ATTACHMENT B.2. MODEL A AND THE ARCHETYPAL SCENARIOS

In this attachment we present a model of world development and use it to construct quantitative developmental scenarios. The name of this model is "Model A."

Model A shows changes in population, economic output, energy use and income distribution over the period 2000-2150. Model A aggregates the countries of the world into four sectors: low-income countries, China, middle-income countries, and high-income countries.[1] Decadal rates of change of population, per capita GDP, energy intensity and income distribution are specified exogenously.

Below we construct and describe quantitative elements of the three archetypal scenarios presented in the main text: Techno-Progressivism, Balanced Equitable World and Green Sustainability.

We start with Techno-Progressivism as the business-as-usual or reference case scenario, as motivated in the main text. We'll use this scenario to introduce the major structural elements and assumptions of the model, and modify these to generate the other two scenarios.

The equations of Model A are shown in **Box B2-1** and **Box B2-2**. Derivation of initial values and growth rate projections can be seen in Hayes (2004; Appendix 2). A display of key variables, their initial values, and their values as of 2150 under the three archetypal scenarios is shown in **Box B2-3**. Supplemental discussion of the income distribution dynamics of Model A can be seen in the **Addendum**. Graphic displays of the three archetypal scenarios can be seen in **Box B2-4** through **Box B2-9**. A complete print-out of the reference case scenario (Techno-Progressivism) appears as **Box B2-10.**

a. TECHNO-PROGRESSIVE WORLD

* Population growth: World population growth slows gradually and stabilizes at 11 billion by 2100. This is slightly above the median population projection of 10 billion prepared by the United Nations, but markedly lower than its high projection in which population appears to stabilize at about 18 billion by 2150. The techno-progressive vision is actually rather agnostic concerning population. Some advocates see no reason that advanced technologies cannot support populations of 30 or 40 billion or more. Many believe that the human future will be largely either extra-terrestrial or downloaded to silicon-based nano-scale platforms, or both, such that population size is effectively unlimited and could grow to many trillions over the coming two or three centuries. Still other techno-progressives advocate a *minimal* terrestrial population, perhaps only a few hundred million, of super-empowered post-human entities. The stable population of 11 billion chosen here for the Techno-progressive scenario is consistent with moderate versions of Techno-progressivism, and serves as a convenient reference level for the two other archetypcal scenarios, both of which call for lower populations.

[1] These sectors follow the classification used by the World Bank in its World Development Report (1996), with the exception that we show China as a separate sector rather than included as one of the low income countries. See Hayes (2004; Appendix 2) for the list of countries included in each sector.

BOX B2-1. MODEL A

Equations of the Model

(1) $P_{i1} = P_{i0}(1 + n_{i0})^{10}$ population growth

(2) $y_{i1} = y_{i0}(1 + g_{i0})^{10}$ per capita income growth

(3) $e_{i1} = e_{i0}(1 + q_{i0})^{10}$ changes in energy intensity

(4) $y_{ij1} = y_{ij0}(1 + g_{i0})^{10} + s_{ij} r_{i0}(y_{i40} + y_{i50} - 2\,y_{i0}); \quad j = 1, 2, 3$
$= y_{ij0}(1 + g_{i0})^{10} - r_{i0}(y_{ij0} - y_{i0}); \quad j = 4, 5$
changes in income distribution
[see Box B2-2 and Addendum for discussion]

(5) $G_{i0} = 1.2 - [\,[\,\Sigma^{5}_{j=1}(6 - j)\,y_{ij0}\,] / 12.5\,(y_{i0})^2]$
Gini coefficient
[see Hayes (2004; Appendix A4) for discussion]

Variables and Parameters of the Model

P = population (billions)
y = per capita income (1990 US $)
e = energy intensity (total terawatts/total GDP)
G = Gini coefficient

n = population growth rate (%/year)
g = per capita income growth rate (%/year)
q = energy intensity growth rate [<0] (%/year)

i = sectoral index: 1, 4 [low income, China, middle income, high income]
j = income quintile: 1, 5 [Q1, Q2, Q3, Q4, Q5]
time subscript = 0, 1, 2… = 2000, 2010, 2020…

s_{ij} = redistributive proportionality factor = $(y_i - y_{ij}) / [3\,y_i - (y_{i1} + y_{i2} + y_{i3})]$
r = rate of redistribution (%)

Initial and Reference Scenario values are shown in Box B2-10.

BOX B2-2. MODELING CHANGES IN THE DISTRIBUTION OF INCOME

The equations below model changes in the distribution of income within an income sector. The per capita income of sector i grows at annual rate g_i, compounded decadally. In the absence of redistributive pressure (r = 0) all quintiles share equally in this growth. At the end of each decade income can be redistributed from those quintiles in which income is above the sector mean to those quintiles in which income is below the mean. The proportion of the total income above the mean that is redistributed in any period is given by the redistributive variable r, with $0 < r \leq 1$. The value of r can be varied by time period. Meanwhile, the proportionality factor s ensures that the amount which a quintile whose income is below the mean receives from the total amount to be distributed is proportional to the amount by which that quintile is below the mean. If a constant r is maintained over decades the incomes of all quintiles converge. The larger the value of r, the faster the convergence. We can also show $r < 0$, in which case incomes will be redistributed from those quintiles below the mean to those above the mean. The Addendum illustrates the derivation and interpretation of the model in more detail. The model is a calculatory convenience that allows scenarios to be generated showing changes in the level and distribution of income. It does not embody a theory of income distribution. This would require that r be made a function of other variables in the model, such as the growth rate g or per capita income, rather than standing as an exogenous variable.

(4.1) $y_{i11} = y_{i10}(1 + g_{i0})^{10} + s_{i1} r_{i0} (y_{i40} + y_{i50} - 2y_{i0})$

(4.2) $y_{i21} = y_{i20}(1 + g_{i0})^{10} + s_{i2} r_{i0} (y_{i40} + y_{i50} - 2y_{i0})$

(4.3) $y_{i31} = y_{i30}(1 + g_{i0})^{10} + s_{i3} r_{i0} (y_{i40} + y_{i50} - 2y_{i0})$

(4.4) $y_{i41} = y_{i40}(1 + g_{i0})^{10} - r_{i0} (y_{i40} - y_{i0})$

(4.5) $y_{i51} = y_{i50}(1 + g_{i0})^{10} - r_{i0} (y_{i50} - y_{i0})$

where

(6) $s_{ij} = (y_i - y_{ij}) / [3y_i - (y_{i1} + y_{i2} + y_{i3})]$

(7) $y_i = 1/5 \Sigma y_{ij}$

definitions:
y_{ijt} = per capita income of quintile j of income sector i in year t
y_{it} = per capita income of the full income sector i in year t
g_{it} = growth rate of per capita income in income sector i in year t
s_{ij} = redistributive proportionality factor for each quintile j of income sector i
r_{it} = rate of redistribution for income sector i in year t

* Economic Growth: Under Techno-Progressivism per capita GDP growth in the high income countries recovers from its current Great Recession slump, reaches a slightly-better-than-historic-average rate of 2% annually after 2030, and stays at that level indefinitely. The other regions maintain their current catch-up rates of 4-5% for some time before slowing to sustained rates of 2%. The middle income countries, China and the low income countries stabilize at this 2% annual rate of per capita CGP growth at about the time that each of them reach per capita output levels near $25,000. By 2150 per capita GDP worldwide has reached $127,000, a level 26 times its 2000 level of $4,900. The low income countries have grown faster than the high income countries, reaching levels of GDP fully 181 times greater than their levels in 2000. However, the per capita income of $466,000 in the high income countries remains absolutely higher than the low income country level of $66,000, a ratio of 7:1.

Note that the sustained rate of 2% per capita growth is barely the level most mainstream economists and political leaders appear to believe is necessary to maintain social cohesion and political stability in advanced societies. However, it is significantly *above* the 0.5- 1.2% percent that some analysts foresee as the new normal following the end of the one-time long-term technological boom of the late 19th through mid-20th centuries. Still, an annual growth rate of even just 0.5% represents a 136-year doubling time.

* Energy use: Energy intensity is the measure of how much energy it takes to generate a dollar of output. It is measured in units of TW/$1000 GDP. Under Techno-Progressivism energy intensity declines (i.e., production becomes more energy efficient) along the historically aggressive path described in Appendix Box A2-6 and Box A2-7 of Hayes (2004). Initially it declines most rapidly in China and least rapidly in the low and middle income countries. Meanwhile the rate of decline decreases in the developed countries in the late 21st century, reflecting technological constraints in the face of very high, and continually increasing, absolute levels of energy production. By 2100 energy intensity is declining in all sectors at the same moderate rate of 0.5% annually. By 2150 $1000 of GDP requires 80 KW of energy, compared with 450 KW in 2000, a 560% improvement in energy intensity. Total energy production reaches 115 TW by 2150, over eight times the level of 13.6 TW generated in 2000. As noted in the main text of the whitepaper outline, proposals to generate energy at this level rely on technologies that have not yet been shown to be feasible, much less practicable.

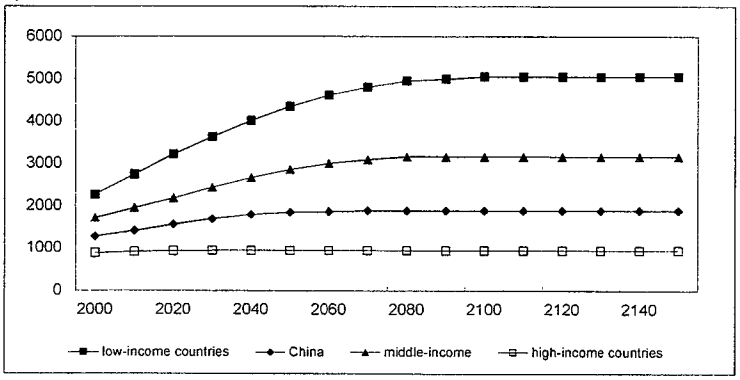
* Income distribution within countries: Under Techno-Progressivism everyone is doing absolutely better indefinitely, and as a consequence concern about economic inequality is minimal. We show inequality in the high-income countries increasing at 6% per decade, roughly the rate that the top/bottom (20/20) quintile ratio in the United States increased over the three decades 1980-2010. Under this assumption, the 20/20 ratio in the high-income countries increases from 6.5:1 in 2000 to 15.6:1 in 2150. This is equivalent to the 20/20 ratios that obtained in, for example, Thailand, Columbia and Zimbabwe in the late 1990s. The other three income sectors begin in 2000 with 20/20 ratios higher than in the high-income countries. As a simplifying assumption we show them experiencing greater economic inequality as per capita income approaches the levels of the high-income countries, and increasing at the same rate of 6% per decade. By 2150 the 20/20 ratios in all four income sectors have converged to the same value of about 15:1. Both per capita GDP and economic inequality continue to increase after that point, at rates of 2% annually and 6% per decade respectively.

	BOX B2-3. MODEL A - Preliminary Results, 6/2/14					
			Historical	ARCHETYPAL SCENARIOS - values as of 2150		
			Values -	Techno-Progressive	Balanced Equitable	Green
	Variable	Units	2000	World (BAU)	World	Sustainability
1	World population	billions	6.2	11	9	7
2	World GDP	trillions ('90 US$)	30	1,402	676	178
3	World GDP/capita	$/person ('90 US$)	4,876	127,000	75,000	25,000
4	World population growth rate	%/yr	1.3	0	0	0
5	World GDP/capita growth rate	%/yr	1.2	2	0	0
6	World energy use	TW	13.6	115	60	18
7	World energy use/capita	KW/person	2.2	10.4	6.7	2.6
8	Energy intensity	W/$1000 ('90 US$)	450	80	90	100
	GDP/capita (by income sector)	('90 US$)				
9	low-income countries		366	66,000	75,000	25,000
10	China		628	93,000	75,000	25,000
11	middle-income countries		2,752	143,000	75,000	25,000
12	high-income countries		26,689	466,000	75,000	25,000
	Ratio of per capita GDP of high-income countries to others					
13	low-income countries		73	7	1	1
14	China		43	5	1	1
15	middle-income countries		10	3	1	1
16	high-income countries		1	1	1	1
	Ratio of top income quintile to bottom income quintile, in each sector					
17	low-income countries		7.8	15.7	3.0	3.0
18	China		7.1	15.7	3.0	3.0
19	middle-income countries		7.4	15.7	3.0	3.0
20	high-income countries		6.5	15.7	3.0	3.0
	Gini Coefficients					
21	low-income countries		0.38	0.52	0.27	0.27
22	China		0.36	0.51	0.27	0.27
23	middle-income countries		0.37	0.49	0.27	0.27
24	high-income countries		0.32	0.42	0.27	0.27
	Mean Household Income (by quintil	('90 US$)				
	Low-Income Countries (n=51)					
25	1st		248	23,000	90,000	30,000
26	2nd		411	55,000	111,000	39,000
27	3rd		586	89,000	134,000	46,000
28	4th		850	141,000	166,000	57,000
29	5th		1,931	354,000	270,000	90,000
	China (n=1)					
30	1st		424	29,000	90,000	30,000
31	2nd		718	78,000	111,000	39,000
32	3rd		1,080	137,000	134,000	46,000
33	4th		1,613	226,000	166,000	57,000
34	5th		3,002	455,000	270,000	90,000
	Middle-Income Countires (n=57)					
35	1st		1,934	51,000	90,000	30,000
36	2nd		3,157	124,000	111,000	39,000
37	3rd		4,463	202,000	134,000	46,000
38	4th		6,387	317,000	166,000	57,000
39	5th		14,327	793,000	270,000	90,000
	High-Income Countries (n=25)					
40	1st		18,267	145,000	90,000	30,000
41	2nd		34,983	498,000	111,000	39,000
42	3rd		50,728	830,000	134,000	46,000
43	4th		69,979	1,235,000	166,000	57,000
44	5th		119,257	2,274,000	270,000	90,000
45	**Ratio of high income top quintile/low income bottom quintile**		481:1	99:1	3:1	3:1
	NB: For Techno-Progressive World (BAU) values of per capita GDP, energy use and inequality continue to increase after 2150. For Balanced Equitable World and Green Sustainability World these values are constant after 2150. The final working paper will show all dollar values in current US $.					

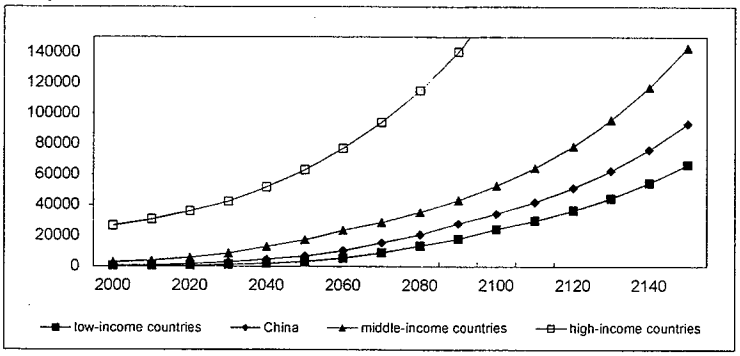
BOX B2-4. TECHNO-PROGRESSIVISM (BAU)

POPULATION AND ECONOMIC TRAJECTORIES

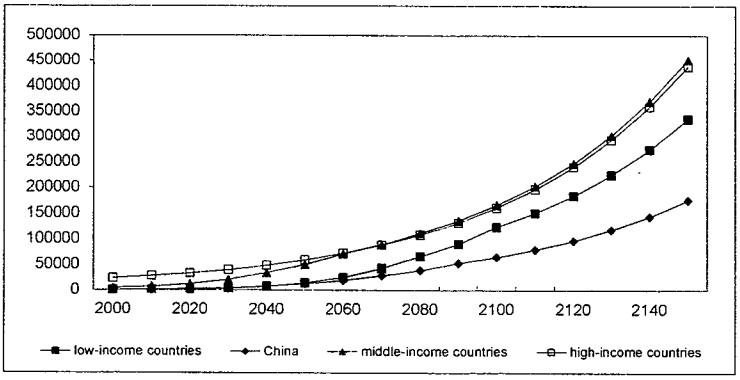
Population



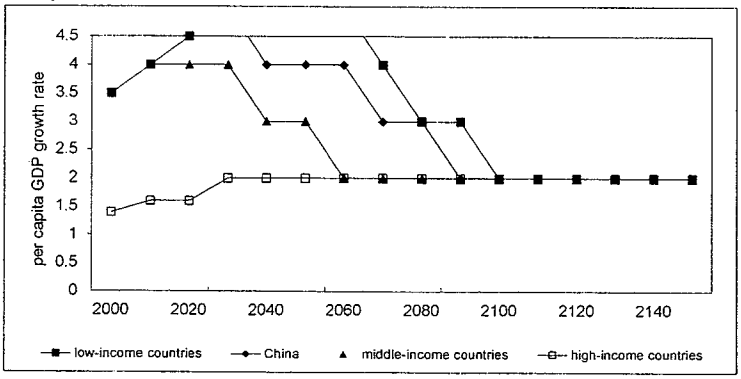
Per capita GDP



Total GDP

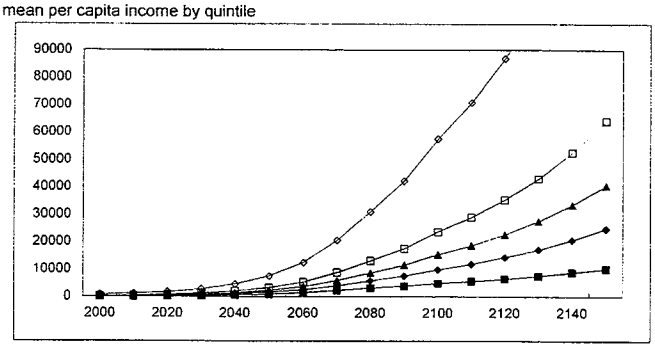


Per Capita GDP Growth Rates

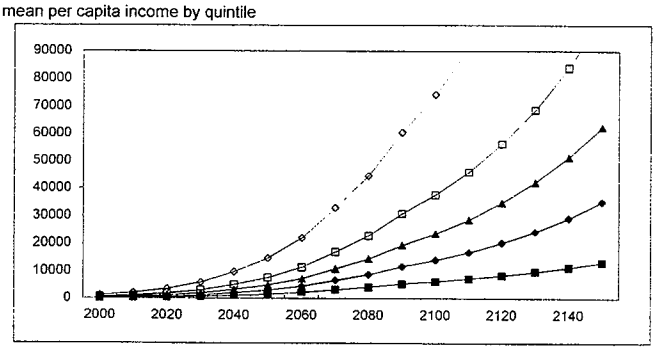


BOX B2-5. TECHNO-PROGRESSIVE INCOME DISTRIBUTION TRAJECTORIES
[All values 1990 US$; all axes to same sacle]

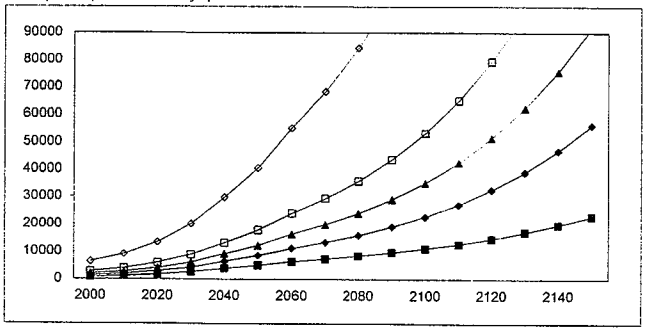
LOW-INCOME COUNTRIES
mean per capita income by quintile



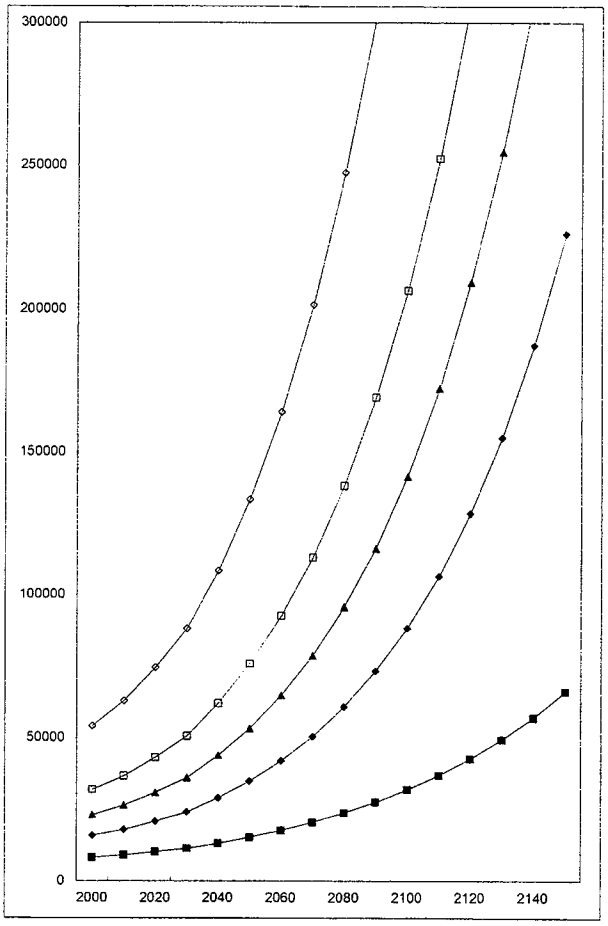
CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



HIGH-INCOME COUNTRIES
mean per capita income by quintile



b. BALANCED EQUITABLE WORLD

Balanced Equitable World (BEW) seeks to maintain the best features of modernity and global industrial civilization while respecting the imperatives of biogeophysical limits, ensuring an equitable distribution of wealth and income, and avoiding the use of technologies that destabilize ecological systems and the nature of human life.

* Population growth – Population growth rates follow the Techno-Progressive business-as-usual trajectory and decline slowly to 2020. After 2020 population growth slows more rapidly than under Techno-Progressivism, reflecting a stronger expressed preference for a smaller global population. Global population reaches 9 billion by 2050 and remains at that level indefinitely.

* Economic growth – Per capita GDP growth follows the business-as-usual scenario through 2030. After that time growth rates in high-income countries begin to decline, reach zero in 2150, and remain stable at zero after that. Middle-income countries grow strongly until 2050 but increasingly more slowly after that. Growth rates in lower-come countries and China don't begin to decline until later in the 21st century, as they have larger gaps to close. By 2150, however, the per capita income gap among all four income sectors has closed and economic output no longer increases. Note that at no point over this 150-year period did the level of economic output *decline*. In 2150 per capita GDP worldwide is $75,000, a 15-fold increase over its level of $4,900 in 2000. By any measure this is a world of extraordinary material abundance, shared equitably by all.

* Energy use: - Total energy production in 2150 is 60 TW, nearly 50% lower than the business-as-usual Techno-Progressive level of 115 TW. Importantly, energy production is kept at this level indefinitely. The lower level of global energy production is attributable to the 41% lower level of per capita GDP and the 18% lower level of world population. (This lower level of energy demand is offset slightly by the somewhat arbitrary 12% higher level of energy intensity used in this scenario, reflecting constraints on technological innovation.) Still, 60 TW is 4.4 times the level of 13.6 TW produced in 2000. Establishing an indefinitely sustainable, carbon-free global energy regime of that scope and scale, over the next 150 years, represents a major challenge for the Balanced Equitable World scenario. At present there are no good proposals showing how this might be accomplished.

* Income distribution within countries: Under Balanced Equitable World income inequality in all sectors follows the business-as-usual pattern of increasing inequality until 2020. At that point the inequality growth rate begins to decline. It reaches zero by 2030 and by 2040 inequality begins to decline absolutley. This pattern reflects institutional, behavioral, political and other changes of a transformative nature worldwide over the two decades 2020-2040. Inequality continues to decline absolutely through the second half of the 21st century and beyond, resulting in a 20/20 quintile ratio of 3:1 in all sectors by 2150. At that time the top quintile of households worldwide have a mean annual income of $270,000, while the bottom quintile receives $90,000. These represent increases since 2000 of 230% for the top quintile and 360% for the bottom quintile. Note that these quintile figures are consistent with both a perfectly static income distribution, in which households stay within a given quintile throughout the income-receiving years of their members, and with a perfectly mobile distribution, in which all households begin at $90K and end at $270K. An important feature of the Balanced Equitable World scenario is that although the overall rate of economic growth is slower than most economists and political leaders would accept today, it is sufficient to allow economic inequality to be dramatically reduced without any income quintile in any income sector needing to undergo any absolute reduction in income at any time.

c. GREEN SUSTAINABILITY WORLD

The scenario of Green Sustainability World is based on the assumption that Balanced Equitable World is most likely unrealizable and in any event unsustainable. It calls for an eventual steady-state global economy in which the annual incomes received by households in the highest income quintiles are lower than they are today, and in which those in today's lowest income quinitiles are significantly better off than they are today. Under Green Sustainability the world of 2150 is one of frugality but hardly one of poverty.

* Population growth – The population trajectory follows that of Balanced Equitable World through 2050, at which point the growth rate reaches zero and world population is 9 billion. Rather than stabilizing indefinitely at that level, however, after 2060 population begins a slow absolute decline and stabilizes at 7 billion by 2150.

* Economic growth - Per capita GDP growth rates follow the Balanced Equitable World scenario through 2030. After that growth rates in the high income countries begin to decline steadily, reaching zero by 2050. In 2060 output begins to decline absolutely. This decline continues through the 21st century but begins to moderate in the early 22nd century and by 2150 output stabilizes at a new steady-state level. Over this period the developing countries have grown slowly but continuously, and the historic per capita income gap between the developed and the developing world is now closed. Global per capita output is now $25,000, a 680% increase for the low income countries. For the high income countries it represents effectively no change from their per capita level of output in 2000, but it is a 46% decline from the $47,000 peak level realized in 2050-2060.

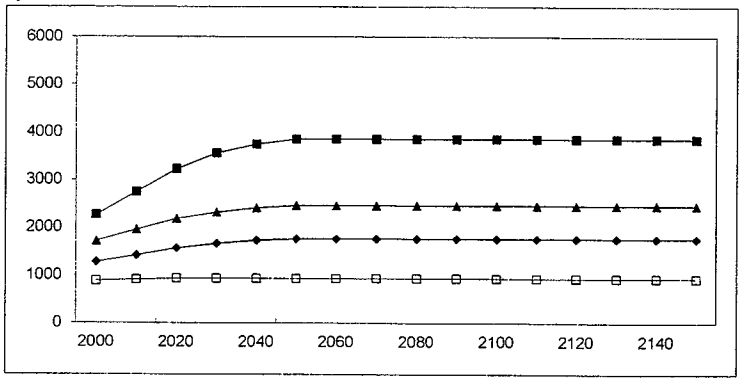
* Energy use: - Under Green Sustainability world energy production in 2150 is 18 TW, 32% greater than the 13.6 TW level of 2000 but dramatically lower than the 60 TW of Balanced Equitable World and the 115 TW of Techno-Progressivism. The difference is largely due to the combined effects of lower population and the lower levels of per capita GDP. Note, however, that energy use goes through a rise-and-decline trajectory, with levels above 30 TW throughout the half century between 2040 and 2090 and peaking at over 38 TW in 2060. As a consequence, interim sources will be needed to provide another 20 TW of energy above the sustainable level of 18 TW. Somewhat arbitrarily, energy intensity for Green Sustainability is shown to be 100 W/$1000 GDP, somewhat greater than the levels in the other two scenarios. This is meant to reflect the generally lower level of technological innovation and efficiency that might be expected under this scenario.

* Income distribution within countries: Under Green Sustainability economic inequality within countries follows a pattern similar to that of Balanced Equitable World. It continues to increase until 2020, stabilizes during the 2030s, and then declines to a 20/20 quintile ratio of 3:1 by 2150. However, the challenge of reducing economic inequality is much greater in this scenario because the overall level of economic output is declining as well. In order to achieve both reduced output and reduced inequity, the upper quintile of households in the high-income countries must undergo a significant absolute decline in income. In 2000 the mean household income in this quintile was $119,000; it rises to $203,000 by 2060 but over the subsequent century declines to $90,000, a decrease of 24% from its 2000 level and 56% from that of 2060. Note, of course, that $90,000 in annual household income is a 470% *increase* for those initially in the top quintile of the *lowest* income countries. Even given the markedly reduced rates of growth under Green Sustainability, nearly 95% of the world's population is doing absolutely better economically in 2150 than it was in 2000. This is a consequence of the dynamics of exponential change: even very low rates of annual change generate large absolute changes if sustained over a long enough period.

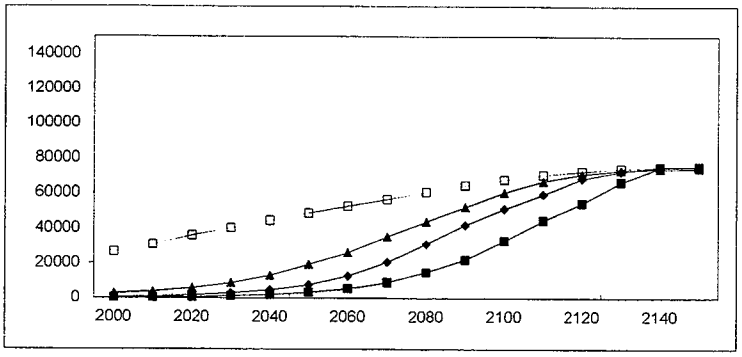
BOX B2-6. BALANCED EQUITABLE WORLD

POPULATION AND ECONOMIC TRAJECTORIES

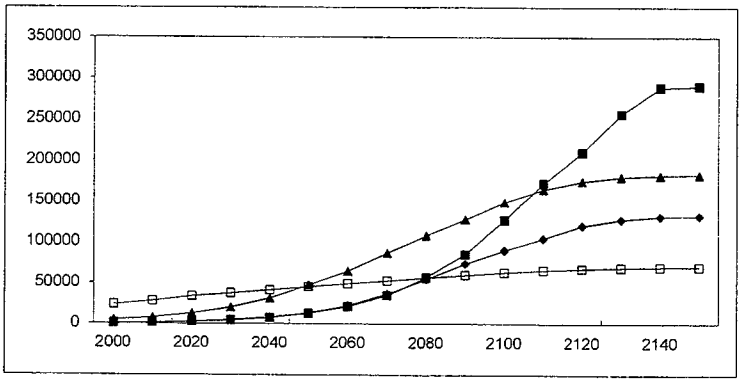
Population



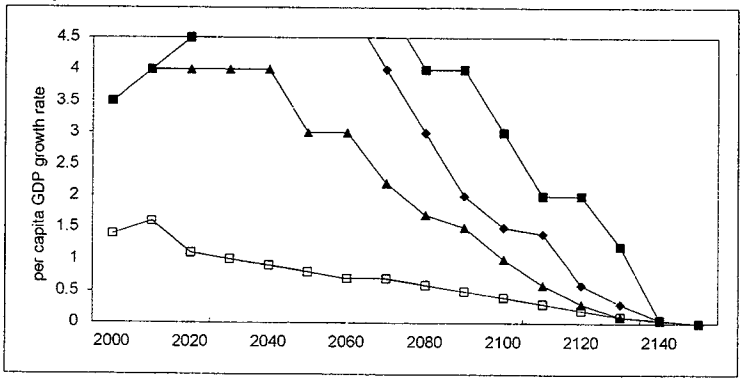
Per capita GDP



Total GDP

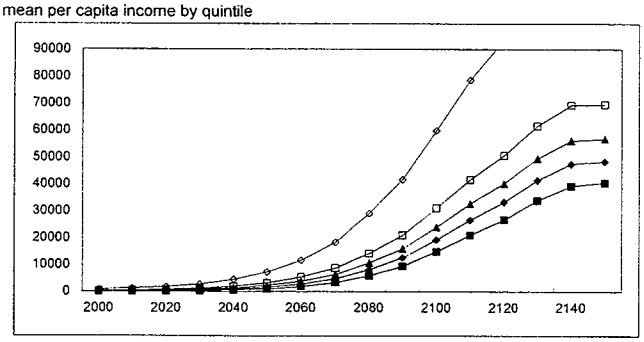


Per Capita GDP Growth Rates

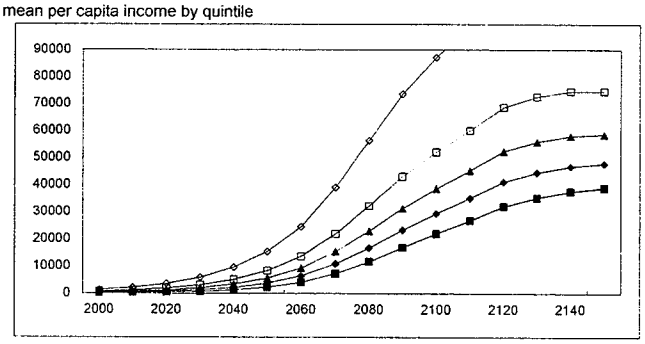


BOX B2-7. BALANCED EQUITABLE WORLD INCOME DISTRIBUTION TRAJECTORIES
[All values 1990 US$; all axes to same scale]

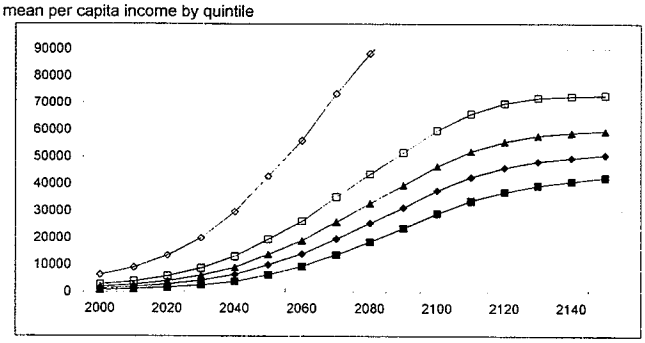
LOW-INCOME COUNTRIES
mean per capita income by quintile



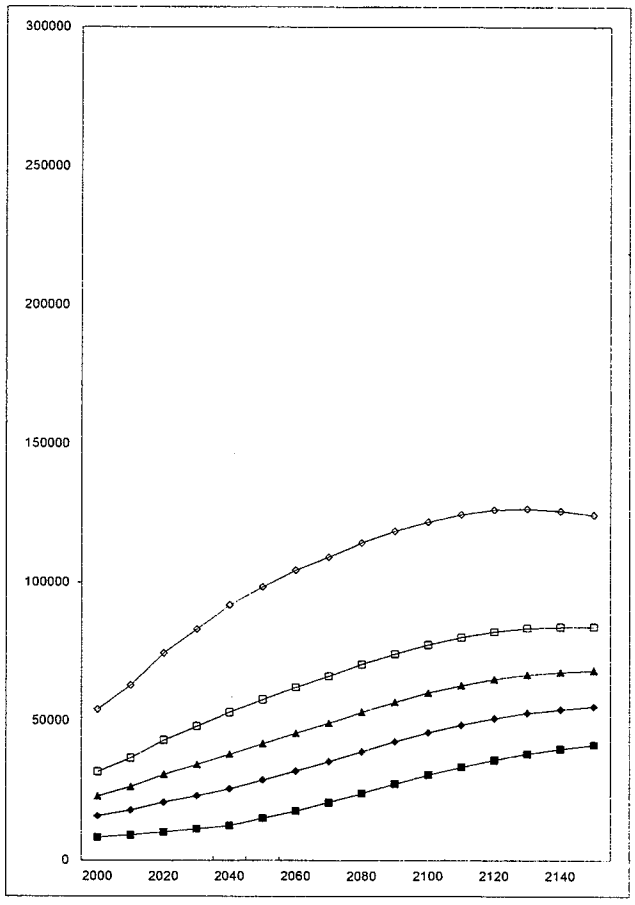
CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



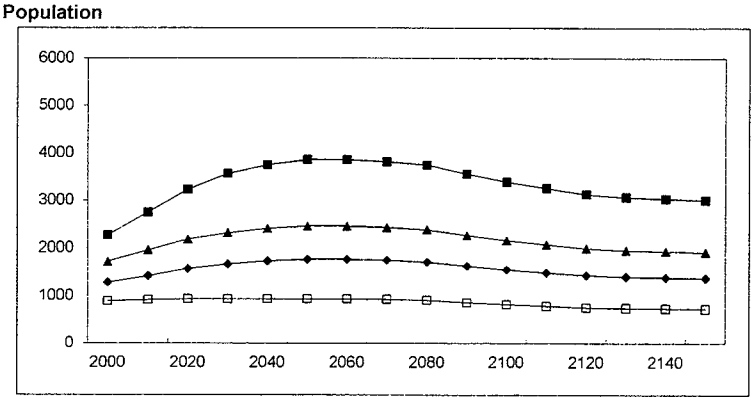
HIGH-INCOME COUNTRIES
mean per capita income by quintile



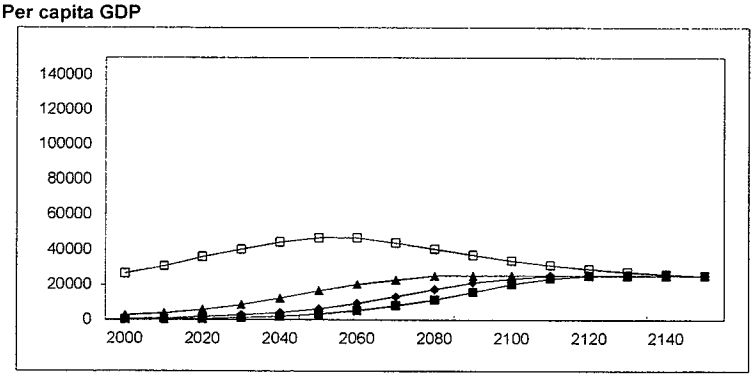
BOX B2-8. GREEN SUSTAINABILITY WORLD

POPULATION AND ECONOMIC TRAJECTORIES

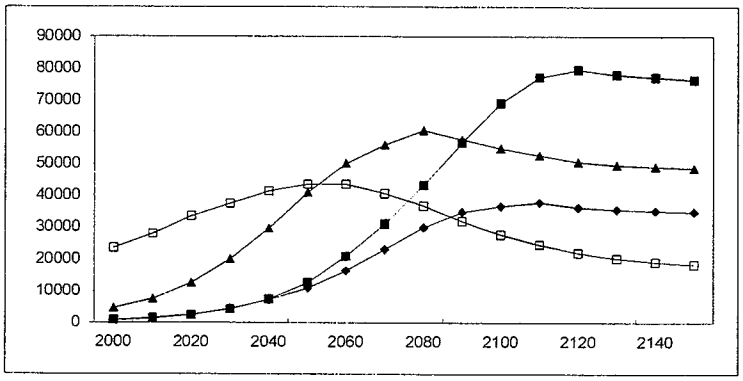
Population



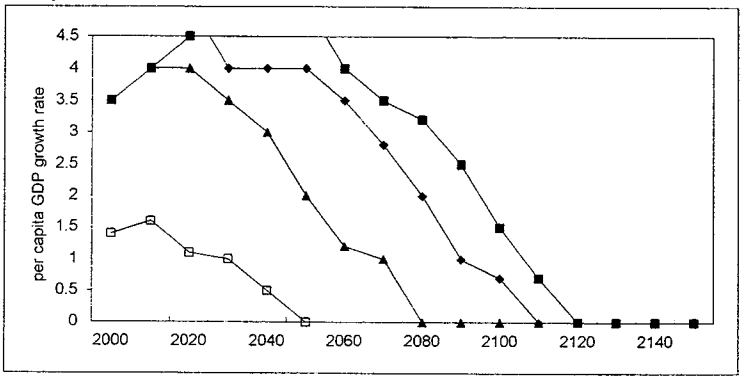
Per capita GDP



Total GDP

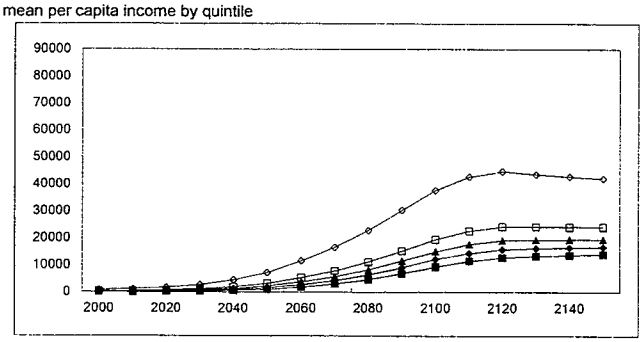


Per Capita GDP Growth Rates

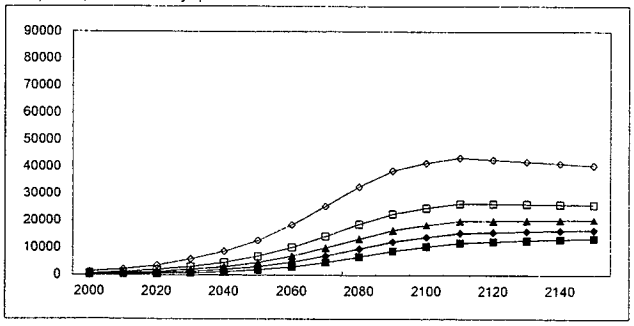


BOX B2-9. GREEN SUSTAINABILITY WORLD INCOME DISTRIBUTION TRAJECTORIES
[All values 1990 US$; all axes to same scale]

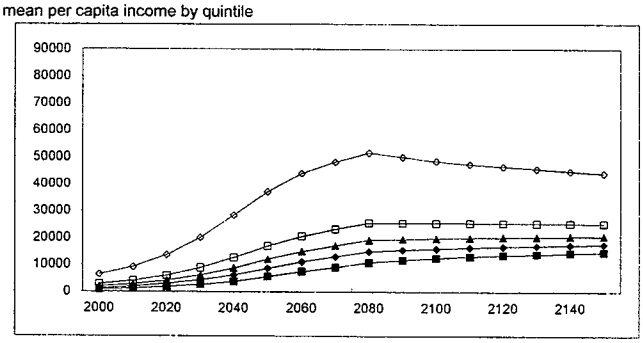
LOW-INCOME COUNTRIES
mean per capita income by quintile



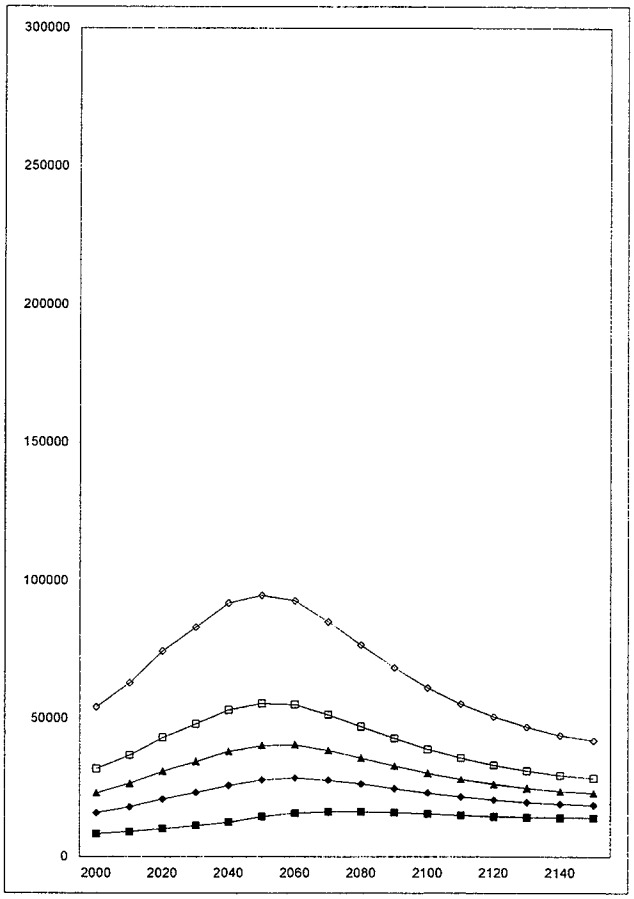
CHINA
mean per capita income by quintile



MIDDLE-INCOME COUNTRIES
mean per capita income by quintile



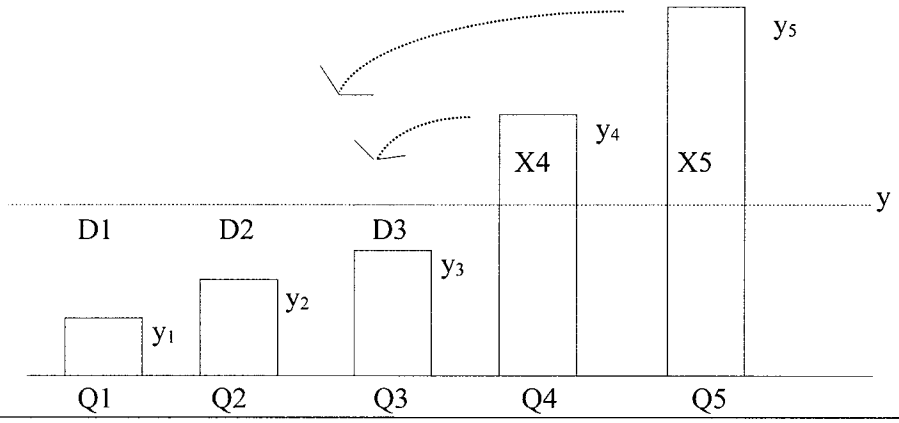
HIGH-INCOME COUNTRIES
mean per capita income by quintile



ADDENDUM: SUPPLEMENTAL NOTE ON MODELING CHANGES IN THE DISTRIBUTION OF INCOME

The equations shown in **Boxes B2-1** and **B2-2** above allow us to model changes in the distribution of income among quintiles over time. The **Addendum Box 1** below illustrates how this works.

Addendum Box 1. Model A Income Distribution Procedure



At the end of each period proportion "r" of the total income above the mean income y [r (X4 + X5)] is redistributed to the three quintiles below the mean in the same proportion "s" that each of them is below the mean. For example, for the bottom quintile, Q1, this proportion is: s_1 = D1/(D1 + D2 + D3). We call "s" the redistributive proportionality factor.

This value can be expressed in terms of the mean income of the quintile (y_i) and the mean income of the sector as a whole (y), as:

$$s_1 = (y - y_1) / [(y - y_1)+(y - y_2)+(y - y_3)]$$
$$= (y - y_1) / [3y - (y_1 + y_2 + y_3)],$$

which is equivalent to equation (6) shown in Box B2-2 (without the income sector subscript i).

If a positive "r" is maintained over time the incomes for all quintiles will converge. A negative "r" will redistribute income from the three quintiles below the mean to the two above the mean.

The model allows a growth rate "g" to be exogenously specified for the economy as a whole. Thus the model can show how the per capita incomes of any quintile, and of the income sector as a whole, will change given assumptions about the aggregate growth rates of income and rates of change in the distribution of income.

The figures in **Addendum Box 2** illustrate Model A's income distribution dynamics. Figure A shows the quintile distribution of income for the United States in 1990, in 1990 dollars, and illustrates the trivial scenario in which there is no change in the level of total income (g = 0), and no change in the distribution of income (r = 0), over the period between 1990 and 2100.

Figure B illustrates a scenario in which the economy grows at a constant rate of 1% per year (g = .01) but the distribution of income is unchanged (r = 0). Both the 20/20 quintile ratio and the Gini coefficient remain constant over time. However, the absolute difference between the incomes received by each quintile becomes greater.

Figure C shows total income growing at the same rate of 1% as in Figure B, but now shows redistributive pressure of 1% (r = .01). This means that 1% of the income of the top two quintiles that is above the mean of all five quintiles is redistributed to the bottom three quintiles, at the end of each period. Now the 20/20 ratio and Gini coefficients decline over time, while the absolute difference among quintiles remains constant.

Figures D and E show the results of progressively stronger redistributive efforts, r = .0175 and r = .04, respectively. For any given rate of aggregate growth (in this example, 1%) there is a threshold level of redistributive effort above which the top quintile will be forced to undergo an absolute reduction in its income, rather than simply a reduction in its relative income share. In Figure D (r = .0175) incomes converge rapidly but at no point need the top income quintile forsake further income growth entirely. In Figure E however (r = .04), the incomes of the top quintile must decline until 2025, at which time they can begin to grow once more. Note that as the average incomes of the quintiles converge, their rates of growth do so as well.

Figure F illustrates a scenario in which there is no aggregate economic growth (g = 0) but the distribution of income becomes more equal. In this situation there is no choice but that the top quintiles undergo an absolute decline in their average incomes. It is instructive to compare Figure F with Figure C. Both show a redistributive pressure of 1% (r = .01) and thus show the same 20/20 ratios and Gini coefficients at every point in time. But in C this takes place while aggregate income is growing at 1%, while in F there is no growth of aggregate income.

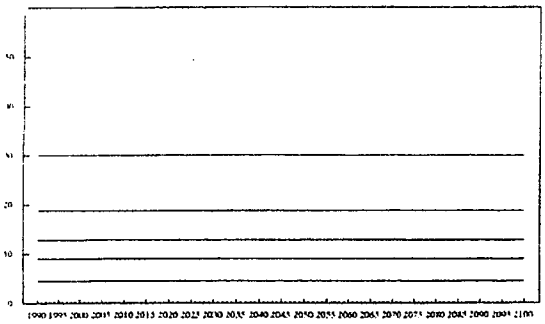
Interpretation of "r"

As noted in the text, the term "redistributive pressure" is used here in a very general sense. It might refer to policies that take from the rich and give directly to the poor. It might refer to policies that tax the rich to provide educational services that increase the earnings abilities of the poor. It might refer to market mechanisms that generate greater income equality, perhaps by creating incentives for hard work. Its use in Model A is heuristic, not analytic.

Addendum Box 2. Model A Income Distribution Dynamics

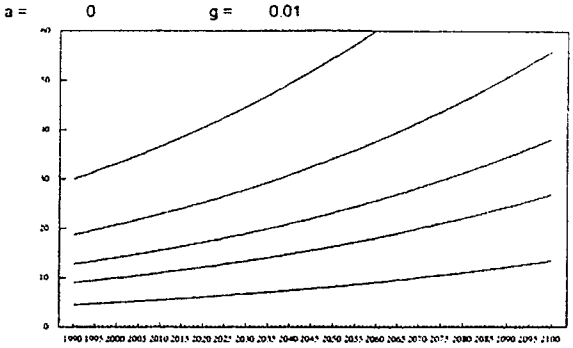
A. 0% Growth, 0% Redistributional effort

0 g = 0



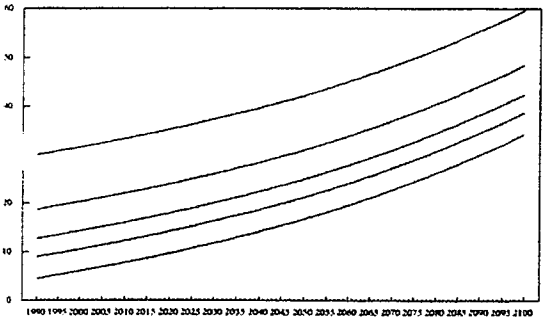
B. 1% Growth, 0% Redistributional effort

a = 0 g = 0.01



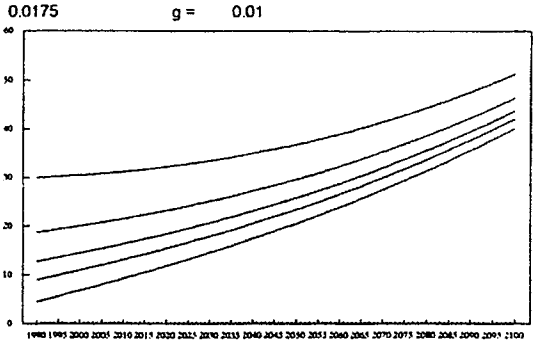
C. 1% Growth, 1% Redistributional effort

0.01 g = 0.01



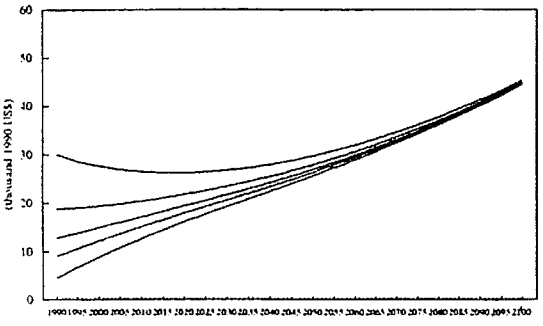
D. 1% Growth, 1.75% Redistributional effort

0.0175 g = 0.01



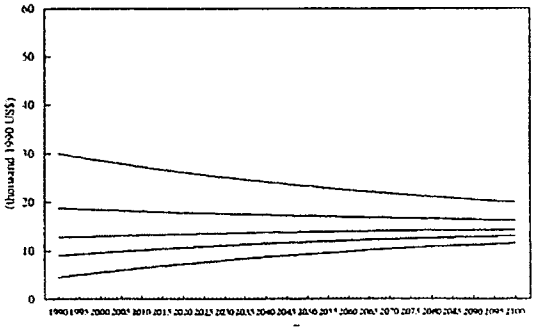
E. 1% Growth, 4% Redistributional effort

0.04 g = 0.01



F. 0% Growth, 1% Redistributional effort

0.01 g = 0



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1																						
2	**BOX B2-10**																					
3																						
4	**MODEL A - REFERENCE SCENARIO (TECHNO-PROGRESSIVISM)**																					
5	Richard Hayes - 9/30/14																					
6																						
7					1990	1994	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150
8																						
9	**POPULATION GROWTH (%/yr)**																					
10	low-income countries				2.17	2.2	1.9	1.6	1.2	1	0.8	0.6	0.4	0.3	0.1	0.1	0	0	0	0	0	0
11	China				1.2	1.2	1	1	0.8	0.6	0.3	0.1	0.1	0	0	0	0	0	0	0	0	0
12	middle-income countries				1.5	1.5	1.3	1.1	1.1	0.9	0.7	0.5	0.3	0.2	0	0	0	0	0	0	0	0
13	high-income countries				0.7	0.7	0.3	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
14																						
15	world				1.541568	1.5722	1.329689	1.168263	0.969477	0.790845	0.600003	0.424947	0.282328	0.192798	0.045388	0.045636	0	0	0	0	0	
16																						
17	**POPULATION (10^6)**																					
18	low-income countries				1826	1991	2271.947	2747.351	3224.046	3635.101	4017.408	4352.007	4621.12	4809.711	4956.189	5005.999	5056.31	5056.31	5056.31	5056.31	5056.31	5056.31
19	China				1135	1191	1279.915	1414.524	1563.291	1693.493	1798.213	1852.977	1871.599	1890.409	1890.409	1890.409	1890.409	1890.409	1890.409	1890.409	1890.409	1890.409
20	middle-income countries				1479	1570	1717.854	1956.34	2183.82	2437.75	2667.324	2860.727	3007.399	3098.988	3161.592	3161.592	3161.592	3161.592	3161.592	3161.592	3161.592	3161.592
21	high-income countries				827	850	886.4603	913.457	931.9101	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276	941.276
22																						
23	world				5267	5602	6156.175	7031.672	7903.067	8707.621	9424.221	10006.99	10441.39	10740.38	10949.47	10999.28	11049.59	11049.59	11049.59	11049.59	11049.59	11049.59
24																						
25	**PER CAPITA GDP**																					
26	**GROWTH RATE (%/yr)**																					
27	low-income countries				-0.08	1	3.5	4	4.5	5	5	5	5	4	3	3	2	2	2	2	2	2
28	China				11.7	6	5	5	5	5	4	4	4	3	3	2	2	2	2	2	2	2
29	middle-income countries				-1.3	1	3.5	4	4	4	3	3	2	2	2	2	2	2	2	2	2	2
30	high-income countries				1	2	1.4	1.6	1.6	2	2	2	2	2	2	2	2	2	2	2	2	2
31																						
32	world				0.106173	1.215774	1.177115	1.714593	2.13061	2.710628	2.563696	2.769366	2.577126	2.428499	2.312635	2.20691	2	2	2	2	2	
33																						
34	**PER CAPITA GDP ($/k)**																					
35	low-income countries				346	345	366.3336	519.8521	775.5283	1216.27	2005.291	3306.166	5450.946	8987.09	13407.16	18097.78	24429.44	29838.19	36444.45	44513.35	54368.73	66406.11
36	China				275	438	627.7983	1035.064	1706.533	2813.597	4638.837	6920.331	10323.92	15401.48	20789.82	28063.33	34276.62	41865.56	51134.72	62456.08	76284.03	93173.53
37	middle-income countries				2731	2592	2752.28	3905.672	5826.578	8692.232	12967.29	17504.01	23627.94	28859.23	35248.74	43052.91	52584.94	64227.39	78447.51	95816.01	117029.9	142940.7
38	high-income countries				22742	23671	26688.98	30699.63	36026.35	42277.32	51637.63	63070.34	77034.29	94089.9	114921.7	140365.6	171443	209400.9	255762.9	312389.5	381553.3	466030.3
39																						
40	world				4514.524	4533.738	4876.819	5486.029	6512.113	8058.48	10567.55	13655.7	18013	23308.23	29715.13	37446.75	46693.78	57031.91	69658.93	85081.61	103918.9	126926.8
41																						
42	**GDP GROWTH RATE (%/yr)**																					
43	low-income countries				2.09	3.2	5.4	5.6	5.7	6	5.8	5.6	5.4	4.3	3.1	3.1	2	2	2	2	2	2
44	China				12.9	7.2	6	6	5.8	5.6	4.3	4.1	4.1	3	3	2	2	2	2	2	2	2
45	middle-income countries				0.2	2.5	4.8	5.1	5.1	4.9	3.7	3.5	2.3	2.2	2	2	2	2	2	2	2	2
46	high-income countries				1.7	2.7	1.7	1.8	1.7	2	2	2	2	2	2	2	2	2	2	2	2	2
47																						
48	world				1.647741	2.787974	2.506804	2.882856	3.100087	3.501473	3.1637	3.194313	2.859454	2.621296	2.358023	2.252546	2	2	2	2	2	
49																						
50	**GDP (10^9 $)**																					
51	low-income countries				631	686	832.2904	1428.216	2500.339	4421.266	8056.073	14388.46	25189.47	43225.31	66448.43	90597.46	123522.9	150871.2	184274.4	225073.3	274905.2	335769.9
52	China				312	522	803.5281	1464.124	2667.807	4764.806	8341.616	12823.21	19322.24	29115.1	39301.27	53051.17	64796.85	79143.05	96665.53	118067.6	144208	176136.1
53	middle-income countries				4038	4070	4728.015	7640.824	12724.2	21189.49	34587.95	50074.17	71058.64	89434.4	111442.1	136115.7	166252.1	203060.8	248019	302931.1	370000.9	451920.1
54	high-income countries				18797	20120	23658.72	28042.8	33573.32	39794.62	48605.26	59366.6	72510.53	88564.56	108173	132122.8	161375.1	197104	240743.4	294044.7	359147	438663.1
55																						
56	world				23778	25398	30022.55	38575.96	51465.66	70170.19	99590.9	136652.4	188080.9	250339.4	325364.8	411887.1	515947	630179	769702.4	940116.6	1148261	1402489
57																						
58	**RATIO OF HIGH-INCOME PER CAPITA**																					
59	**GDP TO THAT OF OTHER COUNTRIES**																					
60	low-income countries				65.72832	68.61159	72.8543	59.05455	46.45395	34.7598	25.75069	19.07658	14.13228	10.46945	8.571661	7.75596	7.017882	7.017882	7.017882	7.017882	7.017882	7.017882
61	China				82.69818	54.04338	42.51203	29.65964	21.11085	15.02608	11.13159	9.113775	7.461728	6.109146	5.527784	5.001746	5.001746	5.001746	5.001746	5.001746	5.001746	5.001746
62	middle-income countries				8.327353	9.13233	9.697042	7.860269	6.183107	4.863804	3.982146	3.603195	3.260305	3.260305	3.260305	3.260305	3.260305	3.260305	3.260305	3.260305	3.260305	3.260305
63	high-income countries				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
64																						
65					1990	1994	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150
66	**REFERENCE CASE**																					
67	**DISTRIBUTIONAL CHANGE (%)**																					
68	low-income countries					0	0	0	0	0	0	-0.25	-0.25	-0.26	-0.26	-0.22	-0.14	-0.134	-0.127	-0.118	-0.108	
69	China					0	0	-0.08	-0.23	-0.23	-0.19	-0.17	-0.16	-0.154	-0.15	-0.135	-0.13	-0.123	-0.116	-0.109	-0.1	
70	middle-income countries					0	0	0	0	0	-0.24	-0.24	-0.24	-0.22	-0.2	-0.2	-0.2	-0.133	-0.127	-0.118	-0.108	
71	hi-income countries					0	-0.21	-0.2	-0.19	-0.18	-0.17	-0.16	-0.15	-0.14	-0.135	-0.126	-0.12	-0.115	-0.107	-0.102	-0.093	
72																						
73	**REFERENCE CASE QUINTILES (mean $/person)**																					
74	low-income countries																					
75		Q1				106	112.5211	158.7222	234.9476	364.8664	594.329	968.0993	1491.435	2286.773	3157.862	3927.882	4910.848	5692.909	6592.678	7630.434	8836.04	10246.02
76		Q2				176	186.8275	263.5387	390.1017	605.816	986.8104	1607.41	2557.867	4065.684	5857.662	7648.824	10019.33	12006.12	14390.15	17254.52	20704.17	24867.12
77		Q3				251	266.4416	375.8421	556.3382	863.9762	1407.326	2292.386	3700.472	5971.66	8750.303	11635.54	15492.69	18770.26	22744.56	27566.02	33420.01	40532.56
78		Q4				364	386.3933	545.046	806.8012	1252.938	2040.903	3324.416	5421.998	8843.33	13108.55	17642.2	23739.23	28961.57	35331.89	43102.02	52578.54	64135.17
79		Q5				827	877.8772	1238.332	1833.035	2846.647	4636.887	7553.001	12475.68	20609.55	30965.79	42253.56	57528.13	70718.89	86906.51	106758.4	131077.7	160843.2
80	China																					
81		Q1				136	192.9186	314.2441	503.1748	778.3197	1199.041	1688.249	2382.28	3361.111	4297.927	5484.952	6359.096	7362.794	8521.046	9858.83	11406.02	13212.56
82		Q2				230	326.2594	531.4422	859.6724	1371.863	2187.248	3177.982	4623.761	6730.45	8894.197	11752.5	14100.93	16921.02	20313.73	24398.37	29319.95	35264.58
83		Q3				346	490.8076	799.4739	1299.606	2104.321	3406.738	5016.376	7389.845	10888.36	14566.19	19486.93	23654.68	28716.27	34866.41	42340.78	51426.51	62477.71
84		Q4				517	733.3744	1194.59	1948.128	3184.064	5204.434	7726.422	11467.43	17017.69	22927.49	30888.54	37738.23	46104.1	56319.06	68790.37	84014.62	102593.6
85		Q5				962	1364.615	2222.815	3635.803	5993.923	9882.65	14778.88	22078.7	32968.29	44686.43	60559.39	74388.4	91353.13	112146.1	137621.2	168819.9	206988.8
86	middle-income countires																					
87		Q1				828	878.9387	1239.83	1835.251	2716.62	4021.261	5133.104	6525.502	7484.596	8586.536	9859.262	11262.98	12790.45	14817.49	17149.94	19859.65	23028.7
88		Q2				1352	1435.175	2024.456	2996.69	4435.833	6566.117	8633.71	11340.8	13494	16071.51	19163.89	22829.64	27169.07	32574.84	39067.07	46887.2	56325.65
89		Q3				1911	2028.565	2861.491	4235.706	6269.88	9280.954	12368.13	16477.73	19904.8	24056.43	29090.02	35168.89	42508.09	51518.27	62448.14	75720.04	91846.64
90		Q4				2735	2903.258	4095.332	6062.091	8973.376	13282.79	17872.9	24049.88	29354.7	35826.7	43721.73	53357.69	65118.74	79442.03	96913.26	118221.4	144206.7
91		Q5				6135	6512.426	9186.42	13598.15	20128.58	29795.21	40586.76	55294.17	68347.03	84393.32	104095.3	128408.6	158415.1	194661.5	239123.7	293591	360255.7
92	high-income countries																					
93		Q1				7373	8303.196	9100.81	10165.21	11345.04	13163.17	15265.35	17698.31	20518.15	23792.83	27551.35	31911.66	36933.93	42698.69	49385.15	57072.27	66060.74
94		Q2				14120	15901.41	18014.88	20820.22	24068.5	28948.88	34831.17	41925.72	50488.42	60830.97	73301.77	88373.93	106575.2	128552.9	155144.1	187286.8	226244.7
95		Q3				20475	23058.18	26411.05	30856.18	36052.73	43817.44	53260.22	64745.52	78717.42	95717.2	116394.1	141555.7	172170.2	209419.1	254758.4	309935.9	377122.1
96		Q4				28245	31808.46	36676.7	43126.74	50705.35	61996.63	75792.67	92646.35	113231.9	138371.2	169081.3	206579	252370.7	308290.8	376552.8	459893.9	561593.6
97		Q5				48135	54207.83	62955.19	74537.48	88213.81	108532.5	133472.3	164068.2	201583.5	247558.8	303952.5	373028.5	457671.4	561387.1	688327.6	843763.4	1033802
98																						
99	**REFERENCE CASE 80/20 ratios**																					
100	low-income countries					7.80	7.80	7.80	7.80	7.80	7.80	7.80	8.36	9.01	9.81	10.76	11.71	12.42	13.18	13.99	14.83	15.70
101	China					7.07	7.07	7.07	7.23	7.70	8.24	8.75	9.27	9.81	10.40	11.04	11.70	12.41	13.16	13.96	14.80	15.67
102	middle-income countries					7.41	7.41	7.41	7.41	7.41	7.41	7.91	8.47	9.13	9.83	10.56	11.40	12.39	13.14	13.94	14.78	15.64
103	high-income countries					6.53	6.53	6.92	7.33	7.78	8.25	8.74	9.27	9.82	10.40	11.03	11.69	12.39	13.15	13.94	14.78	15.65
104																						
105	**REFERENCE CASE GINI Coefficients**																					
106	low-income countries					0.378667	0.378911	0.383812	0.390147	0.39807	0.407714	0.417241	0.435219	0.453082	0.46813	0.480887	0.492276	0.499041	0.505622	0.511971	0.518003	0.523665
107	China					0.353607	0.362353	0.372426	0.384994	0.402329	0.41953	0.432013	0.443779	0.455157	0.463846	0.472411	0.478743	0.484934	0.490903	0.496643	0.502146	0.507331
108	middle-income countries					0.370185	0.370432	0.375383	0.381784	0.388136	0.394438	0.406411	0.418492	0.428892	0.438702	0.447882	0.45718	0.466599	0.473413	0.480026	0.486308	0.492207
109	high-income countries					0.323332	0.32437	0.331963	0.339593	0.347	0.354741	0.362218	0.369417	0.376325	0.382928	0.389396	0.395577	0.401572	0.407412	0.41298	0.418381	0.423459
110																						

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
156																						
157					1990	1994	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150
158	**Energy/GDP change (%/yr)**																					
159	low-income countries					0.00	0.00	-1.00	-2.00	-2.00	-2.20	-2.40	-2.50	-2.40	-2.00	-2.00	-1.20	-1.00	-1.00	-0.50	-0.50	-0.50
160	China					-1.00	-1.00	-1.00	-2.00	-2.00	-2.20	-2.40	-2.50	-2.40	-2.00	-2.00	-1.20	-1.00	-1.00	-0.50	-0.50	-0.50
161	middle-income countries					-0.12	-0.12	-1.00	-2.00	-2.00	-2.20	-2.40	-2.50	-2.40	-2.00	-2.00	-1.20	-1.00	-1.00	-0.50	-0.50	-0.50
162	high-income countries					-0.50	-0.50	-1.50	-2.50	-2.60	-2.70	-2.70	-2.50	-2.20	-2.00	-2.00	-1.20	-1.00	-1.00	-0.50	-0.50	-0.50
163																						
164	world					-0.05518	0.595456	-0.061199	-0.95081	-1.08626	-1.610066	-1.850381	-2.014741	-2.116923	-1.795707	-1.954672	-1.2	-1	-1	-0.5	-0.5	
165																						
166	**Energy/GDP (W/$)**																					
167	low-income countries					0.937	0.937	0.937	0.847833	0.694147	0.568319	0.456087	0.358771	0.279411	0.219792	0.179951	0.147331	0.130671	0.118236	0.106984	0.101767	0.096804
168	China					2.094	1.972055	1.784389	1.614582	1.321908	1.082287	0.868555	0.68323	0.5321	0.418565	0.342692	0.280572	0.248845	0.225165	0.203737	0.193801	0.184349
169	middle-income countries					0.873	0.866737	0.856398	0.774901	0.634435	0.519432	0.416854	0.327909	0.255376	0.200886	0.164471	0.134658	0.119431	0.108065	0.097782	0.093013	0.088476
170	high-income countries					0.31	0.300838	0.286166	0.246305	0.191823	0.147905	0.112908	0.086192	0.067126	0.05387	0.044105	0.03611	0.032027	0.028979	0.026221	0.024942	0.023726
171																						
172	world					0.453822	0.452322	0.480073	0.477144	0.433867	0.389207	0.331327	0.275357	0.225111	0.182163	0.152221	0.125194	0.111037	0.10047	0.090909	0.086476	0.082258
173																						
174	**TOTAL ENERGY USE (TW)**																					
175	low-income countries					0.642782	0.779856	1.338238	2.119869	3.069007	4.578421	6.562385	9.037243	12.07762	14.60486	16.30308	18.19877	19.7145	21.78789	24.07934	27.9762	32.50371
176	China					1.093068	1.584602	2.612566	4.307394	6.298636	9.02802	11.13767	13.20153	15.49214	16.45012	18.1802	18.1802	19.69437	21.76565	24.05476	27.94765	32.47053
177	middle-income countries					3.55311	4.097945	6.543588	9.859995	13.44336	17.96608	20.87361	23.30075	22.83937	22.38712	22.38712	22.38712	24.25167	26.80225	29.62106	34.41476	39.98425
178	high-income countries					6.2372	7.117445	8.024896	8.269291	7.633518	7.188976	6.702957	6.249796	5.944989	5.827271	5.827271	5.827271	6.312607	6.97651	7.710236	8.958016	10.40773
179																						
180	world					11.52616	13.57985	18.51929	24.55655	30.44453	38.7615	45.27662	51.78933	56.35412	59.26937	62.69767	64.59336	69.97315	77.33229	85.4654	99.29663	115.3662
181																						
182	**TOTAL ENERGY USE CHANGE (%/yr)**																					
183	low-income countries					3.2	5.4	4.6	3.7	4	3.6	3.2	2.9	1.9	1.1	1.1	0.8	1	1	1.5	1.5	
184	China					6.2	5	5	3.8	3.6	2.1	1.7	1.6	0.6	1	0	0.8	1	1	1.5	1.5	
185	middle-income countries					2.38	4.68	4.1	3.1	2.9	1.5	1.1	-0.2	-0.2	0	0	0.8	1	1	1.5	1.5	
186	high-income countries					2.2	1.2	0.3	-0.8	-0.6	-0.7	-0.7	-0.5	-0.2	0	0	0.8	1	1	1.5	1.5	
187																						
188	world					2.732794	3.10226	2.821657	2.149276	2.415213	1.553634	1.343932	0.844713	0.504373	0.562316	0.297873	0.8	1	1	1.5	1.5	
189																						
190	**ENERGY/CAPITA (kW)**																					
191	low-income countries					0.322844	0.343255	0.487101	0.657518	0.84427	1.139645	1.507899	1.955639	2.511091	2.946792	3.256709	3.59922	3.898988	4.309049	4.762235	5.532928	6.428345
192	China					0.917773	1.238053	1.846958	2.755337	3.719316	5.020551	6.010691	7.053611	8.195127	8.701886	9.617071	9.617071	10.41805	11.51372	12.72463	14.78391	17.17646
193	middle-income countries					2.263127	2.385503	3.344811	4.515022	5.51466	6.735621	7.296611	7.747809	7.369944	7.080964	7.080964	7.080964	7.670717	8.477453	9.369035	10.88527	12.64687
194	high-income countries					7.337882	8.029062	8.785193	8.873486	8.109755	7.63748	7.121139	6.639706	6.315884	6.190821	6.190821	6.190821	6.706436	7.411758	8.19126	9.516886	11.05704
195																						
196	world					2.057508	2.20589	2.633696	3.107218	3.496308	4.112966	4.524502	4.960001	5.246937	5.412992	5.700163	5.845771	6.332649	6.998659	7.734714	8.986456	10.44077
197																						
198	**ENERGY/CAPITA CHANGE (%/yr)**																					
199	low-income countries					1	3.5	3	2.5	3	2.8	2.6	2.5	1.6	1	1	0.8	1	1	1.5	1.5	1.5
200	China					5	4	4	3	3	1.8	1.6	1.5	0.6	1	0	0.8	1	1	1.5	1.5	1.5
201	middle-income countries					0.88	3.38	3	2	2	0.8	0.6	-0.5	-0.4	0	0	0.8	1	1	1.5	1.5	1.5
202	high-income countries					1.5	0.9	0.1	-0.9	-0.6	-0.7	-0.7	-0.5	-0.2	0	0	0.8	1	1	1.5	1.5	1.5
203																						
204	world					1.160595	1.772571	1.653394	1.179799	1.624368	0.95363	0.918985	0.562385	0.311575	0.516928	0.252237	0.8	1	1	1.5	1.5	