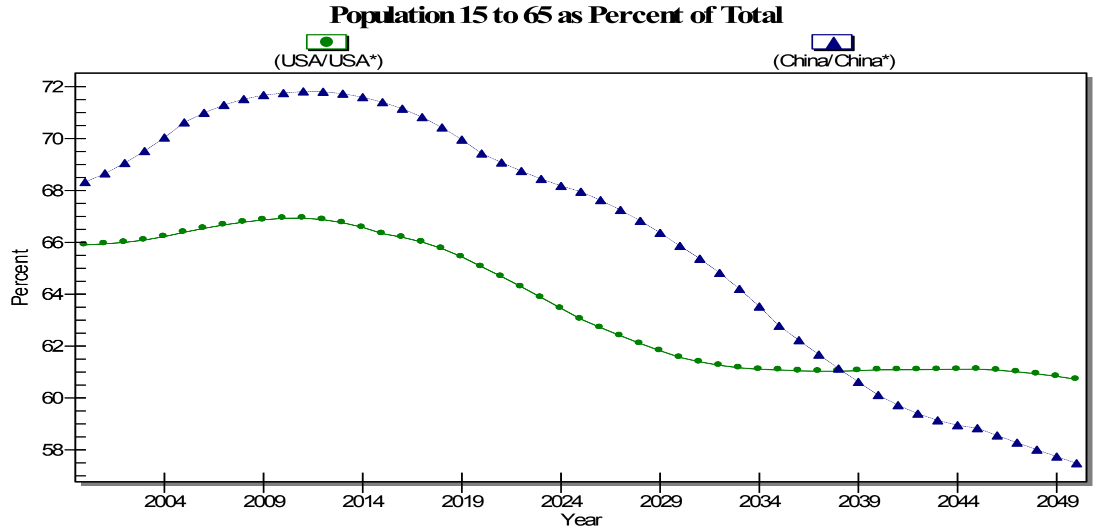


Interestingly, China never reaches much above 80% of U.S. power with this operationalization of power and the underlying drivers of the base case. One reason will surprise many readers. In the longer term, the inclusion and equal weighting of population with other components actually works against China. As the graph below indicates, China already has a slower population growth rate than does the U.S. With base-case assumptions about continued immigration into the U.S. and about continued lower fertility in China, the gap in growth rates widens over time.

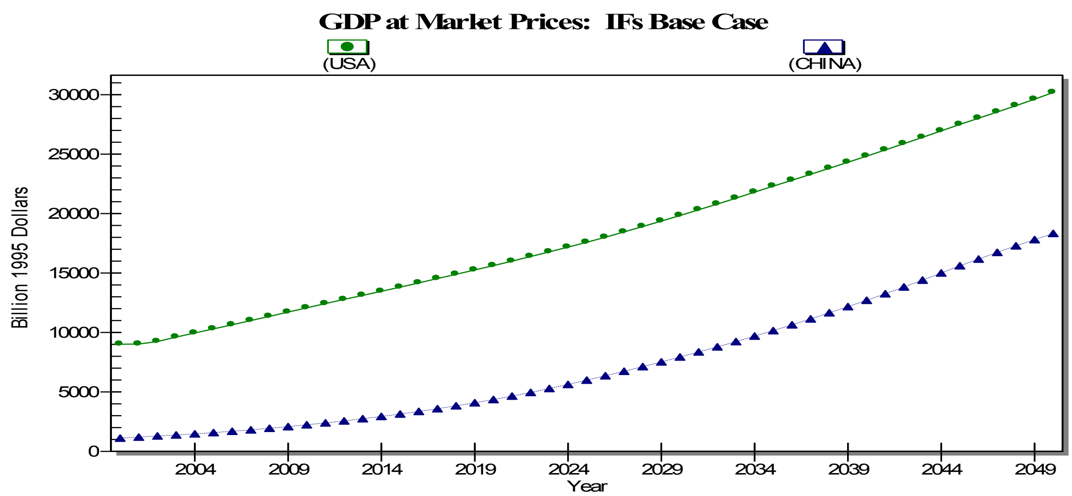
The graph below and subsequent ones focus on the period between now and mid-century; even that period is fraught with incredible unknowns and uncertainties. Attempting to analyze power relationships in last half of the century probably has little benefit.



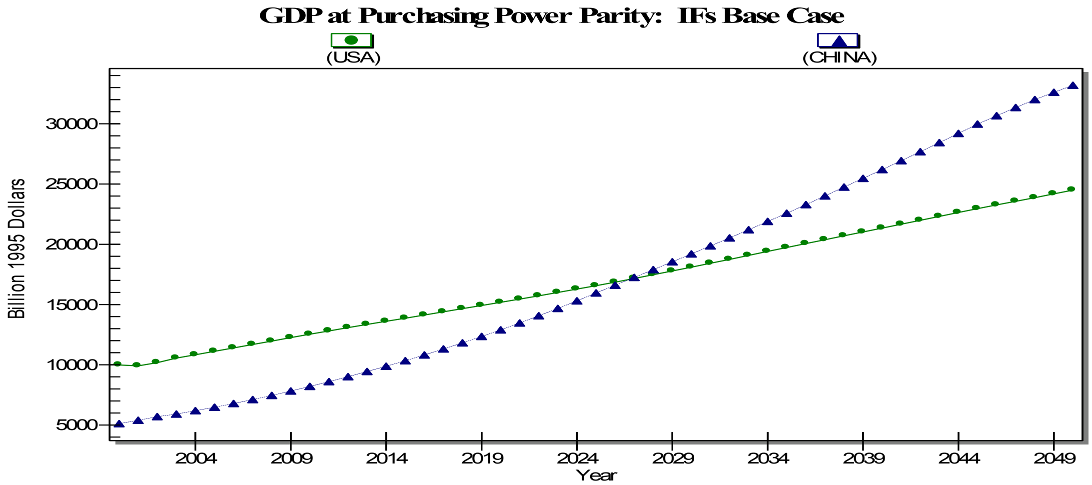
Although not in the power index, another indication that demographics may not work for China in the long run comes from at look at the portion of U.S. and Chinese populations in the traditional working years (15-64). At this point China is still getting a "demographic bonus" because the size of the youth population is dropping faster than the aged population is growing. That advantage will begin narrowing about 2010 and by 2040 the U.S. may have a larger share of its population in work-force age groups than does China.



Not unrelated to the unfolding demographic futures, the GDP of China at market prices in the base case does not converge to that of the U.S., as indicated in the figure below. Although the ratio narrows from nearly 9-to-1 to about 2-to-1, the absolute gap does not close by mid-century. And, although not shown, military spending is unlikely to shift the balance of power between the two countries given these demographic and economic forecasts.

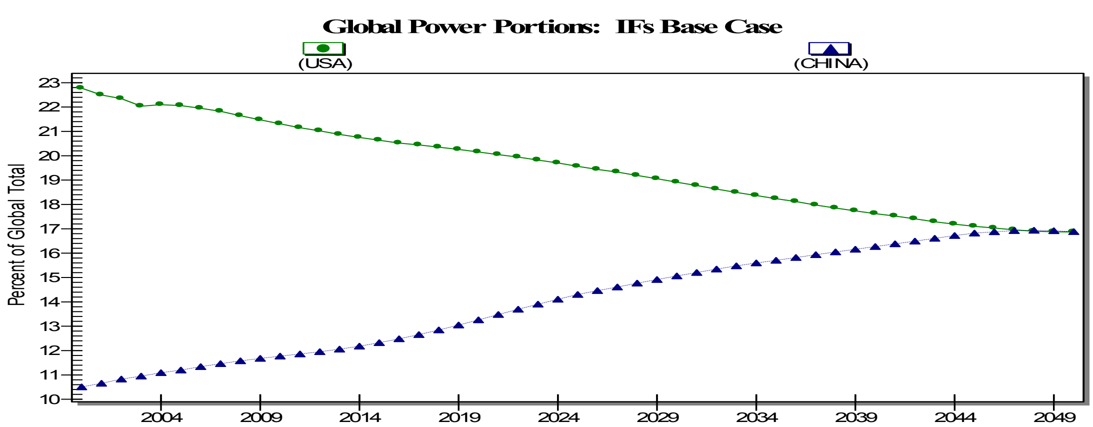


Often, observers argue that purchasing power parity is a superior measure of economic size and the graph below does indicate that at PPP the Chinese economy overtakes that of the U.S. before 2030 in the base case.

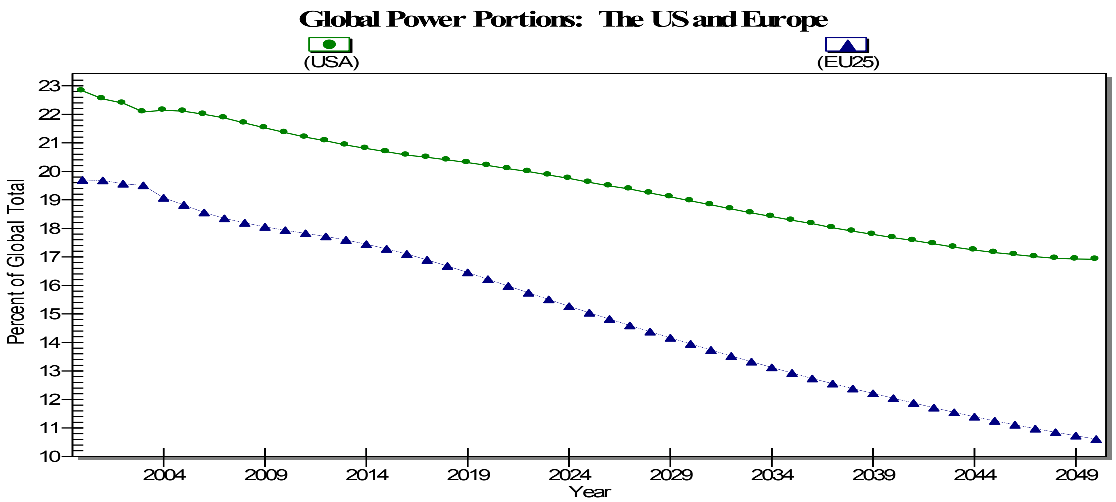


Although it could be argued that GDP at PPP is more relevant in looking at human well-being than at interstate power (which, like GDP at market prices, is inherently a globally-determined concept), the IFs base case measure of power has shifted to purchasing power. The current measure, always subject to change over time and especially to alternative scenarios by the model user, is an index with four components. Paul Herman of the CIA's Strategic Assessment Group, in consultation with Evan Hillebrand, was instrumental in developing the form of the current index. Population enters with a weight of 0.8, slightly underweighting it by traditional standards. GDP at PPP enters with a weight of 1.1, slightly overweighting it. In addition, however, GDPPC at PPP (weighted by GDP) enters as the proxy for the technological capability discussed earlier, with a weight of 0.3. Finally, military spending enters with a weight of 0.9. A major reason for underweighting it is the inclusion of technological capability, so important in today's military capability.

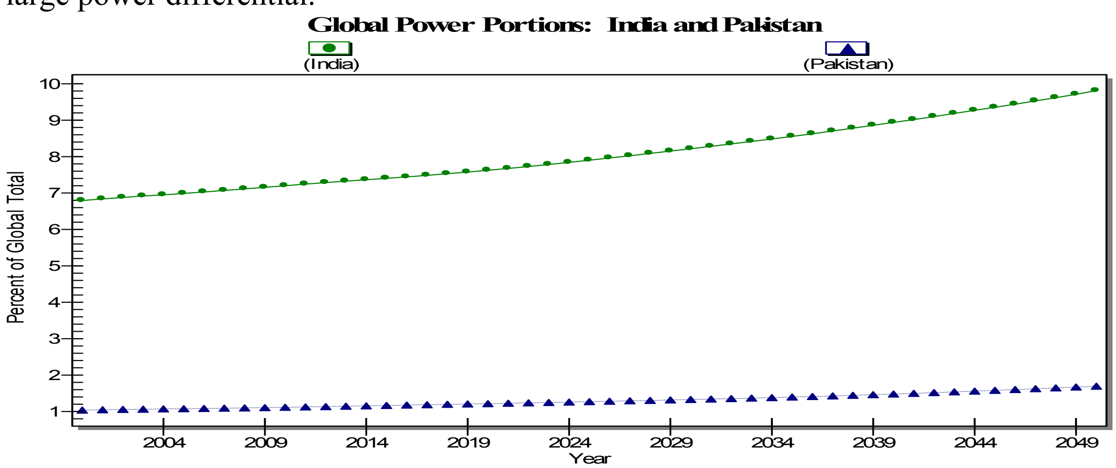
Given this building of the power index, the gap between the power of the U.S. and China does eventually close, as shown below. With this operationalization, Chinese power steadily closes on that of the United States, reaching 90% of the U.S. level before 2040. Once again, all caveats pertain to this base case forecast. For instance, even a percentage point difference in U.S. or Chinese long-term economic growth would significantly alter the pattern.



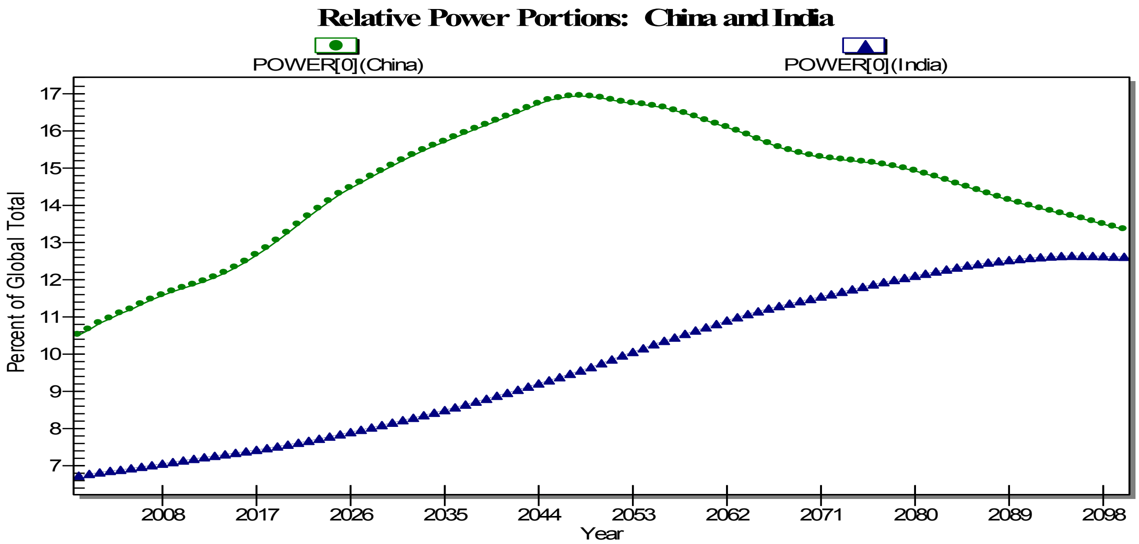
For quick reference, the graph below shows U.S. power using the same measure, versus power of the expanded European Union of 25 countries. The use of a 25-member EU puts that grouping relatively near the level of the U.S. in power initially. Because in substantial part of differing population growth rates, which in turn affect economic prospects, the EU falls further behind U.S. power levels, even by 2020. Interestingly, power transition theory often points to eras of such a divergence as times of increased tension.



Again for quick reference, the following graph shows a regional power balance between India and Pakistan, arguably one of the more dangerous dyads globally, given the nuclear capabilities of two developing countries. The base case suggests no narrowing of the large power differential.



Although it was suggested above that forecasts even to 2050 are a stretch, the graph below looks at the possible evolution of the China-India dyad through the end of the century. Again, the demographic element becomes very important, and it would be quite possible to argue that the greater population growth of India will prove a handicap for indefinitely, rather than a potential strength at some distant point. Yet, using the formulation described earlier, with a reduction in the traditional weight given population, India looks potentially poised to challenge China by the end of the century.

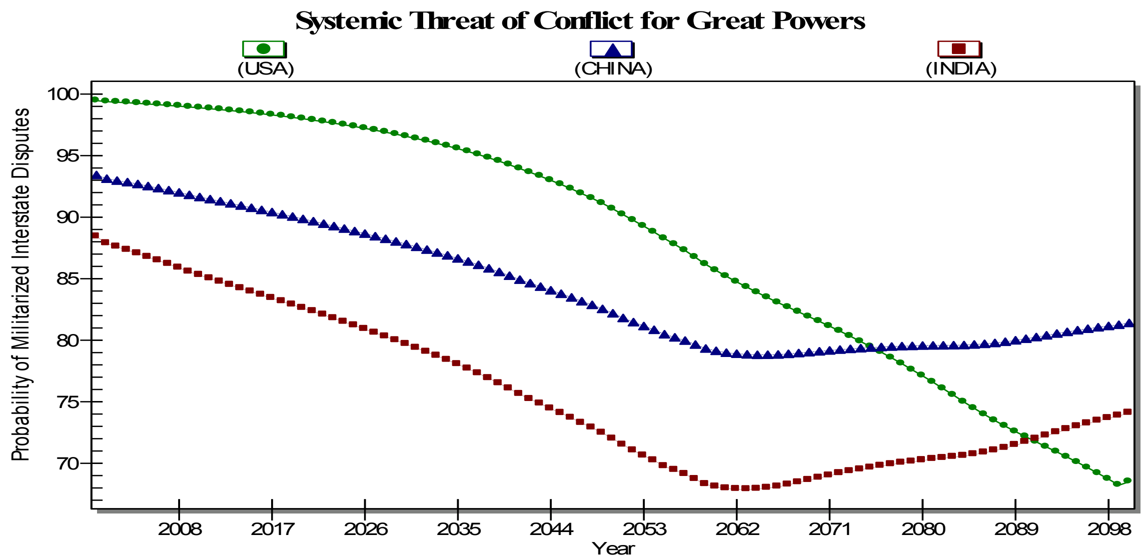


Once again, there is a large but highly disparate literature on specific countries, selected regions, and contemporary great powers. Some of that will provide forecasts, but most of those require teasing out of the text. It is difficult to find long-term power analyses against which to compare the IFs base case.

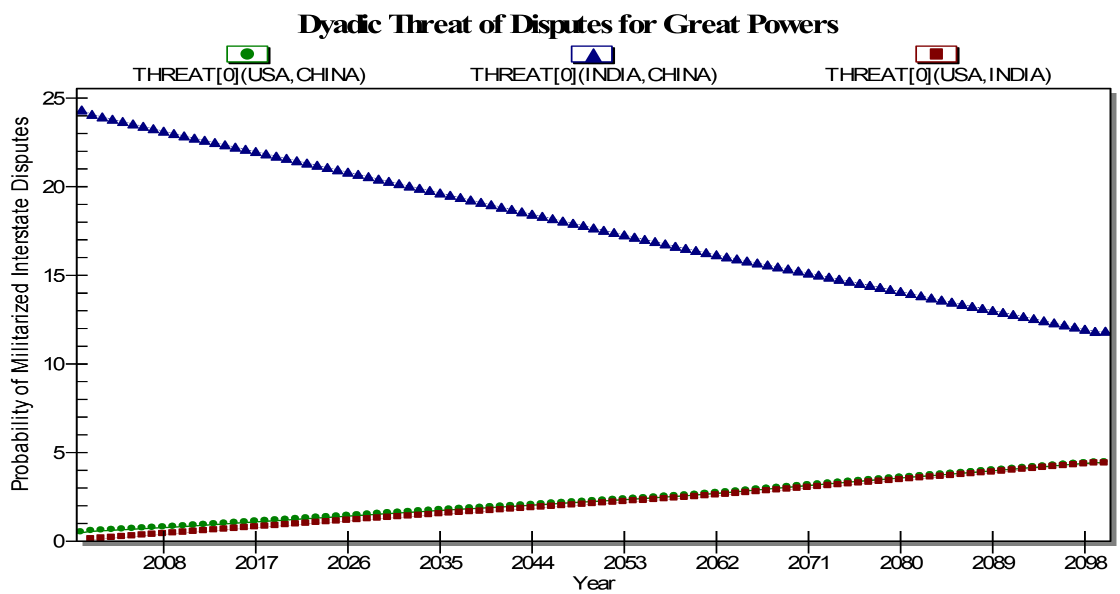
It is, of course, even more difficult to find any forecasting source bold or foolish enough to forecast the overall threat environment of the United States. The two figures below do so, but should be treated with even greater caution. The formulation for threat index used in the IFs base case was built eclectically from theory involving power balances (as above), systemic power concentration, levels of democracy, extent of trade, and other variables.[57] The graph below suggests a gradual long-term decrease in the threat to the United States of interstate conflict (the scale is percentage probability of annual involvement in militarized interstate disputes, with the initial value tied to longer-term historic experience).

The first of the two figures below shows an estimate of the systemic threat environment for three current and/or future great powers: the US, China, and India. It suggests mostly the obvious. Great powers have exceptionally high levels of involvement, essentially constant, in disputes with other states (the conceptualization does not involve non-state actors) that involve the use or threat of force. There may be some tendency over the century for that involvement to be reduced, substantially because of the growth of democracy systemically. At the same time, as the global roles of China and India rise, the threat of involvement for them may actually increase.

[57] Although none of them bear any responsibility for the ultimate formulation, the expert advice of Stuart Bremer and Edward Mansfield, as well as the expertise and empirical analysis of Mark Crescenzi, Douglas Lemke, and Paul Senese were important in providing input to the formulation. The author asked especially for their help identifying "stylized facts" from the empirically complex causes of war literature, in order to be able to build a crude but usable multivariate threat-forecasting formulation.



Ideally we would like to be able to forecast the threat of disputes within dyads of states. The forecast below suggests that the relatively high level of threat between India and China may gradually decline, a pattern driven by a combination of democratization and economic connection. At the same time, the threat of conflict between the U.S. and both China and India may rise. In those dyads, power shifts appear to be overriding democratization and economic connections.



The above two figures are presented in part because they illustrate the great limits on what we can do with such an approach. While they may be somewhat suggestive, they have two great failings. First, they do not inspire great confidence; although our formulations were built with inputs from both experts and the empirical literature, they remain somewhat ad hoc.[58] Second, if we are interested in conflict threat over the next 5

[58] Equations for all IFs formulations are in its Help system.

or even 20 years, forecasts that change gradually through a century give us little information that is not imbedded in the initial condition. Obviously, the real-world pattern of conflicts is highly erratic, responding to specific actions of leaders, accidents on the high seas or in air space, media attention to perceived grievances, etc. Such factors, perhaps especially leadership, can be essential in either resolving or losing control of conflicts such as that in Palestine-Israel. Smooth patterns help us relatively little, and there is no way of forecasting "trigger events" other than by treating them as wild cards.

In addition, the IFs modelling system also does not yet represent some of the underlying forces or drivers known to be relevant to assessing international conflict and cooperation. For instance, there is no representation of the strength or intentions of non-state actors that have made the U.S. a target of their hostility. Given that these have both persistence/driver characteristics as well as trigger event/wild card characteristics, it might be possible to represent some of the former aspects, perhaps tying them to regional dynamics of value change.

Good advice to modelers is always to "model only what it is possible to model." IFs may well have already overstepped that boundary in some areas, particularly some addressed by this chapter. The point of the chapter has been to communicate how far we have come in modelling the "social fabric," demonstrating through the base case both the model's strengths and many weaknesses. Another motivation is to invite suggestions for possible improvements/extensions. It is important to re-iterate that a model like IFs is a thinking tool, not a predictive one. The intent in developing the system has been to provide elements for forecasting that may be useful for thought and discussion, not to suggest that the future will be that of the base case.

One of the best cures for becoming too attached to a base case is the development of scenarios. The next chapter provides a quick introduction to global scenarios, a subject that a later report will need develop more fully.

8. Integrated Forecasting and Scenario Analysis

There are relatively few organizations or individuals that attempt to do global forecasting across multiple issue areas. One of these, the United Nations, occasionally draws together analysis by others from multiple issue areas, sometimes under the rubric of "Critical Trends." The Department of Economic and Social Affairs published *Global Challenge, Global Opportunity: Critical Trends in Sustainable Development* in support of the 2002 Johannesburg Summit. The useful portraits in different issue areas are, however, largely hung together, not fully integrated in the sense of explaining how the various issue areas interact and collectively create global futures.

Most truly integrated forecasting tends to grow out of efforts to look at futures that extend to the environment, to the socio-political system, or both. Because forecasting in either of these two areas requires attention to technological, demographic, and economic drivers (and to energy and agricultural systems, at least for environmental forecasting), those whose interests extend to the environment or to the socio-political system are almost required to provide broadly ranging and quite integrated images of the future.[59] The complexity of such integrated forecasting generally gives rise to (1) group efforts for their creation and (2) multiple scenarios to portray the possibilities.

Many such efforts look to computer simulations, not for the full richness of the scenarios, which must retain substantial qualitative content, but at least for the provision of some quantitative foundation and some consistency across the wide range of issue areas. A useful study by the International Centre for Integrative Studies (ICIS 2000) for the European Environment Agency assesses critically both scenario analysis and the modeling underpinnings of it.[60]

[59] The IEA (2003) volume on Energy to 2050 reviews very well many integrated scenario efforts, especially those that build to the energy-environment nexus. In addition to those studies reviewed in this chapter, the volume presents snapshots of scenario studies emerging from Canada, the Netherlands, and the UK. The Hart/Rudman Commission's Study Addendum (US Commission on National Security/21st Century 1999b) also provides a very good review of most integrated scenario analyses to the time of its release, especially those with an emphasis on socio-political futures. Among those discussed by Hart/Rudman that are not reviewed here are the U.S. Air Force 2025 study (1996); see especially the monograph on *Alternative Futures for 2025: Security Planning to Avoid Surprise*, with some wonderfully-named and nicely developed scenarios for the future. Hart/Rudman also summarize Khalilzad and Lesser's (1998) three scenarios across global regions and attempt to identify some key wild cards. And they outline the Project 2025 of the Institute for National Strategic Studies at the National Defense University. Beyond the coverage of Hart/Rudman and the discussion here, there are periodic surveys, somewhat in the spirit of this report, produced by a wide range of global forecasting projects. The UK Defence Evaluation and Research Agency undertook such a review of *Strategic Futures Thinking* in 2001.[59] A virtue of that analysis was an explicit effort to identify wild cards associated with the key issue areas.

[60] A work in progress by Dale S. Rothman, formerly of ICIS, somewhat updates that effort with a focus on environmental scenarios.

In the environmental arena, the reports of the Intergovernmental Panel on Climate Change (IPCC) are good illustrations of integrated analysis.[61] The IPCC has drawn upon inputs from hundreds of scientists and used scenarios to frame its reports. And it has used a variety of simulation tools in support of the analysis. To summarize the scenario families of the third IPCC report briefly:

- **A1.** Rapid economic growth, global population decline after mid-century, rapid technological change. Convergence among regions, capacity building, increased cultural and social interactions, reductions in regional differences in per capita income. Within the A1 family there are three groups that represent different energy technologies (fossil-fuel intensive, balanced, and predominantly non-fossil fuel).

- **A2.** Very heterogeneous world. Self-reliance and preservation of local identities. Continuously increasing global population. Economic development and per capita income more fragmented.

- **B1**. Convergent world with global population decline after mid-century. Rapid changes toward service and information economy, reductions in material intensity and introduction of clean, resource-efficient technologies. Global solutions to economic, social, and environmental sustainability, including improved equity.

- **B2.** Local solutions to economic, social and environmental sustainability. Continuously increasing global population (lower than A2), intermediate levels of economic development, less rapid and more diverse technological change than in B1 and A1.

Similarly, the Global Scenario Group (GSG),[62] convened by the Stockholm Environment Institute in 1995, has drawn upon the talents of many in creation of its scenarios, which cut across environmental and socio-political arenas. Moreover, it has used the Polestar modeling system in support of several scenario reports, including *Great Transition: The Promise and Lure of the Times Ahead* (Raskin, et al., 2002). Briefly, the GSG scenarios, also elaborated by Hammond (1998) are:

- **Market World.** Rapid technological innovation, economic reform, and economic growth. Integrated world markets. Widespread prosperity, peace, and stability.

- **Fortress World.** Failure of market-led growth to redress social wrongs and environmental disaster. Widening inequality, conflict, and instability.

- **Transformed World**. Power is more widely shared and social coalitions work at grass roots level. Markets are effective, but do not substitute for deliberate social

[61] See http://www.ipcc.ch/; January 16, 2004.
[62] See http://gsg.org/; January 16, 2004.

choices. Fundamental change for the better in politics, social institutions and the environment.

Analyses with the Polestar model[63] of the Stockholm Environmental Institute have also been used in support of UNEP's Global Environmental Outlook (GEO-3), to provide some integration across the multiple issue areas of that analysis.

The World Business Council for Sustainable Development (1997, 1999, and 2000) provided additional integrated scenarios with a heavy environmental emphasis. These include (as presented in IEA 2003: 179-185):

- **FROG (First Raise Our Growth),** a world emphasizing growth first and the environment secondarily.
- **GEOpolicy**, a world in which environmental shocks early in the century lead to global organizational restructuring, including the Global Ecosystem Organization (GEO).
- **Jazz,** a decentralized, deregulated world that brings many advantages but that ultimately cannot create a path towards sustainability.

In the socio-political arena, the Hart-Rudman Commission, more formally the United States Commission on National Security/21st Century (1999a) began in 1998 to develop reports to accomplish what it described as the "most comprehensive government-sponsored review of U.S. national security in more than 50 years." Although most of the Commission's reporting was focused on quite specific issues and geographic regions, and although it argued that the future would likely be a patchwork of elements, it concluded its Phase I report on *The New World Coming* with a brief elaboration of four scenarios:

- **A Democratic Peace.** Democratic norms predominate, there is no sharp ideological conflict, and political cooperation among states is high. The scenario is built on assumptions of moderate economic growth and a continuing information revolution, but also posits global inequalities and other challenges.

- **Protectionism and Nationalism**. Global economic crisis or other factors lead to the rise of nationalism and of regional power blocks. The developing world suffers economic decline in the face of decreasing trade and financial flows. Nationalism, ethnicity, and fundamentalism direct some politics and even governments.

- **Globalization Triumphant**. Rapid progress in technology and global growth in economies allows developing countries to create larger economies than those in the developed world. There is widespread commitment to more equitable income, to development of human capital, to peaceful conflict resolution, and to sustainable environmental policies.

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[63] See http://www.seib.org/polestar/Projects.html; January 16, 2004.

- **Division and Mayhem**. Diffusion of dangerous technologies, breakdown of globalization processes, or environmental crisis could give rise to this world. Internationalism breaks down, with restrictions on trade, financial and information flows. Many countries fragment ethnically, culturally, or religiously. Terrorist attacks on U.S. cities reorient U.S. policy towards preventing more attacks and away from broader global engagement, giving rise to a downward spiral.

Once again reaching into the socio-political arena, the Forward Studies Unit of the European Commission (1999) put forward five possible futures with a focus on Europe:

- **Triumphant Markets.** This is essentially another victory of globalization scenario, but drawing attention to negative aspects of liberal markets for some participants within two-tier labor markets, including growing inequality as well as a loss of social benefits and support systems.

- **The Hundred Flowers.** Economically less successful globalization and the weakening of governments allows corporate excesses and growth of crime, accompanied by rising public dissatisfaction in a world of highly uneven performance and a more ominous international situation, including an introspective United States.

- **Shared Responsibilities.** Successful and extended integration of societies by the European Union set in motion a dynamics of reform, renewal and coordination in policy and the establishment of a clear European model for economic and socio-political systems, with support for European leadership in multilateralism and global systems.

- **Creative Societies**. Aggressive European reforms reduce the governmental footprint and give rise initially to backlash and socio-political problems including slowed expansion, but suggest the possibility for an emergence of ultimately more creative government and renewed society.

- **Turbulent Neighbourhoods**. Ethnic wars, terrorism and rising criminality around the world, to which other actors and global systems respond incoherently, bring themselves to Europe's doorstep forcing Europe to narrow its geographic definition and focus on security issues, but at great cost in other arenas and without great success even with respect to security.

The Millennium Project has developed many scenarios over time, including (ACUNU 1998 as described in IEA 2003: 186-190):

- **Cybertopia**. Free trade and globalization, highly developed information/communications, low governmental profile, and high security.

- **The Rich Get Richer**. Like Cybertopia, except that income inequalities grow, environmental problems are more pronounced, and security is low.
- **A Passive Mean World**. Barriers to trade, stagnant communications, and high levels of government combine with high unemployment. Poor countries develop slowly and people turn inward within and across regions of the world.
- **Trading Places**. Open trade, highly developed information/communications, low government profile and low security. The rich countries suffer economically more than the emerging countries like China, however, who surge ahead in the system and become dominant powers.

At the Inaugural Conference of Project 2020, Ted Gordon of the Millennium Project sketched four other scenarios, which collectively place considerable emphasis on alternative technological futures:

- **Science and Technology Develops a Mind of its Own.** Scientific and technological discoveries accelerate ahead of the ability of governments to keep pace.
- **The World Wakes Up**. An individual murders 25 million people with a genetically-modified virus leading to more control of science.
- **Please Turn off the Spigot.** Science is seen as not meeting the needs, especially of the poor, and a global commission attempts to intervene.
- **Backlash.** Negative consequences of innovation lead to mass concern, unsuccessful regulation and stalled progress.

Also in the socio-political arena, the National Intelligence Council (NIC), providing integrated strategic thinking for the Director of Central Intelligence and the broader U.S. government, prepared a report on *Global Trends 2010* (1997), a second report on *Global Trends 2015* (2000) and is preparing *Global Trends 2020*. As part of its past analysis it identified demographics, natural resources and the environment, science and technology, the global economy and globalization, national and international governance, future conflict, and the role of the United States as key drivers. Although most of its report elaborated the unfolding of those drivers globally and within specific countries and regions, the NIC, like Hart-Rudman, also concluded its 2015 report with four general scenarios:

- **Inclusive Globalization.** Technological development and diffusion, economic growth with wealth diffusion, effective national and international governance, and conflict reduction create a virtuous circle for all but a minority of the world's population.
- **Pernicious Globalization.** Population growth and resource scarcities burden many developing countries more than technological advance is able to help them,

leading to a splitting of the global economy and the failure of a majority of global population to benefit from globalization.

- **Regional Competition**. Regional groupings in Europe, Asia, and the Americas emerge and compete economically and with respect to technology, also leaving other areas, such as Sub-Saharan Africa, the Middle East, and Central and South Asia behind and giving rise to overt conflicts in such regions.

- **Post-Polar World.** The U.S. economy slows and stagnates, focusing attention inward, and causing the U.S.-European alliance to deteriorate, while regional tensions in Asia and growing Chinese capabilities give rise to military tensions and possible conflict for which the U.S. has little outside support.

Key Global Uncertainties. The scenario families of many studies tend to identify similar sets of key uncertainties in mapping their scenarios. In fact, the names and characters of the large framing scenarios begin to sound much alike. How much alike are they? Some dimensions of uncertainty clearly come back from one analysis to the next:

1. **Pace of Technological Change and/or Economic Growth.** Essentially all scenario groupings exhibit internal variation with respect to either or both of these key underlying drivers.

2. **Level of Globalization and Cultural Differences**. Again, nearly all recent groupings make differing assumptions across scenarios with respect to the extent of globalization and the continuing role of regional cultural differences (a *Lexus and the Olive Tree* juxtaposition). Sometimes, variation in globalization intensity is considered only economically, but increasingly studies think through also its impact on cultural regions.

3. **Income Distribution.** This dimension of underlying variation in scenarios is very common across sets; the distributional attention is primarily interstate, but can also be intrastate.

4. **Demographic patterns.** The IPCC creates two general alternative demographic futures. Demographic futures are, however, less widely distinguished in scenario sets than many other driver sets, in part because of substantial convergence in assumptions.

5. **International Cooperation or Lack of Cooperation**. Many scenario sets introduce variation in behavior of the United States and sometimes of other actors in the extent of unilateralism or multilateralism in policy.

6. **Governance Success.** In some scenarios the success or quality of governance is explicitly variable and in some analyses the size of it also varies.

7. **Material Intensity of Economy and Character of the Energy System**. The IPCC focuses heavily on this, and *Which World?* creates one scenario around a environmentally pessimistic future.

8. **Global power configurations.** Substantial numbers of scenarios that look at global politics explicitly differentiate possible future power distributions.

9. **Nationalism and other isms.** A considerable number of global political scenarios look at the intensity of national, religious or other identities and/or ideologies.

10. **Wild Cards.** Many scenarios reach out for their central character to improbable but theoretically possible events, from plagues through meteor collisions to specific technological breakthroughs.

The final chapter of this report begins what will become an extended discussion of the approach to scenarios within the IFs project.

9. Concluding Remarks: Scenarios with IFs

As stressed at the beginning of this report, the base case is only a starting point for analysis. Because the base case is explicitly assessed against and adjusted towards the thinking of experts in many areas, *it is a scenario* for the future. Yet, like other scenarios, it is a very low probability image of the future. The analytic use of IFs absolutely requires extended scenario analysis around the base case. How can the interface, structure, and use of IFs facilitate such analysis?

In thinking about the process of scenario development, it is useful to keep in mind at least two key dimensions that can differentiate scenarios. The first is between framing-assumption scenarios and leverage-exertion scenarios. The second is between narrowly-targeted interventions and between large-scale scenario visions. The two-by-two table below suggests the pure forms of analysis framed by the two dimensions. In reality, most scenario analysis mixes framing assumptions with leverage exertions and/or builds up large-scale vision scenarios from individual targeted interventions. There is nothing at all wrong with doing either, but it is useful to recognize it when one does so.

	Framing Assumptions	**Leverage Interventions**
Targeted Interventions	Assumption Sensitivity Analysis	Policy Assessment
Large-Scale Vision Scenarios	Framing Scenarios	Road-Map/Normative Scenarios

With respect to the first dimension, some analyses will build on assumptions concerning issues that are in part or wholly beyond the control of human intervention. Examples of alternative framing assumptions include differing values for ultimately available fossil fuels in Iran or different dates by which the introduction of a vaccine against HIV/AIDS could cause infection prevalence to peak globally. In contrast, a leverage-exertion scenario might consider the impact of more spending on education in Sub-Saharan Africa or of immigration controls in Europe. Such targeted interventions can be especially useful for investigating the sensitivity of the base case of the model or in assessment the potency of a particular policy lever. Some such interventions could be wild cards, such as an oil embargo by OPEC members in years 2014-15. From the point of view of the United States this might be a framing assumption, whereas from the point of view of OPEC this would be a leverage exertion. The categories are by no means fully pure.

With respect to the second dimension, each of the examples in the preceding paragraph was a quite narrowly-targeted intervention. In contrast, within the European Commission-sponsored TERRA project, the IFs team developed a Sustainability Scenario that built up a package of leverage initiatives with respect to human capital development, pursuit of growth with equity, and environmental sustainability (Hughes 2003). The intent was to help develop a “road map” scenario with respect to sustainability.

Similarly, the alternative fossil fuel families within the A1 scenario of the IPCC have the character of framing scenarios.

Obviously, large-scale scenario visions can and often are built up from targeted interventions. It would, for instance, be possible to build an extensive framing image of an environmentally-fragile world in which non-renewable resources were more limited than expected and environmental impacts were more unforgiving. Or to build an environmentally-robust world. Inside such framing scenarios, we could explore human leverage to achieve growth with equity. It is also possible to begin with a vision scenario and work back to the interventions, somewhat as is happening with the Great Transition scenario of the Global Scenario Group.

In terms of building a road-map, the IFs project in association with the Rand Pardee Center has begun to explore leverage using the Center's Computer Assisted Reasoning System (CARS; Lempert, Popper, and Bankes 2003). The combined CARS-IFs system can explore a vast space of runs or cases from the model, each involving one or more targeted interventions, in order to seek robust strategy packages to best pursue desired outcomes. The robustness of the strategies will come at least in part from their ability to stand up to different framing assumptions (such as, again, the unfolding of AIDS). Thus the system essentially will facilitate the development of road maps across multiple possible framing scenarios.

How does IFs facilitate the movement within and across these categories? The "scenario tree" of the IFs interface allows manipulation of every parameter in the model, including many multipliers that have been created specifically to represent the exertion of leverage. The top two branches on the scenario tree give access to technological and environmental parameters, both of which generally have the character of framing assumptions. The next branches on the tree give access to interventions that generally represent the actions of agent classes, notably households, firms, and governments. In short these help organize leverage exertions.

When using the scenario tree, it is possible to stop at a single intervention, run the model, and consider the results relative to the base case. It is also possible to hang multiple interventions on the tree and thereby to elaborate vision scenarios. Any configuration on the tree can be saved to a file for later retrieval. And the project has begun developing a library of scenario files that package an assortment of interventions for the user to load into the tree, one at a time or additively. Ideally, many of the scenarios discussed in the last chapter or developed explicitly for the 2020 Project should be available in such files for easy retrieval and analysis. Initial versions of the IPCC scenarios have been packaged in that way.

Other reports from the IFs projects will, however, provide information concerning such scenario analysis using the system. This report has served its own purposes of elaborating the IFs base case and providing context for it.

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