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Welfare vs. Income Convergence and Environmental Externalities

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Welfare vs. Income Convergence and Environmental Externalities

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Abstract

We present estimates of welfare by country for 2007 and 2014 using the methodology of Jones and Klenow (2016) which incorporates consumption, leisure, mortality and inequality, and we extend the methodology to include environmental externalities. During the period of the global financial crisis welfare grew slightly more rapidly than income per capita, mainly due to improvements in life expectancy. This led to welfare convergence in most regions towards advanced country levels. Introducing environmental effects changes the welfare ranking for countries that rely heavily on natural resources, highlighting the importance of the natural resource base in welfare. This methodology could provide a theoretically consistent and tractable way of monitoring progress in several Sustainable Development Goal (SDG) indicators.

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CONTENTS

I. INTRODUCTION

Comparisons of living standards over time and across countries have relied heavily on GDP (or GNI) per capita and its evolution, for lack of a better indicator. It is well known, however, that GDP excludes many dimensions of economic activity that affect welfare, including the distribution of income and wealth, household production, the use and destruction of the natural environment, and inequality in economic opportunity. It also omits many other important determinants of well-being, such as governance, security, health and longevity.[2]

In response to these limitations, several approaches have been developed to incorporate non-income dimensions of welfare into the analysis of economic development. For example, the Stiglitz commission report (Stiglitz et al., 2009) proposed alternative indicators of economic performance and social progress. The IMF has recently focused on the implications of income distribution (Ostry et al., 2014 "Redistribution, Inequality and Growth" and Clements et al. 2015 *Inequality and Fiscal Policy*), and opportunities for women (Kochhar et al., 2017 *Women, Work and Economic Growth*) for economic performance. The Sustainable Development Goals (SDGs) at the core of the post-2015 development agenda (United Nations, 2015), also recognize the many dimensions of welfare including equality, education, gender and environmental protection. Summary measures that attempt to capture differences in dimensions of welfare across countries have been developed, for example the Human Development Index (HDI) (UNDP, 2009), the Inclusive Development Index (IDI) (World Economic Forum, 2017), and the Multidimensional Poverty Index (Alkire and Foster, 2011). However these kinds of indexes have been criticized for their lack of theoretical foundations (Fleurbaey, 2009 and Ravallion, 2012).

A recent attempt to fill the gap between theory and measurement of welfare is developed by Jones and Klenow (2010, 2016). They propose a summary measure of welfare at the country level based on a consumption equivalent, in the tradition of Lucas (1987). Using the economics of expected utility, they combine data on consumption, leisure, inequality and mortality to calculate expected lifetime utility across countries. To calculate their index they ask the question: what proportion of consumption in the United States, given the U.S. valuation for leisure, mortality and inequality, would yield the same expected utility as the values of consumption, leisure, mortality and inequality in another country. Using the U.S. as a benchmark, the index thus calculates consumption equivalent welfare for each country and across time, taking into account variations in leisure, mortality and inequality.[3]

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[2] GDP also omits measures of the digital economy, as has been noted by many analysts. See, for example, the report by Charles Bean on U.K. economic statistics (Bean, 2016). This paper does not offer solutions to the measurement of the digital economy.

[3] The index presents an economically consistent methodology that could potentially be used for measuring progress in some of the SDGs in a theoretically consistent manner that is comparable across time and countries. In particular, the introduction of consumption equivalents of environmental and social variables could allow for a theoretically consistent quantification, in principle, of the welfare benefits of advances in implementing some of the SDGs.

In this paper, we first update the index calculation for the years 2007 and 2014 using a broader set of countries.[4] This allows us to look at the distribution of the welfare index across countries in 2014, and then to assess changes in the index between 2007 and 2014, a period that reflects the impact of the global financial crisis. This gives us some insights into convergence in the welfare index and income over the period.

Second, we extend the Jones and Klenow (2016) specification to incorporate environmental externalities and the sustainable use of natural resources. As is well known, negative externalities result in the underpricing of environmental goods like clean ground, water, and air, and in the overexploitation of natural resources like minerals, forests and fisheries. The consumption equivalent approach of Jones and Klenow (2016) lends itself to incorporation of some of these environmental effects. Our measure extends Jones and Klenow (2016) by incorporating a national level public environmental "bad." The presence of this public bad (pollution) reduces the welfare of the representative household in a country, in three ways: first by lowering the household's expected consumption by increasing mortality/morbidity due to environmental health effects. Second, by reducing the household's consumption in proportion to a tax on a global environmental externality (in this case greenhouse gas emissions (GHG)). And third, by lowering consumption in proportion to the level of unsustainable exploitation of natural resources.

Our updated results for 2014 are similar to Jones and Klenow for earlier years: welfare is highly correlated with GDP per capita, but there are significant deviations, mostly related to the effects of differences in life expectancy. However, consumption, leisure and inequality also have a role to play in particular cases. For Asian countries, for example, welfare is in general related to differences in life expectancy, but consumption, leisure and inequality all have negative effects on the index as Asian households tend to consume less, work more and face higher inequality than in the US.

When we look at growth of welfare and income between 2007 and 2014, we find that income and welfare follow the same regional pattern, but that, in the aggregate, welfare grew more quickly than income. At a regional level, crisis countries (in Western Europe and North America) saw much slower income growth than the rest of the world, as expected. But here and across most other regions welfare growth outpaced income, mainly due to gains in life expectancy. The exception is Asia, where the substantial growth in welfare lagged the remarkably rapid growth in income, due mainly to the fact that the income share of current consumption did not grow as rapidly. Thus the period from 2007 to 2014 saw convergence in income per capita across countries, but even greater convergence in welfare.

Introducing environmental effects into the welfare calculation illustrates how important the use of the natural environment is for welfare in certain countries. Accounting for the loss of life years from environmental diseases has only a very small effect on the index, concentrated in poor countries where life expectancy is already very low. In contrast, accounting for the effects of GHG emissions has a large effect on welfare in some countries, illustrating how much welfare in these countries relies on the use of environmental resources. Interestingly, the countries most affected are not necessarily countries that would otherwise

[4] Jones and Klenow (2016) calculate the index for 1980 and 2007.

have been identified as low ranking on indices of environmental protection (for example the Environmental Protection Index calculated at Yale University – Hsu et al., 2016). However, they are among the countries that have been identified by the World Bank (WB 2011) as consuming environmental resources in an unsustainable fashion, according to the adjusted net savings (ANS) metric.

The rest of this paper is structured as follows. Section 2 presents the results of the welfare index calculations for 152 countries in 2014 to examine patterns of welfare across countries. Section 3 looks at the results of the welfare calculations over time. We measure changes in the index between 2007 and 2014 to gain insights into the effects of the global financial crisis on welfare and to assess patterns of welfare and income convergence over the period. Section 4 presents our extension of Jones and Klenow's methodology to include environmental externalities and sustainable consumption for 2012, where data is available. A final section presents concluding remarks.

II. Welfare and GDP in 2014

In this section we present results for the update of the Jones and Klenow (2016) welfare index to 2014. We follow Jones and Klenow's "macro" data calculation, which requires strong assumptions with respect to the distribution of consumption, the discount rate and growth of consumption over a household's lifetime, and excludes some dimensions of welfare such as the distribution of leisure over households. Jones and Klenow calculate a more detailed version of the index for a smaller group of countries for which detailed consumer expenditure surveys are available.[5] The advantage of the macro calculation is that it is based on data that are publicly available for a broad list of countries. When comparing the micro and macro results, Jones and Klenow find that the results are quite consistent and comparable.

Jones and Klenow macro methodology

Using the expected utility framework in Jones and Klenow's macro formulation, the formula for lifetime utility in country i is given by:

(1) $$U_i = e_i\left(\bar{u} + logc_i + v(\ell_i) - \frac{1}{2}\sigma_i^2\right)$$

Where e_i is life expectancy in years, and the expression inside the parentheses is the annual flow of utility, which depends on an intercept term, $\bar{u}$, which corresponds roughly to the annual value of remaining life of a 40-year old in the U.S., $logc_i$, the mean of log consumption per capita, $v(\ell_i)$, which is a term that captures the utility from leisure and home production, and σ_i^2, which is the variance of log consumption.[6] To calculate the index, Jones

[5] This includes the U.S., Brazil, China, France, India, Indonesia, Italy, Malawi, Mexico, Russia, South Africa, Spain and the United Kingdom.

[6] The relevant assumptions are that consumption is lognormally distributed across people at a point in time and independent of age and mortality, the growth rate of consumption over the relevant lifetime is zero, and the discount rate is 1. The assumption of constant lifetime consumption probably underestimates the value of

and Klenow then ask by what factor λ_i must consumption in the U.S. be adjusted, to make an average consumer indifferent to living the rest of their life in the U.S. or in country i.[7] The answer to this question yields and index of welfare λ_i that satisfies the following equation:

(2) $U_{US}(\lambda_i) = U_i(1)$

Implementing (2) using (1) yields an expression for the welfare index, which can be decomposed into constituent terms reflecting the effects of differences in life expectancy, consumption, leisure and inequality:

$$(3) \quad log\lambda_i = \frac{e_i - e_{us}}{e_{us}}\left(\bar{u} + logc_i + v(\ell_i) - \frac{1}{2}\sigma_i^2\right) \qquad \textit{life expectancy}$$

$$+ logc_i - logc_{us} \qquad \textit{consumption}$$

$$+ v(\ell_i) - v(\ell_{us}) \qquad \textit{leisure}$$

$$- \frac{1}{2}(\sigma_i^2 - \sigma_{us}^2) \qquad \textit{consumption inequality}$$

This is the baseline formulation that we implement for our calculations for 2007, 2012 and 2014, over a sample of 152 countries, using data from Penn World Tables version 9.0, and the World Bank. Our sample, data sources and methodology are described in the Appendix.

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lifetime utility for high-saving countries, and overestimates consumption where it is unsustainable. We attempt to address this latter issue later in the paper. We refer the reader to the data appendix for the assumptions underlying the calculation of $v(\ell_i)$ which follow Jones and Klenow (2016).

[7] The use of the U.S. as benchmark is justified in this case as the utility function is calibrated for the representative agent in the U.S., where information for the relevant parameters (for example the Frisch elasticity) is readily available. In theory, any country could be used as benchmark, as long as information was available, or one could use a composite high-income average at the risk of the results becoming more difficult to interpret.

The welfare index across countries in 2014

On an aggregate level, our results are very similar to those of Jones and Klenow (2016). As illustrated in Charts 1 and 2, welfare and GDP per capita are highly correlated (correlation coefficient of 0.95), but with substantial variation in the ratio of lambda to GDP per capita (mean absolute deviation from unity of the ratio is about 15 percent).

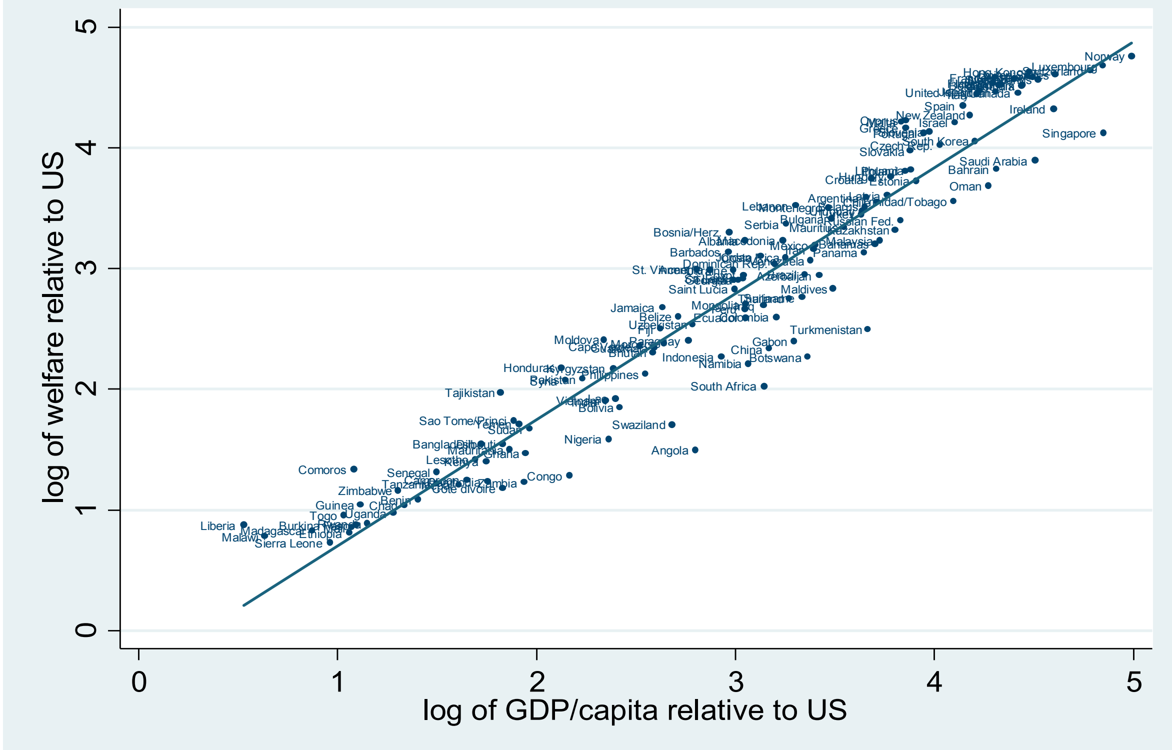
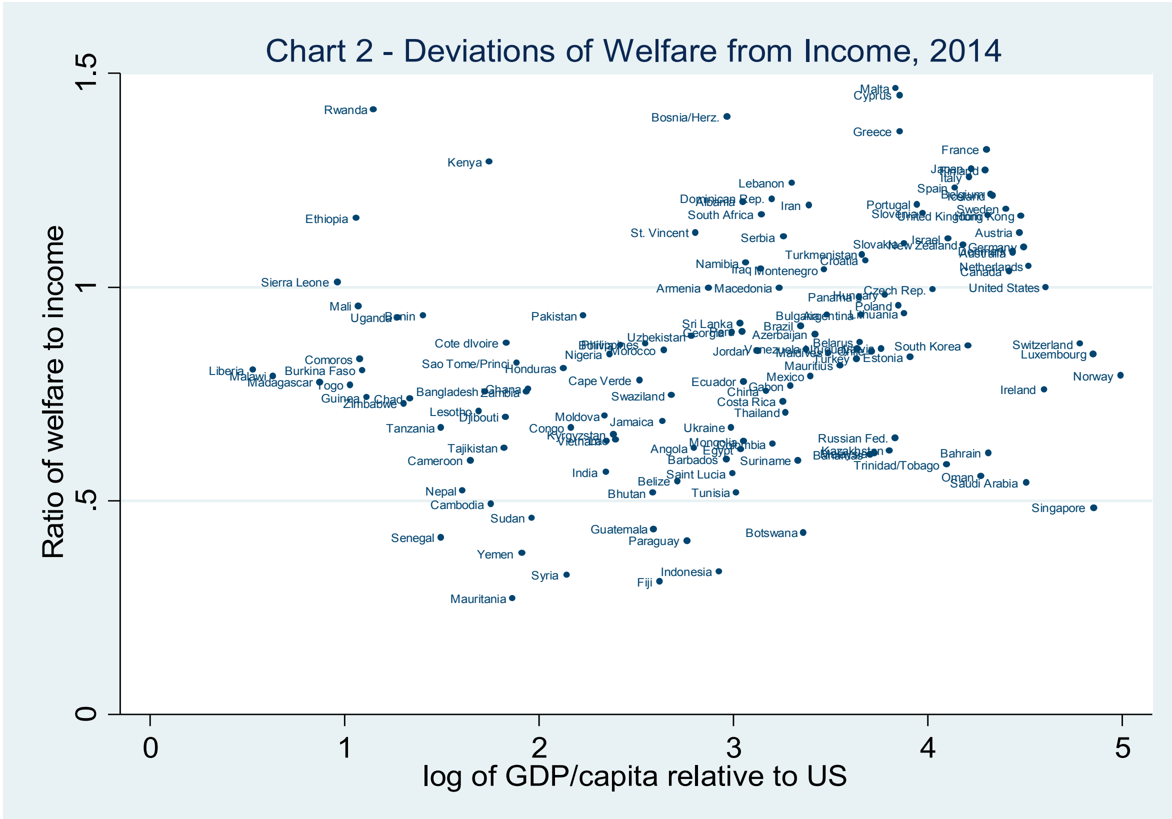


Chart 1 - Welfare vs Income in 2014



The results by income level are also similar to Jones and Klenow (2016). Among high income countries, clustered at the top right of Chart 1, many have a higher index of welfare relative to income (they are above the 45 degree line); that is, the welfare index puts them close to or above the U.S. in welfare while their income level puts them substantially below the U.S. The main reason is that they have higher life expectancy, more leisure and less inequality, as the example from France presented by Jones and Klenow illustrates. Among these factors, the most important is life expectancy, which contributes to a higher level of welfare, because consumption is already high in these countries and additional years of life consumption add a significant component to expected lifetime utility, as can be seen in equation (1). Among low-income countries, the opposite is true. The welfare index is below the relative income level compared to the US as they have much lower life expectancy and higher inequality. The welfare index is thus dominated by life-expectancy effects, as additional or fewer years of life have a large effect on expected lifetime consumption. Countries where life expectancy has its highest relative contribution to welfare include Asian high income countries (Hong Kong, Japan, Singapore, Australia and South Korea) and European high income countries. Countries where life expectancy has the largest negative contribution include African countries where life expectancy is low, including Swaziland, Lesotho, Nigeria and Angola.

However, consumption, leisure and inequality also have a role to play in particular cases. Countries where ***consumption*** has the highest relative contribution to the welfare index are mostly poorer countries and small island economies, both of which receive a large proportion of grants relative to income, and therefore can consistently consume beyond their income.

Countries where the ***inequality*** term has the highest positive contribution to the welfare index include mostly high income European countries where inequality is low relative to the US. On the other hand, countries where inequality has the largest negative contribution are in Africa and Latin America.

Results by broad regional aggregates, presented in Table 1 (Macro Welfare Summary Statistics, 2014), confirm this analysis. The results for welfare (lambda) and income are presented relative to the U.S. level, and the log ratio is the log of the ratio of welfare to income.[8] The decomposition of the log ratio shows those factors that contribute most to the difference between welfare and income. The overall population weighted average welfare (in the second row) is 22.6 percent of the US level, lower than the weighted average per capita income of 28 percent of the US level. All the factors in the welfare index contribute to this discrepancy, but lower life expectancy and lower current consumption dominate.

Table 1 - Macro Welfare Summary Statistics, 2014

				Decomposition			
Country	Welfare Lambda	Per Capita income	log ratio	Life exp.	C/Y	Leisure	Cons. Ineq.
Avg (unweight)	30.6	36.6	-0.226	-0.156	-0.046	0.014	-0.029
Avg (pop wght)	22.6	28.0	-0.396	-0.168	-0.155	-0.015	-0.058
Regional Averages (population weighted)							
Europe	58.0	56.0	-0.039	-0.068	-0.036	0.016	0.048
W. Europe	85.2	73.8	0.144	0.121	-0.074	0.029	0.068
E. Europe	27.6	35.9	-0.245	-0.280	0.008	0.002	0.025
N. America	79.2	80.4	-0.051	-0.011	-0.010	-0.007	-0.023
Canada	86.0	82.9	0.036	0.155	-0.130	-0.026	0.037
Mexico	24.3	29.9	-0.205	-0.085	-0.001	-0.020	-0.099
Latin America	20.7	27.9	-0.321	-0.135	-0.027	-0.010	-0.149
Asia	13.0	20.1	-0.560	-0.159	-0.271	-0.051	-0.078
ASEAN	10.8	19.1	-0.551	-0.229	-0.152	-0.086	-0.084
M. East and N. Africa	16.8	23.1	-0.210	-0.280	-0.011	0.066	0.014
Sub Saharan Africa	4.2	7.8	-0.469	-0.376	-0.036	0.041	-0.098

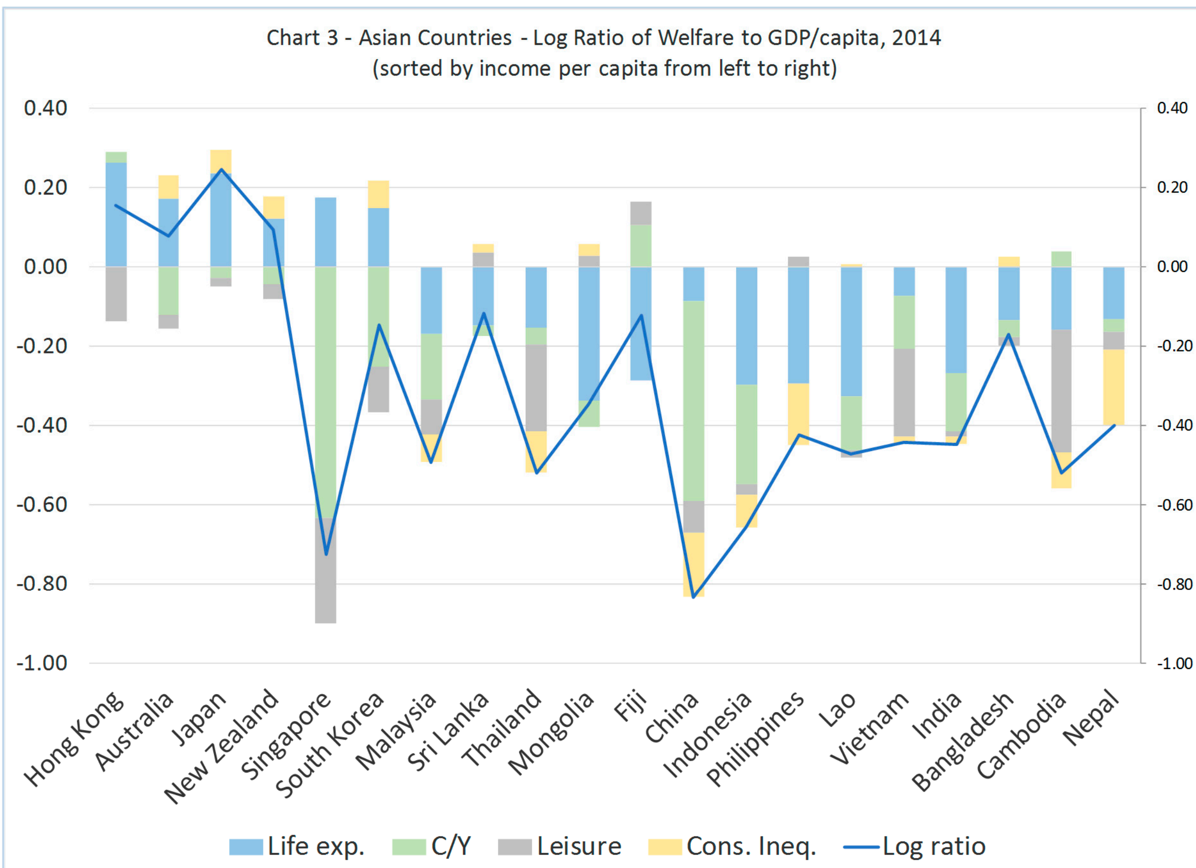
For Europe as a whole the welfare index is close to the per capita income index. However separating into sub-regions illustrates the dichotomy between developing and advanced countries. Western European countries have higher welfare relative to GDP per capita (the

[8] Note that the log ratio may not correspond to the numbers in the table due to the aggregation process.

log-ratio is positive) mainly due to higher life expectancy, as we saw above, although higher leisure and lower inequality also contribute. In contrast, Eastern European countries have lower welfare compared to per capita income (the log ratio is negative) due mainly to lower life expectancy.[9] The same is true in North America, with Canada enjoying higher welfare relative to income due mainly to longer life expectancy (despite lower levels of consumption), while Mexico has lower welfare relative to income mainly due to lower life expectancy and also higher inequality.

Asia and Latin America have a similar pattern, with relative welfare below the level of income mainly explained by lower life expectancy and lower consumption, although this masks considerable heterogeneity within countries for Asia, as described below.

For the Middle East and African countries welfare is also lower than income mainly due to lower life expectancy, though consumption also has a negative contribution. Leisure has a positive contribution to the log ratio, though this result may be spurious as data used to measure hours worked may not fully take into account hours worked by the self-employed, unpaid family workers and informal employees.



[9] Many of the countries in this region, including Turkmenistan, Uzbekistan, Kazakhstan, Azerbaijan and Ukraine have significantly lower life expectancy than the US.

Asian countries. Chart 3 shows the log ratio of welfare and income and its decomposition for Asian countries in our sample. The countries are sorted by income from highest (at left) to lowest (at right). Where the log ratio is positive it indicates that welfare is higher than income relative to the US level. The first point to note is that in Asia, as in the sample as a whole, high income countries enjoy higher welfare relative to income (the log ratio is positive), and lower income countries have higher income than welfare (the log ratio is negative), and this effect is mainly due to higher life expectancy. The interesting exceptions in this case are Singapore and South Korea, where a large negative contribution from current consumption and leisure bring welfare down. As Jones and Klenow point out, this is a reflection of the pattern of growth of these economies, including high savings rates, high levels of investment, and economic expansion based on the application of factors of production (including more labor hours and less leisure). This is also a pattern in many middle and lower-income Asian countries, including especially the two most populous, China and Indonesia, but also Malaysia, Thailand, Laos, Vietnam and India. Thus, for these countries, and others with low ratios of consumption to GDP, the IMF's longstanding advice to rebalance away from investment and exports towards a more sustainable growth path based on domestic consumption would also raise levels of welfare. It is interesting to note that the contribution of inequality is generally positive in higher income countries and negative in lower income countries, and strikingly so in the lowest income country, Nepal.

III. Welfare and Income Over Time (2007–2014)

The methodology allows for a calculation of the growth of welfare from 2007 to 2014, which can be readily compared to the growth of income per capita. This can be achieved by using the same country in an earlier year as a benchmark, instead of the U.S.:

$$U_i^{2007}(\lambda_i) = U_i^{2014}(1) \tag{4}$$

Jones and Klenow (2016) do a similar analysis for a longer time period (1980–2007). Our updated results allow for a view of how welfare has changed over the period of the global financial crisis and recovery. It also provides some insight into whether and how welfare and income of the poorer nations has converged towards the level of rich countries.

Convergence 2007-2014

Before we look at rates of change, however, it is instructive to compare the index in levels for 2007 and 2014, since this gives us some insights into welfare and income convergence. Both welfare and income are presented in percent of the US level, so we can look at absolute changes in the indices, presented in Table 2, to assess whether there has been convergence to the US level, and by how much.[10]

The results for the population weighted average (in the second row) indicate that there has been a gradual convergence in the aggregate of both income and welfare, but that

[10] We could also look at the mean absolute deviation by income levels to see how convergence occurred among different country income groups, either by World Bank classification (i.e. LIC, emerging markets, advanced) or by quintiles of the income distribution.

convergence of income has been about twice as fast as that of welfare. The decomposition indicates that despite improvements in life expectancy, improvements in consumption, leisure and inequality were not sufficient to bring welfare growth to the level of income. Europe saw strong convergence in both welfare and income, as did Latin America. Interestingly, despite very strong income growth, Asia saw only low convergence of welfare. The Middle East and Sub-Saharan Africa also saw gradual convergence, albeit with welfare convergence falling slightly behind that of income.

Table 2 - Convergence, 2007-2014

Country	Change in Welfare Lambda	Change in Per Cap. income	log ratio	Decomposition: Life exp.	C/Y	Leisure	Cons. Ineq.
Avg (unweight)	3.7	3.8	-0.007	0.013	0.005	-0.020	-0.004
Avg (pop wght)	2.5	4.6	-0.054	0.002	-0.031	-0.016	-0.008
Regional Averages (population weighted)							
Europe	7.0	5.1	0.047	0.029	0.035	-0.013	-0.006
W. Europe	6.4	2.9	0.042	0.029	0.024	-0.006	-0.005
E. Europe	7.6	8.7	0.053	0.029	0.051	-0.019	-0.007
N. America	0.5	0.5	0.003	0.003	0.004	-0.010	0.006
Canada	1.5	-0.1	0.019	0.018	0.021	-0.014	-0.006
Mexico	1.6	1.8	0.005	0.005	0.011	-0.036	0.024
Latin America	4.2	5.6	0.003	0.007	0.015	-0.026	0.007
Asia	2.6	5.7	-0.107	-0.013	-0.066	-0.015	-0.014
ASEAN	2.6	6.4	-0.168	-0.026	-0.065	-0.030	-0.047
M. East and N. Afric	3.3	3.8	-0.004	-0.010	0.037	-0.025	-0.006
Sub Saharan Africa	0.7	1.5	-0.091	0.010	-0.067	-0.026	-0.007

Growth 2007–2014

The results for the growth calculations presented in Table 3 (Macro Welfare Growth Summary Statistics, 2007–2014) show a similar outcome.

Table 3. Macro Welfare Growth Summary Statistics, 2007-2014 1/

Country/Region	Welfare	Per capita Income	Difference	Decomposition of Difference			
	(1)	(2)	(1)-(2)	Life Exp.	C/Y	Leisure	Ineq.
Average, unweighted	3.92	2.92	1.00	1.08	-0.09	-0.04	0.06
Average, pop-weighted	4.87	4.64	0.23	0.90	-0.66	0.01	-0.02
Standard deviation	2.98	3.47	1.96	0.70	1.77	0.28	0.16
Europe	4.18	2.47	1.71	1.29	0.32	0.08	0.02
W. Europe	2.33	0.88	1.45	1.10	0.15	0.17	0.04
E. Europe	6.16	4.16	2.00	1.50	0.51	-0.02	0.01
N. America	1.33	0.42	0.92	0.74	-0.13	0.10	0.20
Latin America	4.48	3.55	0.93	0.81	0.03	-0.12	0.21
Asia	5.78	6.21	-0.43	0.74	-1.12	0.04	-0.09
ASEAN	5.46	6.77	-1.31	0.55	-1.11	-0.18	-0.56
Middle East	4.54	3.46	1.08	0.82	0.34	-0.10	0.02
Sub-Saharan Africa	3.77	3.60	0.16	1.28	-1.01	-0.11	0.01

1/ Average annual growth rates. The decomposition applies to the difference between columns one and two. Sample size is 157 countries.

Aggregate growth. The population weighted growth rate of welfare over the period is similar to the rate of growth of (PPP adjusted) per capita income. Both grew at a rapid rate of between 4 ½ and 5 percent per annum over the period. This reflects the large weight in our sample of fast growing countries (China, Indonesia), and the difference between the growth of welfare and income is mainly due to improvements in life expectancy. In fact, only two countries in our sample (Syria and Tunisia) saw declines in life expectancy over the period.

Growth by region. When we look at the results for different regions the picture looks very good for convergence. Less advanced and emerging economies grew much more quickly than advanced economies, a tangible result of the global financial crisis. In fact, Western Europe and North America saw income and welfare grow much more slowly than other regions. But even in these advanced country regions, welfare grew more rapidly than income. In both Western Europe and North America this reflected improvements in life expectancy, leisure and lower inequality, although in North America, the contribution of current consumption was negative. Convergence is particularly evident in Eastern Europe, which saw very rapid gains in welfare that outstripped already robust growth in income, mainly due to important improvements in life expectancy and current consumption. This is also true, though to a lesser extent, of the Middle East. Both these regions benefitted from large gains in commodity export terms of trade during the period, reflected in high income and welfare growth.

In contrast, although Asia also saw very rapid growth in welfare, this did not fully reflect the improvements in income, mainly due to declines in the income share of current consumption and a worsening of inequality. This is the same pattern detected by Jones and Klenow (2016) for their analysis of the earlier period (1980–2007). Their observation is that as Asian growth is based on factor accumulation (investment and increases in hours worked), it comes at the expense of current consumption and leisure, so that increases in per capita income are not fully reflected in increases in welfare. This is especially true in our sample for ASEAN countries, where slower growth in current consumption relative to income, declines in leisure and increases in inequality led to lower growth in welfare than in income.[11]

In contrast to its performance during the earlier period identified by Jones and Klenow (2016), Sub-Saharan Africa experienced relatively rapid growth of both welfare and (PPP adjusted) income of around 3½ percent from 2007–2014. As in Asia, gains in welfare came mainly from increases in life expectancy, and current consumption grew more slowly than income. Nevertheless this is a positive development as it shows Sub-Saharan Africa converging, albeit slowly, to advanced country levels of income and welfare.

To summarize, over the period 2007 to 2014, gains in income were largely matched by gains in welfare, and there was convergence in most regions towards advanced country levels. However the main contribution to growth in welfare came from improvements in life expectancy while gains in current consumption were small or negative. Leisure and inequality did not change significantly over the period and therefore were not important factors in explaining welfare growth.

Selected countries. Results for selected countries are presented in Table 4. (Macro Welfare Growth Statistics for Selected Countries, 2007–2014).

European crisis countries. The top rows describe results for European crisis countries. For these countries, the positive contribution of leisure to changes in the index, due to the decline in hours worked, has been set to zero, as this is almost certainly due to an increase in involuntary unemployment.[12] As expected, most had very low or negative income growth, but for Greece, Cyprus and Ireland the decline in welfare was less than the decline in income, and Spain and Italy saw fairly robust increases in welfare. The main contributors were improvements in life expectancy as health outcomes continued to be protected by social safety nets, and increases in the proportion of consumption out of income, as investment fell. For a number of crisis countries the contribution of current consumption is negative, but this is especially true of Iceland and the United Kingdom.

[11] However, as we shall see below, this is due to the high population weight of Indonesia in the ASEAN groups as the particular outcome discussed here turns out to be true only for the Philippines and Indonesia. Other ASEAN countries, including Malaysia and Thailand, show a very different result.

[12] This is a drawback of the data used in the index to account for hours worked. Data is from Penn Tables 9.0 (see the data appendix) which does not take into account the effects of involuntary unemployment or informal labor. Ideally the data would be adjusted for these effects across countries.

Table 4. Macro Welfare Growth Statistics for Selected Countries, 2007-2014 1/

Country/Region	Welfare	Per capita Income	Difference	Decomposition of Difference			
	(1)	(2)	(1)-(2)	Life Exp.	C/Y	Leisure 2/	Ineq.
European Crisis Countries:							
Greece	-0.51	-2.10	1.58	1.26	0.30	0.00	0.02
Cyprus	-0.63	-1.28	0.65	0.90	-0.26	0.00	0.01
Ireland	-0.36	-1.22	0.87	1.07	-0.23	0.00	0.02
Spain	1.11	-0.47	1.57	1.50	0.08	0.00	0.00
Italy	1.24	-0.24	1.48	0.87	0.53	0.00	0.07
Iceland	0.01	1.12	-1.11	0.44	-1.88	0.00	0.33
United Kingdom	0.40	0.13	0.27	1.19	-1.01	0.00	0.09
United States	1.12	0.19	0.93	0.76	-0.19	0.25	0.11
Advanced Asia Economies:							
Japan	1.92	-0.35	2.27	0.74	1.28	0.20	0.05
Hong Kong	3.64	-1.99	5.63	1.15	4.69	-0.32	0.11
South Korea	3.72	1.52	2.20	1.79	0.31	0.07	0.02
Singapore	1.33	0.97	0.36	1.44	-0.28	-0.91	0.11
Emerging Asia							
China	4.86	6.54	-1.68	0.56	-2.24	0.01	0.00
Indonesia	6.01	9.52	-3.51	0.59	-2.86	0.02	-1.27
Malaysia	4.96	3.66	1.30	0.52	1.42	-0.64	0.00
Thailand	5.13	3.36	1.77	0.76	1.27	-0.25	0.00
Low Income Asia							
Cambodia	5.26	4.49	0.77	0.79	-0.33	0.31	0.00
Lao PDR	10.51	9.25	1.25	1.24	0.21	-0.19	0.00
Vietnam	5.05	5.07	-0.02	0.34	0.38	-0.74	0.00
Oil Exporters:							
Russian Fed.	7.17	4.16	3.01	2.00	1.03	-0.03	0.00
Saudi Arabia	7.84	4.72	3.12	0.70	2.61	-0.29	0.11

1/ Average annual growth rates. The decomposition applies to the difference between columns one and two.
2/ The positive contriblution of leisure due to the decline in hours worked has been set to zero for European Crisis Countries.

United States. As in Europe, the US experienced positive growth in welfare (of around 1 percent per annum), led by improvements in life expectancy and leisure, even while income growth remained stagnant.

High Income Asia. Advanced economies in Asia saw significant growth in welfare. In Japan and Hong Kong, welfare grew despite a contraction in (PPP adjusted) income, due mainly to an increase in the income share of current consumption (C/Y). This is especially true of Hong Kong where the income share of consumption grew over 4 percent. South Korea also saw a robust growth in welfare that was more than double the rate of growth of per capita income, based mainly on gains in life expectancy and a smaller increase in income share of current consumption. Singapore's gains were almost entirely due to gains in life expectancy with negative contribution from the income share of current consumption.

Emerging Asia. China and Indonesia, two countries with the largest populations, had much lower welfare growth than income, due in large part to negative contributions from the growth of the income share of current consumption. These two countries have a heavy weight in our population weighted calculations. However, other parts of emerging Asia, including Malaysia and Thailand, have evolved to look more like high income countries where the contribution of consumption to the growth of welfare is high, leading to faster growth of welfare than income per capita.

Low Income Asia (Cambodia, Lao PDR, Vietnam), saw welfare growth broadly in line with very rapid per capita income growth, although with some penalty for declines in leisure (Lao and Vietnam).

Oil exporters (Russia, Saudi Arabia, Iraq) saw very high rates of growth of welfare, and in the case of Russia and Saudi Arabia welfare grew much faster than income due to increases in current consumption (though increases in life expectancy also had a big effect in Russia).

To summarize, for some European crisis countries and high income Asian countries, despite negative or very low income growth, welfare continued to grow over the period from 2007 to 2014. This was mainly due to improvements in life expectancy, although for high-income Japan and Hong Kong, and emerging Malaysia and Thailand, there is evidence of a rebalancing of growth to include a higher share of consumption out of current income. For the most populous Asian countries, China and Indonesia, welfare growth did not match the extraordinary pace of growth of income, as the pattern of growth continued to emphasize investment over consumption.

IV. ENVIRONMENTAL EXTERNALITIES, SUSTAINABLE CONSUMPTION AND WELFARE

We now turn to the extension of Jones and Klenow's macro methodology to include the effects of environmental externalities and sustainability. We introduce three additional effects into the analysis. First we introduce the effect of environmental pollution on life expectancy by using the concept of Disability Adjusted Life Years (DALYs) attributable to the environment from the World Health Organization.[13] DALYs are a summary measure used to give an indication of the burden of disease: one DALY represents the loss of the equivalent of one year of full health, and includes the burden of diseases (morbidity) as well as death (mortality). Using this indicator we can disaggregate the flow utility calculation in Jones and Klenow (2016) for one year of life into a measure of adjusted life expectancy utility, that is the utility that could have been achieved without the burden of environmental diseases, and the utility lost due to environmental diseases. Second, we introduce an additional term that attempts to capture the welfare loss of global CO_2 emissions, by assuming that the representative consumer pays a tax to defray the global costs of CO_2 emissions per unit of consumption in a given country, following Hamilton and Clemens (1999). Third, where appropriate, we adjust for the sustainability of consumption using a measure of adjusted net savings calculated by the World Bank (World Bank 2011). All these analyses are implemented using 2012 data since much of the information is only available up to this year.

Pollution and externalities

Following Jones and Klenow (2016), the expected lifetime utility for an individual is given by:

(5) $$U = E \sum_{a=1}^{100} \beta^a u(C_a, \ell, d) S(a, d)$$

Where C denotes an individual's annual consumption, ℓ denotes leisure time plus time spent in home production, and d denotes an environmental bad. β is a discount factor, and $S(a, d)$ is the probability that an individual survives to age a, given exposure to the level of environmental pollution d, and the expectations operator applies to the uncertainty with respect to consumption. Environmental pollution thus affects utility directly, and through its effect on mortality. Let $U_i(\lambda)$ denote the expected lifetime utility for an individual in country i if consumption is multiplied by a factor λ at every age,

(6) $$U_i(\lambda) = E \sum_{a=1}^{100} \beta^a u(\lambda C_a, \ell, d) S(a, d)$$

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[13] The website is: http://www.who.int/gho/mortality_burden_disease/countries/situation_trends_dalys/en/ .

The Global Burden of Disease Study by the Institute for Health Metrics and Evaluation (IHME) also has data for the Global Burden of Disease at: http://ghdx.healthdata.org/gbd-results-tool. This indicator includes mortality and morbidity attributable to air, soil and water pollution with chemical or biological agents, ultraviolet and ionizing radiation, built environment, noise, electromagnetic fields, occupational risks, agricultural methods, irrigation schemes, anthropogenic climate changes, ecosystem degradation, individual behaviors related to the environment, such as hand-washing, food contamination with unsafe water or dirty hands.

To implement the welfare calculation Jones and Klenow (2016) ask: by what factor, λ_i, does consumption need to be adjusted in the reference country (in this case the U.S.) to make a representative consumer indifferent to living in the U.S. or some other country i. The answer to this question yields an index of welfare that satisfies equation (2) above as before. Following Jones and Klenow (2016), we assume that flow utility for the representative consumer is:

$$(7) \qquad u(C, \ell, d) = \bar{u} + logC + v(\ell) + r(d)$$

Where $\bar{u}$ is an intercept term denoting basic value of life, $v(\ell)$ captures the utility from leisure and home production, and $r(d)$ captures the utility cost of environmental pollution. Making additional assumptions as in Jones and Klenow (2016) (consumption is lognormally distributed across people at a point in time and independent of age and mortality, the growth rate of consumption is zero, the discount rate is 1, and leisure and pollution are constant across ages and fixed), we can calculate the equivalent of equation (3). We make the additional assumption that the sum of the observed probabilities that an individual survives to age a (which under our assumptions equals observed life expectancy at birth) can be expressed as:

$$(8) \qquad \sum_a S(a, d) = e = e' - \gamma(d)$$

Where e' is adjusted life expectancy at birth and $\gamma(d)$ is the number of years of life lost to environmental pollution. The consumption equivalent welfare expression in (3) becomes:

$$(9) \qquad log\lambda_i = \frac{e_i' - e_{US}'}{e_{us}}\left(\bar{u} + logc_i + v(\ell_i) + r(d_i) - \frac{1}{2}\sigma_i^2\right) \qquad \textit{adjusted life expectancy}$$

$$- \frac{\gamma_i - \gamma_{us}}{e_{us}}\left(\bar{u} + logc_i + v(\ell_i) + r(d_i) - \frac{1}{2}\sigma_i^2\right) \qquad \textit{years of life lost due to environmental pollution}$$

$$+ logc_i - logc_{us} \qquad \textit{consumption}$$

$$+ v(\ell_i) - v(\ell_{us}) \qquad \textit{leisure}$$

$$+ r(d_i) - r(d_{us}) \qquad \textit{utility lost due to environmental pollution}$$

$$- \frac{1}{2}(\sigma_i^2 - \sigma_{us}^2) \qquad \textit{consumption inequality}$$

The first two terms of (9) equal the first term of the equivalent expression in Jones and Klenow (2016) (and our equation 3). They do not add any new calculation to the index but simply disaggregate the life expectancy term into the adjusted life expectancy term (the utility that could be achieved in the absence of the burden of environmental diseases), and the effect of years of life lost due to environmental pollution. The term inside the brackets is flow utility, which is the annual flow of utility for the representative consumer, as in equation (1), but including the utility cost of environmental pollution.

The fifth term in equation (9) represents the utility lost due to environmental pollution d. In order to capture the welfare cost of pollution, $r(d)$, environmental economists typically use different methods of valuation (either revealed or contingent valuation) to calculate the change in income or expenditure required to compensate for a given increase in pollution.[14] In our study we concentrate on the effects of global CO_2 emissions. We start by assuming that the representative consumer is concerned about climate change and willing to sacrifice consumption to abate or remediate damages from carbon. Following Hamilton and Clemens (1999) the damages from CO_2 emissions are charged to the emitting country, so the consumer pays to pollute in his country of residence. In this case, the marginal welfare valuation of an additional ton of carbon emissions is equal to its social cost, and the representative consumer in the U.S. pays his per capita share. This is equivalent to levying a global tax on CO_2 emissions in proportion to its global social cost with each person paying a per-capita share.[15]

To operationalize this approach we let d_i equal tons of CO_2 equivalent greenhouse gases (GHG) emitted into the atmosphere in country i. We value the social cost of each ton conservatively at US\$30, so that the social cost of emission in each country is $CO2_i = d_i \cdot \$30$, converted to PPP equivalent constant dollars. We then set $r(d_i) = \log(1 - \tau_i)$, where $\tau_i = \frac{CO2_i}{c_i}$, the social cost of CO_2 emissions in country i per unit of consumption. The combined effect on flow utility is thus like a tax on consumption equivalent to the CO_2 intensity of consumption.

Sustainable Consumption:

Our third adjustment seeks to take into account the sustainability of consumption into welfare. The representative consumer is now concerned with consuming sustainably, since he is aware that some of the countries may be depleting their natural resources and harming the economic prospects of future generations. Following Hamilton and Clemens (1999) and Heal and Kristrom (2005) and World Bank (2011), he/she is aware of the concept of genuine (or adjusted net) savings, which is a sufficient indicator for sustainable consumption. Genuine or Adjusted Net Savings (ANS) is a measure of saving that takes into account investment in human capital and the depletion of natural resources, as well as damage from pollution emissions.[16] When ANS are negative, this indicates that the economy is living unsustainably

[14] For a review of methodologies see Bockstael and Freeman (2005) and Carson and Haneman (2005).

[15] US EPA The global marginal social cost of a metric ton of CO_2 has been calculated at between US\$36 and US\$42 dollars – this measures the social cost of CO_2 damages from 2015 to 2050 in 2007 dollars, using a discount rate of 3 percent.

[16] Formally, adjusted net savings is equal to net national saving plus education expenditure, minus energy, mineral and forest depletion, and minus carbon dioxide and particulate emissions damage. We operationalize our measure of the gap excluding the cost of CO2 emissions damage to avoid double counting in our measure of welfare loss due to GHG emissions. There are a number of justifications for excluding the CO2 emissions

from its natural resources and hence depleting its wealth (Solow, 1974 and Hartwick, 1977). In our formulation, when ANS is negative, consumption needs to be reduced by the size of the negative net savings gap to bring the economy back to a sustainable path.

In our formulation, the adjusted net savings gap (ANS gap) is denoted by g, and we adjust consumption to make it sustainable (C^s) if the gap is negative:

$C^s = C, if\ g \geq\ 0$, and

$C^s\ = C + g, if\ g <\ 0$

And we implement the calculation using:

(8) $\quad u(C^s, \ell, d) =\ \bar{u} + logc^s + v(\ell) + r(d)$

We assume C^s is distributed in exactly the same way as C so that the consumption inequality term is not affected.

Welfare effects of environmental pollution - years of life lost due to environmental pollution.

This decomposition does not affect the overall level of the welfare index, but allows a decomposition of the life expectancy term into two effects: adjusted life expectancy, which is what life expectancy would have been if there were no mortality or morbidity from environmental effects; and the loss to life expectancy from environmental effects (DALYs). The results are presented in Table 5. Those countries that have highest DALYs relative to the US have the largest welfare loss. These are mostly very poor African countries (Sierra Leone, Chad, Swaziland and Cote d'Ivoire) that already have a very low life expectancy. But the effect is not exactly proportional, because the index weights DALYs with flow utility, so that some countries with relatively high DALYs and relatively higher flow utility in the sample also have a high welfare loss (for example Swaziland and Gabon). Overall, the effect of years of life lost to environmental pollution is small, on the order of one half of one percent of flow utility for the most affected countries. This is due to the fact that even in the most affected countries DALYs due to environmental factors are low (around a third of a year of life per capita).

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component in the World Bank adjusted net savings data. First, the calculation includes only CO2 emissions, not total GHG emissions, which can be substantially larger in some countries. Second, the calculation uses an outdated valuation for CO2 emissions that is considerably lower than the currently accepted values.

Table 5. Effect of Years of Life Lost Due to Environmental Pollution (2012)

Country	Lambda	Life Exp. Term	Decomp of Life Exp. Term Adjusted LE	Years lost	Life Exp.	DALYs	Welfare Loss (percent)
Angola	4.117	-0.627	-0.621	0.005	51.464	0.275	0.531
Nigeria	4.484	-0.648	-0.643	0.005	52.105	0.232	0.444
Sierra Leone	2.377	-0.369	-0.365	0.003	49.749	0.310	0.618
Chad	2.600	-0.398	-0.394	0.003	50.781	0.279	0.547
Swaziland	5.787	-0.932	-0.929	0.003	48.851	0.134	0.273
Cote dIvoire	3.049	-0.483	-0.481	0.003	50.863	0.193	0.377
Lao	6.161	-0.328	-0.325	0.003	65.249	0.143	0.219
Gabon	10.318	-0.513	-0.511	0.003	63.281	0.114	0.180
Cameroon	3.332	-0.430	-0.427	0.003	54.588	0.180	0.328
Lesotho	4.035	-0.712	-0.709	0.003	48.836	0.142	0.291
Congo	3.515	-0.300	-0.297	0.003	60.924	0.185	0.303

Welfare impact of environmental externalities - global GHG emissions

Taking GHG emissions into account has a significant effect on countries where these are large (valued at their social cost) relative to consumption. The effect of a greenhouse gas tax on consumption on the index is twofold. First, the tax reduces the annual flow of consumption (the expression inside the brackets in equation (9)) by the amount of $r(d_i)$. This in turn reduces the welfare loss in the index due to shortfalls in life expectancy relative to the US, $\frac{e_i'-e_{US}'}{e_{us}}$, since the consumption lost for every year of shortfall in life expectancy is lower. For countries with lower life expectancy than the US this effect thus reduces the negative contribution to the index from the shortfall in life expectancy, while for countries with higher life expectancy than the US it reduces the positive contribution. The second effect is simply the direct welfare loss due to the payment of the tax on GHG emissions relative to the tax that would be paid in the US – the fifth element of expression (9): $r(d_i) - r(d_{us})$.

Table 6 (Welfare Loss due to Greenhouse Gas Emissions, 2012 - Main Countries Negatively Affected) shows these effects for the countries most negatively affected in the index. The decomposition of the log ratio (columns eleven and twelve) show the positive indirect life expectancy effect, and the negative direct effect of the GHG term.[17] The negative direct effect offsets and dominates the life expectancy effect. Countries with the highest log ratio difference (column ten) have the largest proportional decline in the welfare index when we include GHG effects.

The countries most negatively affected by the GHG emissions effect are those that have large emissions per unit of consumption (shown in the last column), including Bolivia, Lao PDR and Zambia at the top of the list. These three countries have high levels of CO2 equivalent GHG emissions per unit of consumption, mainly due to land use changes and forestry effects

[17] For simplicity we have left out the other terms of the index (consumption, leisure and inequality) since they are the same for the baseline and the calculation with the GHG effect.

related to deforestation. Taking the social cost of these emissions into account in the index reduces recorded welfare by 5 percent, 3.3 percent, and 1.7 percentage points of the US level respectively. It is interesting to note that these countries are not ranked low on the list of countries in the 2012 Environmental Protection Index (EPI) (Hsu et al., 2016), neither overall nor for climate change effects. Our index presents a new prism for looking at environmental factors by signaling the importance of consumption of natural resources in welfare for these countries.[18]

Table 6. Welfare Loss due to Greenhouse Gas Emissions, 2012
Main Countries Negatively Affected

	GHG emissions effect				Baseline			Difference		Decomposition		
Country	Welfare Lambda	log ratio	Life Exp.	GHG Loss	Welfare Lambda	log ratio	Life Exp.	Welfare Lambda	difference log ratio	Life Exp.	GHG loss	GHG/c
Bolivia	0.89	-2.515	0.061	-2.212	5.92	-0.622	-0.259	-5.02	-1.892	0.319	-2.212	0.892
Lao	2.79	-1.264	-0.161	-0.959	6.16	-0.473	-0.328	-3.37	-0.792	0.167	-0.959	0.622
Zambia	1.49	-1.505	-0.053	-1.033	3.19	-0.743	-0.324	-1.70	-0.762	0.271	-1.033	0.649
Guinea	1.63	-0.507	-0.090	-0.604	2.53	-0.069	-0.255	-0.90	-0.438	0.166	-0.604	0.461
Madagascar	1.58	-0.409	-0.048	-0.491	2.36	-0.010	-0.141	-0.77	-0.398	0.093	-0.491	0.397
Cambodia	2.39	-0.785	-0.106	-0.364	3.26	-0.476	-0.161	-0.87	-0.309	0.055	-0.364	0.315
Chad	2.02	-0.561	-0.250	-0.401	2.60	-0.308	-0.398	-0.58	-0.254	0.147	-0.401	0.340
Botswana	7.22	-1.295	-0.391	-0.307	9.25	-1.047	-0.450	-2.03	-0.248	0.059	-0.307	0.275
Mali	1.83	-0.431	-0.136	-0.311	2.29	-0.209	-0.225	-0.45	-0.222	0.089	-0.311	0.278
Tanzania	2.56	-0.525	-0.166	-0.271	3.17	-0.310	-0.221	-0.61	-0.216	0.055	-0.271	0.248
Sudan	4.33	-0.368	-0.309	-0.257	5.30	-0.165	-0.363	-0.97	-0.202	0.055	-0.257	0.238
Congo	2.90	-1.309	-0.239	-0.253	3.51	-1.116	-0.300	-0.62	-0.193	0.060	-0.253	0.235
Togo	1.91	-0.254	-0.138	-0.213	2.23	-0.100	-0.196	-0.32	-0.155	0.058	-0.213	0.203
Gabon	9.08	-1.162	-0.479	-0.162	10.32	-1.034	-0.513	-1.24	-0.128	0.035	-0.162	0.162
Ethiopia	1.91	-0.276	-0.102	-0.163	2.17	-0.149	-0.137	-0.26	-0.127	0.036	-0.163	0.162
Syria	8.17	-0.197	-0.208	-0.134	9.20	-0.079	-0.223	-1.03	-0.119	0.015	-0.134	0.137
Burkina Faso	2.09	-0.346	-0.177	-0.145	2.31	-0.244	-0.219	-0.23	-0.103	0.042	-0.145	0.147
Turkmenistan	10.03	-1.219	-0.423	-0.126	11.11	-1.117	-0.447	-1.08	-0.102	0.024	-0.126	0.131
Benin	2.67	-0.351	-0.244	-0.134	2.94	-0.254	-0.281	-0.27	-0.097	0.037	-0.134	0.138
Senegal	3.38	-0.227	-0.200	-0.119	3.72	-0.130	-0.222	-0.34	-0.096	0.023	-0.119	0.125
Cape Verde	9.89	-0.246	-0.166	-0.104	10.88	-0.150	-0.175	-0.99	-0.095	0.009	-0.104	0.112
Trinidad/Tobago	30.72	-0.668	-0.389	-0.099	33.51	-0.581	-0.402	-2.79	-0.087	0.012	-0.099	0.107
Zimbabwe	2.78	-0.170	-0.363	-0.133	3.03	-0.084	-0.410	-0.25	-0.086	0.047	-0.133	0.137
Cameroon	3.07	-0.509	-0.387	-0.126	3.33	-0.426	-0.430	-0.27	-0.083	0.043	-0.126	0.131
Uganda	2.35	-0.444	-0.231	-0.116	2.55	-0.363	-0.267	-0.20	-0.080	0.036	-0.116	0.122
Mauritania	4.16	-0.387	-0.305	-0.101	4.50	-0.310	-0.329	-0.33	-0.077	0.024	-0.101	0.109
Ghana	3.99	-0.606	-0.331	-0.101	4.30	-0.531	-0.357	-0.31	-0.075	0.026	-0.101	0.108
China	8.70	-0.912	-0.085	-0.077	9.37	-0.839	-0.089	-0.66	-0.073	0.004	-0.077	0.088

At the other end of the spectrum, Table 7. (Welfare Loss due to Greenhouse Gas Emissions, 2012 - Main Countries Positively Affected) shows those countries where the effect for accounting for GHG emissions is positive, largely because the life expectancy term is vanishingly small and the GHG loss term is positive, as these countries have lower emissions per unit of consumption than the US. This group includes mainly advanced European countries, some advanced Asian countries (Japan and Hong Kong) and Costa Rica,

[18] Rather than penalize these countries in the index by introducing a tax on CO2 consumption, another approach would be to disaggregate consumption into environment/resource related consumption and other consumption, and then develop an environment-related welfare index based on the natural resource intensity of consumption.

known for its environmental stewardship (highest scoring country in Latin America on the EPI). The effect is significant for some countries, ranging from as high as a tenth of one percent of the US level of welfare for Portugal to about 1 percent of the US welfare level for Switzerland.

Table 7. Welfare Loss due to Greenhouse Gas Emissions, 2012
Main Countries Positively Affected

	GHG emissions effect				Baseline			Difference		Decomposition		
Country	Welfare Lambda	log ratio	Life Exp.	GHG Loss	Welfare Lambda	log ratio	Life Exp.	Welfare Lambda	difference log ratio	Life Exp.	GHG loss	CO2/c
Switzerland	102.90	-0.158	0.210	0.010	101.86	-0.168	0.210	1.04	0.010	0.000	0.010	0.004
Sweden	97.84	0.148	0.157	0.009	96.97	0.139	0.157	0.87	0.009	0.000	0.009	0.005
Denmark	90.23	0.043	0.070	0.007	89.58	0.036	0.070	0.65	0.007	0.000	0.007	0.007
Norway	112.51	-0.367	0.149	0.007	111.70	-0.374	0.149	0.80	0.007	0.000	0.007	0.007
France	94.57	0.259	0.169	0.007	93.93	0.252	0.170	0.64	0.007	0.000	0.007	0.007
United Kingdom	85.83	0.190	0.112	0.006	85.33	0.185	0.113	0.50	0.006	0.000	0.006	0.008
Italy	85.63	0.204	0.179	0.005	85.21	0.199	0.179	0.42	0.005	0.000	0.005	0.009
Austria	95.31	0.109	0.117	0.005	94.86	0.104	0.117	0.45	0.005	0.000	0.005	0.009
Japan	86.58	0.215	0.221	0.005	86.20	0.211	0.221	0.38	0.004	-0.001	0.005	0.009
Hong Kong	98.04	0.099	0.246	0.005	97.62	0.095	0.247	0.42	0.004	-0.001	0.005	0.009
Costa Rica	21.18	-0.155	0.011	0.004	21.09	-0.159	0.011	0.09	0.004	0.000	0.004	0.010
Finland	90.69	0.163	0.100	0.004	90.37	0.159	0.100	0.32	0.003	0.000	0.004	0.010
Netherlands	96.52	0.068	0.126	0.004	96.19	0.065	0.126	0.33	0.003	0.000	0.004	0.010
Spain	74.31	0.169	0.182	0.004	74.06	0.166	0.182	0.25	0.003	0.000	0.004	0.010
Germany	96.85	0.122	0.115	0.003	96.56	0.119	0.115	0.29	0.003	0.000	0.003	0.011
Belgium	89.86	0.151	0.087	0.003	89.60	0.148	0.087	0.26	0.003	0.000	0.003	0.011
Cyprus	72.78	0.293	0.052	0.003	72.60	0.290	0.052	0.19	0.003	0.000	0.003	0.011
Portugal	59.55	0.153	0.078	0.002	59.42	0.151	0.078	0.13	0.002	0.000	0.002	0.012
Barbados	23.05	0.103	-0.137	0.002	23.00	0.101	-0.138	0.05	0.002	0.001	0.002	0.013
St. Vincent	19.37	0.127	-0.227	0.000	19.34	0.126	-0.228	0.02	0.001	0.001	0.000	0.014
Israel	65.09	0.088	0.143	0.002	65.01	0.087	0.143	0.07	0.001	0.000	0.002	0.013

Adjusted Net Savings

Including the adjusted net savings gap in the index expands the scope of the analysis to include sustainability. Since a negative net savings gap indicates a breach of the Hartwick rule (Hartwick, 1977) and unsustainable consumption, our index looks at the counterfactual of what would consumption have been in these countries if it had been sustainable, and what are the implications for the welfare index. Another way of looking at these results is as an indicator of how much consuming unsustainably has contributed to welfare in selected countries.

There are only a few countries that according to the World Bank data had a negative adjusted net savings gap in 2012 (Table 8. Countries with Negative ANS in 2012). Most are relatively less developed countries that rely heavily on natural resources, including Guinea (bauxite and alumina), Oman (petroleum), Liberia (iron ore) and Togo (phosphates), but the group also includes some higher income countries (Greece, Lebanon, Portugal) that were going through financial or other crises and were thus not investing. What these countries have in common is that in 2012 they consumed more of their natural resource wealth than they invested and were thus growing unsustainably.

Table 8. Countries with Negative Adjusted Net Savings, 2012

	consumption per capita (percent of US)	ANS gap (percent of consumption)
Guinea	1.85	-44.68
Oman	35.24	-26.10
Liberia	1.93	-21.07
Togo	2.12	-20.48
Greece	50.61	-7.43
Lebanon	33.00	-5.62
Laos	8.23	-4.58
Madagascar	2.83	-3.68
Belize	16.48	-3.53
Cameroon	5.42	-2.17
Malawi	2.68	-1.18
Tunisia	20.67	-0.82
Barbados	30.93	-0.35
Portugal	52.30	-0.21

Table 9 (Welfare Results for countries with negative net savings, 2012) presents the results for the index including the adjusted net savings gap. As in the case of the GHG emissions tax on consumption, the reduction of consumption to account for the negative net savings gap has two counteracting effects: the life expectancy effect is positive as the loss of welfare due to consumption over fewer years of life expectancy relative to the US is reduced; and the direct effect on reducing consumption relative to the US, which is negative. As in the case of GHG effects, the direct consumption effect dominates. In general the effect is proportional to the ANS gap as would be expected. Indeed, many of the countries affected most by GHG emissions are also those with negative ANS, although the effect is not directly proportional. The most affected country, Guinea, has a proportional decline in the welfare index of 35 percent (from 2.5 to 1.6 percentage points of the US level) while declines in other countries range from 25 percent for Oman (11 percentage points of the US level of welfare) to 0.6 percent for Portugal (0.4 of one percentage point of the US level).

Table 9. Welfare results for countries with negative net savings, 2012

	Baseline			Negative ANS			Difference		
Country	log ratio	Life Exp.	C/Y	log ratio	Life Exp.	C/Y	log ratio	Life Exp.	C/Y
Guinea	-0.069	-0.255	0.207	-0.502	-0.097	-0.385	-0.433	0.159	-0.592
Oman	-0.681	-0.100	-0.591	-0.975	-0.091	-0.894	-0.294	0.008	-0.302
Liberia	0.312	-0.170	0.418	0.131	-0.115	0.182	-0.181	0.056	-0.237
Togo	-0.100	-0.196	0.078	-0.270	-0.137	-0.152	-0.170	0.059	-0.229
Greece	0.297	0.092	0.144	0.217	0.090	0.066	-0.080	-0.002	-0.077
Lebanon	0.221	0.007	0.150	0.163	0.007	0.093	-0.058	0.000	-0.058
Lao	-0.473	-0.328	-0.135	-0.511	-0.320	-0.182	-0.039	0.008	-0.047
Madagasca	-0.010	-0.141	0.210	-0.041	-0.134	0.172	-0.030	0.007	-0.038
Belize	-0.100	-0.297	0.157	-0.132	-0.293	0.121	-0.032	0.004	-0.036
Cameroon	-0.426	-0.430	0.082	-0.441	-0.423	0.060	-0.015	0.007	-0.022
Malawi	0.047	-0.171	0.261	0.039	-0.168	0.250	-0.009	0.003	-0.012
Tunisia	-0.177	-0.170	-0.021	-0.184	-0.169	-0.030	-0.007	0.000	-0.008
Barbados	0.101	-0.138	0.400	0.098	-0.138	0.397	-0.003	0.000	-0.004
Portugal	0.151	0.078	0.026	0.145	0.078	0.023	-0.006	0.000	-0.002

V. Conclusion

We calculate the welfare index of Jones and Klenow (2016) to 2014 to shed light on changes in welfare across countries during the period of the global financial crisis and subsequent years. Our results for the index in 2014 are very similar to those of Jones and Klenow: the index is highly correlated to GDP per capita, but there are significant deviations, mostly related to differences in life expectancy. However, differences in consumption, leisure and inequality can also play an important role in particular countries. For example, consumption has a large contribution to welfare beyond the level of GDP in small island countries that receive large grants and therefore can consume beyond their level of income.

We look at growth in welfare and income between 2007 and 2014 to shed light on trends in convergence between poor and advanced countries. Both welfare and income grew more quickly in poorer countries, as would be expected due to the crisis, but almost across the board welfare grew more quickly than income, largely due to improvements in life expectancy. This was true even in some countries at the center of the 2008 financial crisis where income per capita was stagnant or contracted, including the US. The exception is Asia, where growth in welfare lagged the very rapid growth in income, due mainly to the slower growth of the income share of current consumption. For the aggregate of countries in our sample, on a population weighted basis, welfare converged to the US level by 2.5 percentage points over the period, while income converged to the US level by 4.6 percentage points. Welfare lagged as the improvements in consumption did not keep pace with GDP.

In the second section of the paper we introduce environmental effects into the welfare calculation. We first decompose the life expectancy term in the index to include the effect of morbidity and mortality attributable to environmental factors through disability adjusted life-years (DALY). The effect on the index is very small, mainly because the decline in life expectancy from DALYs is also very small, although some countries where DALYs are highest, and life expectancy is already low, see a welfare loss of around one half of one percent.

Next we introduce the effects of GHG emissions by imposing a tax on consumption equivalent to the intensity of the cost of GHG emissions in consumption. For most countries, the direct effect of the tax outweighs the indirect effect of reductions in welfare loss due to lower life expectancy. The most negatively affected countries have the highest emissions of GHG relative to consumption, resulting in decline in the welfare index of between 1 and 5 percentage points of the US level of welfare. Our calculation thus illustrates to what extent the consumption of natural resources is important in welfare for some countries. On the other hand, there are also countries where the inclusion of GHG emissions in the index leads to higher welfare because their emissions per unit of consumption are lower than the US level.

Finally we include a dimension of sustainability by adjusting the index for unsustainable consumption as measured by the negative adjusted net saving gap. Many of these countries are also the ones identified as having high reliance on natural resources in welfare in our GHG calculations, but this group also includes countries at the center of the global financial crisis (crisis countries) that were consuming a high proportion of their income. Welfare losses for the most affected countries amounted to close to one percent of the US level.

The use of the index illustrates how cross-country data can be marshalled to create a measure of welfare that includes factors not covered in traditional measures of income and convergence. In addition to life expectancy, leisure and inequality introduced by Jones and Klenow, we add environmental pollution and sustainability. Additional factors that have an effect on current or potential consumption, and therefore welfare, could be considered, including gender equity, education and health, good governance and measures of social cohesion and capital. The welfare index could also be useful in policy discussions, as it could show the implications of policy reforms for welfare, in addition to income. As such, the measure might be useful in benchmarking the current state of some of the sustainable development goals (SDGs), for example, and quantifying the potential gains from their implementation.

The welfare measure does have some drawbacks. One salient issue touched upon above is the need to adjust measures of labor input to take into account involuntary unemployment, especially in crisis countries, or informal labor in lower income countries. Jones and Klenow have captured some part of informal labor in their micro study, as they use information from income expenditure studies to quantify informal work. However such an adjustment is beyond the scope of the macro approach in the present paper, which uses data on hours worked from the Penn World Tables version 9. Another limitation is the assumption that elements of the index are independent. It is likely that consumption is correlated with life expectancy and leisure, and, as noted, the effects of environmental externalities fall disproportionately on poorer countries. Finally, rather than relying on a measure of the contribution of each country to the global cost of carbon emissions, further work could attempt to quantify the welfare effects of global carbon emissions on particular countries. Potential extensions of this paper could take these factors into account.

Appendix

This appendix describes the data used in the calculation of the variables, the assumptions behind the calibration of the model, and the composition of the regional groupings. As mentioned in the text, for the baseline calculations we follow the Jones and Klenow (2016) macro calculations, and for further justifications of the calibration and methods we refer the reader to the original paper.

Calibration of the underlying utility function:

Intercept in flow utility $\bar{u}$: following Jones and Klenow (2016) calibrated so that the value of remaining life of a 40-year old in the US is equal to US$6 million, a figure consistent with the literature. When normalized by the US aggregate consumption per capita this yields a figure of around 5.

Consumption: ratio of consumption to GDP, including household consumption and government consumption.

Utility from leisure: $v(\ell) = -\theta \frac{\varepsilon}{1+\varepsilon}(1-\ell)^{\frac{1+\varepsilon}{\varepsilon}}$ where ε is a constant Frisch elasticity of labor supply, 1- ℓ is labor supply and θ is the utility weight on leisure or home production. Following Jones and Klenow, θ = 14.2 and $\varepsilon = 1$. ℓ is the proportion of total waking hours spent in leisure, calculated as 5840 (365 days times 16 hours) minus hours worked per capita divided by 5840.

Variance of log consumption σ: derived from the gini coefficient under the assumption that consumption has a lognormal distribution. The mean m and the gini g under the assumption of a lognormal distribution are given by: m=exp(μ $+ \frac{1}{2}\sigma^2$) and g = $erf^{-1}(\frac{\sigma}{2})$ where erf is the error function.

Years of life lost to environmental pollution γ (d): age standardized disability adjusted life years (DALY).

Underlying data:

Variable	Data	Source
Consumption	share of household consumption at current PPPs	Penn World Table version 9.0
Consumption	share of government consumption at current PPPs	Penn World Table version 9.0
Life Expectancy	Life expectancy at birth, total (years). Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.	World Bank WDI
Population	Population (millions)	Penn World Table version 9.0
Income	Expenditure-side real GDP at chained PPPs (in mil. 2011US$)	Penn World Table version 9.0
Income	Output-side real GDP at chained PPPs (in mil. 2011US$)	Penn World Table version 9.0
hours worked	Average annual hours worked by persons engaged (hours)	Penn World Table version 9.0
working age population	Total population between the ages 15 to 64 as a percentage of the total population. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. World Bank staff estimates based on age/sex distributions of United Nations Population Division's World Population Prospects.	World Bank WDI
employment	Number of persons engaged (in millions)	Penn World Table version 9.0
gini coefficient	coefficient as reported by the source	UN-WIDER World Inequality and Income Database (WIID) 3.0
age standardized disability adjusted life years (DALY)	(years) mortality and morbidity attributable to air, soil and water pollution with chemical or biological agents, ultraviolet and ionizing radiation, built environment, noise, electromagnetic fields, occupational risks, agricultural methods, irrigation schemes, anthropogenic climate changes, ecosystem degradation, individual behaviors related to the environment, such as hand-washing, food contamination with unsafe water or dirty hands.	World Health Organization, Global Health Observatory
total greenhous gas emissions (GHG)	Total greenhouse gas emissions in kt of CO2 equivalent are composed of CO2 totals excluding short-cycle biomass burning (such as agricultural waste burning and Savannah burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), all anthropogenic CH4 sources, N2O sources and F-gases (HFCs, PFCs and SF6).	World Bank based on European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR), EDGARv4.2 FT2012: edgar.jrc.ec.europa.eu
Adjusted Net Savings gap	net national saving plus education expenditure, minus energy, mineral and forest depletion, and minus carbon dioxide and particulate emissions damage (millions of current US$)	World Bank WDI

Regional Groupings

Europe: Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia/Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan.

Western Europe: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom.

North America: Canada, Mexico, United States.

Latin America and Caribbean: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Honduras, Jamaica, Mexico, Panama, Paraguay, Peru, Saint Lucia, St. Kitts and Nevis, St. Vincent, Suriname, Trinidad and Tobago, Uruguay, Venezuela.

Asia: Austrialia, Bangladesh, Bhutan, Cambodia, China, Fiji, Hong Kong, India, Indonesia, Japan, Lao PDR, Macao, Malaysia, Maldives, Mongolia, Nepal, Netherlands, New Zealand, Phillippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, Vietnam.

Middle East and North Africa: Brunei, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Pakistan, Qatar, Saudi Arabia, Syria, Tunisia, Yemen.

Sub-Saharan Africa: Angola, Bahrain, Benin, Botswana, Burkina Faso, Burundi, C. Afr. Republic, Cameroon, Cape Verde, Chad, Comoros, Congo, Cote D'Ivoire, Djibouti, Dem. Rep. Congo, Equatorial Guinea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome/Principe, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

References

Alkire, Sabina and James Foster, 2011. "Counting and Multidimensional Poverty Measurement." *Journal of Public Economics*, Vol. 95 issue 7-8, 476-487.

Bean, Charles, 2016. *Independent Review of UK Economic Statistics: Final Report*. Commissioned by the Chancellor of the Exchequer and the Minister for the Cabinet Office. U.K. Government.

Bockstael, Nancy E. and A. Myrick Freeman, 2005. "Welfare Theory and Valuation." *Handbook of Environmental Economics*, Vol 2, chapter 12. 517-570.

Carson, Richard T. and W. Michael Hanemann, 2005. "Contingent Valuation." *Handbook of Environmental Economics*, Vol 2, chapter 17. 821-936.

Elborgh-Woytek, Katrin et al. 2013. *Women, Work, and the Economy: Macroeconomic Gains from Gender Equity.* IMF Staff Discussion Note, SDN/13/10. Washington DC.

Fleurbaey, Marc, 2009. "Beyond GDP: The Quest for a Measure of Social Welfare." *Journal of Economic Literature,* Vol 47, No. 4. 1029-1075.

Kochhar, Kalpana, Sonali Jain-Chandra and Monique Newiak, editors, 2017. *Women, Work and Economic Growth; Leveling the Playing Field.* International Monetary Fund, Washington DC

Hartwick, John M., 1977. "Intergenerational Equity and the Investment of Rents from Exhaustible Resources." *American Economic Review,* Vol. 67, December, 972-974.

Hamilton, Kirk and Michael Clemens, 1999. "Genuine Savings Rates in Developing Countries." *The World Bank Economic Review,* Vol. 13, No. 2. 333-356.

Hsu, Angel, et al., 2016. *2016 Environmental Performance Index*. New Haven, CT: Yale University.

Heal, Geoffrey and Bengt Kristrom, 2005. "National Income and the Envirionment." *Handbook of Environmental Economics*, Vol 2, chapter 22. 1147-1217.

Institute for Health Metrics and Evaluation, 2016. *Global Burden of Disease.*

Jones, Charles I. and Peter J. Klenow, 2016. "Beyond GDP? Welfare Across Countries and Time." *American Economic Review,* Vol 106, No. 9. 2426-2457.

Lucas, Robert E. Jr., 1987. *Models of Business Cycles.* New York, Basil Blackwell.

Ostry, Jonathan David, Andrew Berg and Charalambos G. Tsangarides, 2014. *Redistribution, Inequality and Growth.* IMF Staff Discussion Note, SDN/14/02. Washington DC.

Ravallion, Martin, 2012. “Mashup Indices of Development.” *The World Bank Research Observer*, Vol. 27, No. 1. 1-32.

Solow, Robert M., 1974. “The Economics of Resources or the Resources of Economics.” *American Economic Review,* Vol. 64, No. 2, Papers and Proceedings of the Eighty-sixth Annual meeting of the American Economic Association (May, 1974), 1-14.

Stiglitz, Joseph E., Amartya Sen and Jean-Paul Fitoussi, 2009. *Report by the Commission on the Measurement of Economic Performance and Social Progress.*

United Nations Development Program (UNDP), 2009. *Human Development Report 2009.* Palgrave Macmillan, New York.

United Nations, 2015. *Transforming our world: the 2030 Agenda for Sustainable Development.* United Nations, New York.

World Bank, 2011. *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium.* The World Bank, Washington DC.

World Economic Forum, 2017. *The Global Competitiveness Report, 2017-2018* (Geneva).