# The effect of air quality on welfare accounting

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**Abstract**

For several decades, there has been a discussion in economics on how to appropriately measure economic welfare. Although it is common perception that a simple GDP evaluation bears several shortcomings, GDP per capita is still the most prominent measure of countries' welfare and of its development over time. In a recent paper, Jones and Klenow (2016) extend the huge existing literature on alternative welfare measures by a concept that is based on a utility framework and that incorporates, besides consumption, also life expectancy, inequality, and leisure. In this paper, we add a component of environmental quality, in particular air pollution, to this framework and show that for some country groups accounting for air quality remarkably changes their relative welfare position, both in terms of levels and growth rates over time. Especially for some emerging countries we find strong welfare reductions due to high levels of air pollution. Nevertheless, on average, our welfare measure is still highly correlated with GDP per capita. Our results highlight the importance of environmental aspects in welfare accounting.

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# 1 Introduction

In the last three decades, many emerging countries have exhibited high GDP per capita growth rates, both in absolute terms and relative to highly developed countries. Figure 1 shows the average annual growth rates among the groups of High Income Countries (HIC) and Low and Middle Income Countries (LMIC). As can be seen, the group of LMIC constantly have had positive growth rates since the mid-1990s, on average about twice as high as those of the group of HIC.

Figure 1: Economic growth and air pollution: HIC vs. LMIC

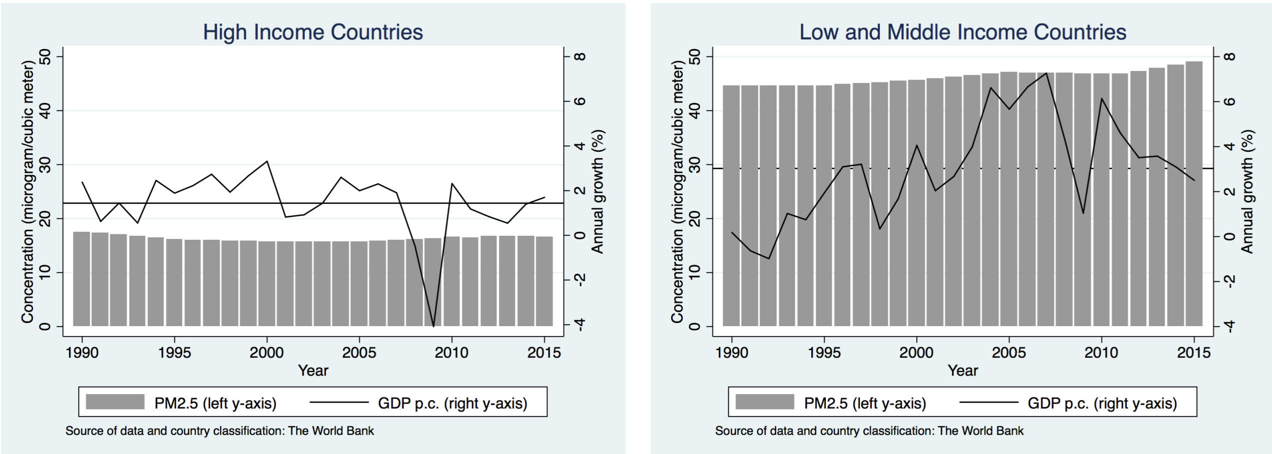
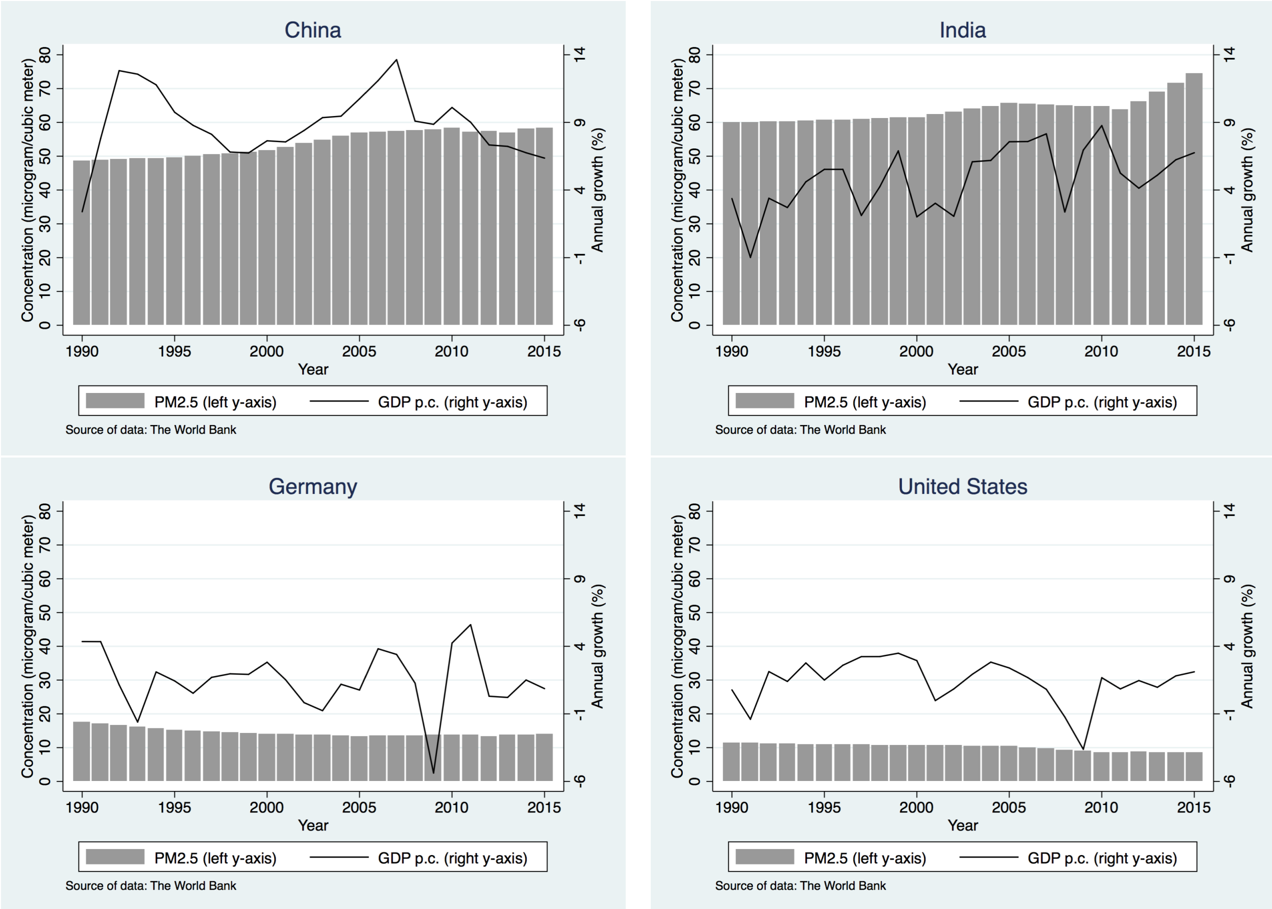



Figure 2 underlines this general observation with two well-known examples for rapidly growing countries, China and India, with annual growth rates of up to more than ten percent in the case of China and of up to eight percent in the case of India during the 1990s and the first decade of the 2000s. Starting with much lower income levels, LMIC seem to catch up with highly developed countries such as, for example, the United States or Germany, whose annual growth rates were much lower and even became negative in some years during the mentioned period. This empirically observed catching-up effect is well-known in the literature as ”economic convergence”.

Figures 1 and 2 additionally show the population-weighted annual exposure of particulate matter with less then 2.5 microns in diameter (PM2.5) for the selected countries and country groups. On average, the group of LMIC has had more than twice as high concentration rates per year as those of the group of HIC and showing a slightly positive long-term trend in the data, while the group of richer countries has been able to slightly decrease its level since the beginning of the 1990s. This observation is in line with the theoretical construct of the environmental Kuznets curve (EKC) that describes an inverse U-shape relationship between economic development

Figure 2: Economic growth and air pollution: Selected countries




and environmental degradation.[1]

The rise in the PM2.5 concentration in India and China since the beginning of the 1990s can at least partly be explained by the industrialization process of those countries' economies, since main sources of artificial particulate matter are the traffic sector and the industrial sector.[2] The share of the industrial sector in total GDP rose from 41 percent to 46.4 percent in China and from 26.5 to 32.4 percent in India between 1990 and 2010, while the share of the agricultural sector declined from 26.5 percent to 9.5 and from 29 to 18.9 percent, respectively.[3] Even if the relationship between economic development and environmental quality does not seem to be straightforward in any detail, it nevertheless raises the question of to what extent the quality of the environment influences peoples' welfare. This paper provides a potential answer to this question. We show that once air quality, in particular the concentration of particulate matter, is taken into account, the welfare ranking between countries substantially changes for some country groups, both in terms of levels and growth rates. Our results show that omitting environmental aspects from welfare accounting might lead to substantially biased conclusions.

[1]See Dinda (2004) for a review of the literature on the EKC.
[2]Further details will be given in section 1.1.
[3]Data: World Bank, WDI.

Moreover, our approach can be used to evaluate the welfare effects from concrete environmental policies such as bans on certain technologies, for example diesel cars.

We contribute to the huge existing literature on alternative welfare measures by adding environmental quality to the utility framework recently developed and published by Jones and Klenow (2016) that adds to the discussion about alternative welfare measures that has been going on for many decades now.

Jones and Klenow (2016) measure welfare as the expected lifetime utility of a random person called *Rawls* living in country $i$ by using a utility function that includes life expectancy, consumption, consumption inequality, and leisure. In particular, they choose the United States as the benchmark country and calculate equivalent and compensating variations to express welfare relative to the benchmark and then compare their relative welfare measure with relative GDP to conclude whether country $i$'s GDP overstates or understates its welfare. By choosing the United States as the benchmark country, they assume the same preferences for all people in all countries, which can be questioned but is necessary from the perspective of the equivalent and the compensating variation and keeps the model tractable. Their welfare measure is highly correlated with GDP per capita but they show that deviations are large for some country groups and that differences in mortality are the main driver for this. One of their main results is that many of the poorest countries worldwide - with regard to income - are even worse off with regard to welfare and we show in this paper that accounting for air quality further strengthens this finding.

In detail, in this paper we use air quality, in particular the concentration of airborne particulate matter, to measure environmental quality. We are aware that there are many other aspects of environmental quality, such as biodiversity, water quality, or soil quality but we use air quality as a proxy for overall environmental quality for two reasons. First, data on air quality is available for a large sample of countries and years and second, there is daily variation in air quality, an important feature for the calibration of the parameter in our utility function.

The main pitfall of our extension is the fact that air quality already enters the framework of Jones and Klenow (2016) indirectly via the life expectancy of a country's population. According to the World Health Organization (WHO), there are more than 2 million premature deaths worldwide caused by air pollution each year (WHO, 2005). We manage to avoid double count of these effects by evaluating only the direct effects of air pollution on subjective well-being, an approach that we describe in detail in section 3.2. We assume that, ceteris paribus, a person's utility increases in air quality, since there is positive utility from consuming a clean environment with clean air. Levinson (2012) shows that perceived happiness is related to local daily air quality and he concludes from his calculated willingness to pay for clean air that people's monetary valuation of clean air might be substantial. Several medical studies link air pollution to faster aging and to lower well being, aspects that reduce utility in addition to lower life expectancy. Weuve et al. (2012) find that long-term exposure to high levels of particulate matter concentration leads to a decline in cognitive capabilities of older women. Fonken et al. (2011) show in their study that male mice that have been exposed to particulate matter are more likely to show depressive-like and anxiety-like behavior compared to mice that have been exposed to clean air over the same time span. The authors conclude that long-term exposure to particulate matter might also affect the cognitive behavior of humans. Taking these results together makes it reasonable to assume that air pollution in general and high levels of particulate matter in particular might have a negative influence on subjective well-being in addition to its detrimental effect on life expectancy. A detailed review of the medical literature on health effects of particulate matter exposure is given in Groneberg et al. (2009).

For several decades, economists and politicians have argued that environmental quality is an important determinant of humans' welfare. In 1968, Robert F. Kennedy claimed that

> "Our gross national product [...] counts the destruction of the redwoods and the loss of our natural wonders [...]" (Kennedy, 1968)

and brought the discussion about environmental accounting in a welfare context to the public. In their famous publication of the "Club of Rome" project on the limits to growth, Meadows et al. (1972) account for several aspects of environmental quality and pollution as well as the finiteness of the world's natural resource reserves. Since then, several alternative welfare measures have been developed over the years that explicitly value environmental quality. Keeler et al. (1972) develop a model to study the optimal control of pollution and consider, for reasons of simplicity, a utility function that is separable in consumption and pollution and that exhibits an increasing marginal disutility of pollution. A similar assumption is made by Michel and Rotillon (1995) in their benchmark model, who study pollution in an endogenous growth model. Moreover, in a second step, the authors introduce a negative effect of pollution on the marginal utility of consumption and call this effect a "Distaste Effect", an assumption that seems plausible especially for air pollution as we use it in our approach to model environmental quality. High concentration rates of particulate matter or ozone limit the possibilities to enjoy outdoor activities and therefore decrease the number of "varieties" of the good leisure and may additionally reduce the utility from consumption. Gradus and Smulders (1993) study the influence of environmental protection efforts on long-term growth rates and treat pollution as a by-product of production that decreases social welfare and creates a trade-off between consumption and abatement of pollution. They assume increasing marginal disutility from pollution and moreover a negative effect of pollution on the marginal utility of consumption, e.g. they consider non-separability of consumption and pollution. Nevertheless, in the course of their paper, they relax the non-separability assumption and model utility as $U(c, P) = \log(c) - \frac{\phi}{1+\psi} P^{1+\psi}$ with $c$ as consumption and $P$ as pollution, to introduce pollution into a neoclassical growth model. For $\psi \to -1$, this function converges to $U(c, P) = \log(c) - \phi \log(P)$. In light of the famous *Millennium Development Goals*, the World Bank (2006) subtracts the estimated damages of air pollution from a nation's calculated net national savings to achieve their well known sustainability measure of "Genuine Saving" to account for the depreciation of physical assets, such as cropland and human capital, due to environmental pollution. While this approach tries to monetize the damages of pollution in the context of wealth accounting, our approach measures the direct disutility of bad environmental conditions in a utility framework. Nevertheless, the negative effect of air pollution on the stock of human capital, in the form of increased mortality, also enters our calculation via the life expectancy term. Fleurbaey and Gaulier (2009) calculate an equivalent variation of income based on GDP per capita corrected for several components to compare the ranking of welfare for several economies. Among other components, they also account for healthy life expectancy and mention environmental quality, as a public good, as a further possible correction, but argue that the willingness to pay in this case is difficult to calculate, which leads them to leave out this aspect. Jones and Klenow (2016) also list environmental aspects as one possible extension of their framework, but leave this approach to further research. We add to this point and explicitly incorporate the quality of the environment, proxied with air quality, into their model.

## 1.1 Stylized Facts about Air Pollution with Particulate Matter

In this paper, we use population-weighted annual country data on air pollution to calculate the welfare effects of environmental degradation. In particular, air pollution is measured as the concentration of particulate matter, for the reasons explained in detail above. There are several sources of particulate matter, both natural and artificial, meaning that both geographical characteristics and economic activities influence the concentration level in a certain region. According to the European Environment Agency (EEA), main natural sources of particulate matter are emissions from volcanoes and seismic activities, mainly wind-blown desert dust, dispensed particles emitted from the surface of the sea, and wildland fires (EEA, 2012). Having these natural sources in mind is important when it comes to interpreting the welfare effects of air pollution. The derivation of policy implications should clearly focus on artificial sources of particulate matter, which are mainly processes of hydrocarbons being burned, such as power generation, heating, and the transportation and traffic sector. Moreover, also the agricultural and the mining sectors cause particulate matter emissions, which means there can be different channels working in different directions through which the relationship of economic development and the level of air pollution can be influenced.

Worldwide, the population-weighted annual exposure to PM2.5 has increased about 10 % from 39.5 $\mu g/m^3$ in 1990 to 44 $\mu g/m^3$ in 2015, whereas during the same period the share of people that are exposed to PM2.5 levels above the WHO guideline of 10 $\mu g/m^3$ has decreased from 95 % to 91 %.[4] Several developments over time working in different directions might explain these patterns. On the one hand, especially in developing and emerging countries more people have become able to afford polluting devices such as cars, and the transportation sector has grown as a result of economic development and globalization. Additionally, in economies moving from an agricultural to an industrial focus people tend to move from rural areas with relatively low levels of air pollution into urban ones with relatively high levels. These factors together lead to an increase of the population-weighted exposure to particulate matter. On the other hand, technical progress leads to cleaner technologies that have the potential to reduce overall air pollution even if penetration rates of polluting devices increase, an effect that counteracts the ones mentioned before. The data suggests that worldwide, on average, the former effects have dominated the latter over the last three decades but with significant regional differences. Taking a look at different regions worldwide, the data shows that there have been huge differences in the development of the particulate matter concentrations over time. While the PM2.5 concentration in the East Asian and Pacific countries increased by about 15 % from 38 $\mu g/m^3$ in 1990 to 44 $\mu g/m^3$ in 2015, the countries of today's European Union experienced a reduction of about 25 % from 20 $\mu g/m^3$ to 15 $\mu g/m^3$ in the same period. The decline of the pollution levels in Europe is less surprising - the European Union implemented limit values for PM10[5] and PM2.5 in 2005 and 2008, respectively - whereas the decline of 26 % of the PM2.5 concentration from 49 $\mu g/m^3$ in 1990 to 36 $\mu g/m^3$ in 2015 in Sub-Saharan Africa is much more surprising. Similar observations can be made regarding the share of the population exposed to particulate matter concentrations exceeding the WHO standards. While this share has decreased from 90 % in 1990 to 85 % in today's European Union, in the Arabian countries and countries from the Middle East, the share has constantly reached 100 % over the last 25 years. This explains why the population-weighted particulate matter concentration worldwide has increased and at the same time the share of the world's population exposed to levels above the WHO standards has declined. The illustrated regional differences both in levels and in the development of air pollution have huge effects on regional differences in welfare and its development, which is shown by the results of this paper.

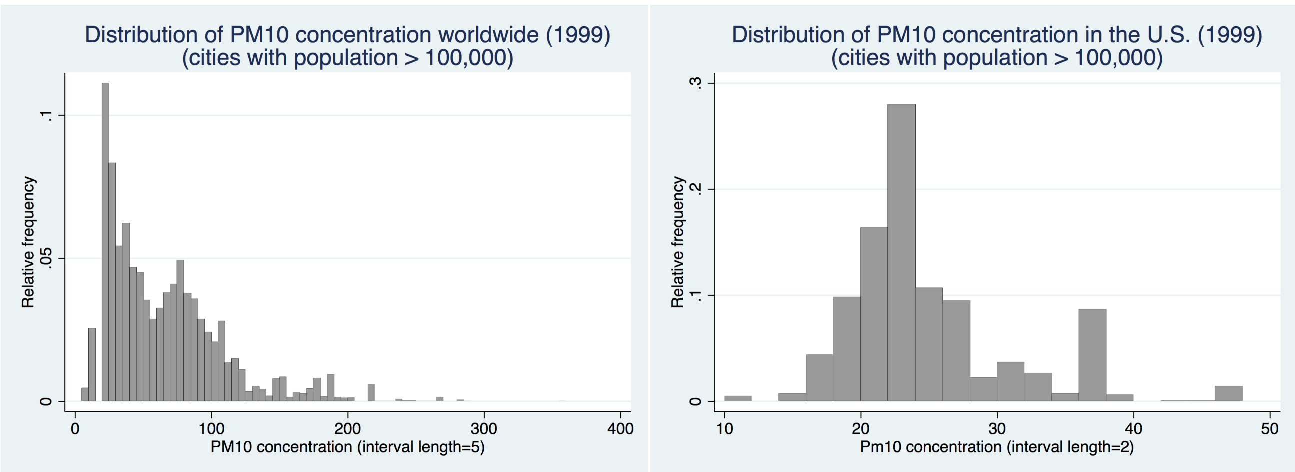
Not only regional- but also country-level data on particulate matter concentration exhibits wide

[4] All data about particulate matter concentration in this chapter is taken from the World Bank, WDI.

[5] Airborne particulates smaller than 10 microns in diameter.

variation, both between countries and over time. For 2007, the year for which we calculate our welfare measure, the data on PM2.5 concentration reveals a minimum value of 5.4 $\mu g/m^3$ in Sweden and a maximum value of 113.5 $\mu g/m^3$ in Niger. The mean value of our sample with 148 countries in 2007 is 28.8 $\mu g/m^3$ with a standard deviation of 20.8. Taking a look at more detailed data on a city level shows that there is not only wide between-country variation but also a lot of variation between different cities within the same country. According to the World Bank, in 1999 the PM10 concentration among 208 cities in the U.S. with a population above 100,000 (not taking into account Honolulu) ranged from 14.7 $\mu g/m^3$ in Beaumont up to 47.6 $\mu g/m^3$ in Phoenix, which accords to an estimated 7 $\mu g/m^3$ and 24 $\mu g/m^3$ of PM2.5 concentration.[6] Figure 3 shows the distribution of population-weighted particulate matter concentration for cities with more than 100,000 inhabitants, both worldwide and across the U.S. in 1999. According to the underlying data, in 1999, the city with the lowest concentration level of 5.8 $\mu g/m^3$ in the sample was Pinsk in Belarus and the one with the highest concentration rate of 358.9 $\mu g/m^3$ was Nyala in the Sudan.

Figure 3: Distribution of air pollution




While one can suggest that the high level of particulate matter in the southern part of the Sudan, where Nyala is located, is mainly caused by dust from the Sahara desert, there are other examples where air pollution can be linked to human activities to a large extent. Ulaanbaatar, the capital of Mongolia, exhibits a particulate matter concentration that is about ten times higher than the Mongolian air quality standards. According to a report of the World Bank (2011), burning of coal and wood by private households highly contributes to the severe concentration rates, which is underlined by the fact that concentration rates are much higher in winter than in summer. Not only between seasons, but even between different times of day

[6] Data stems from: Pandey et al. (2006). The conversion factor from PM10 to PM2.5 is, as mentioned earlier, 0.5.

and night, fluctuations of the particulate matter concentration can be observed, which delivers further evidence that heating plays a major role, especially in areas where it is done with simple devices such as coal ovens (Zhang and Cao, 2015). Industrial sectors such as the steel or the petrochemical industry are other artificial sources that emit high levels of particulate matter, which is especially a problem in many emerging countries, with China as a well known example. With respect to the health damaging effects of particulate matter, according to the WHO (2005) there is no level below which damages of the lung or other organs can be excluded. Following that, in 2005 the WHO formulated the aim to achieve the lowest possible concentration levels, although they formulate guidelines of 10 $\mu g/m^3$ PM2.5 and 20 $\mu g/m^3$ PM10 mean annual exposure, respectively. Nevertheless, the aim of the WHO to reach lowest levels possible leads us to refrain from introducing a lower bound of air pollution into our model.
Figure A1 in the appendix is taken from van Donkelaar et al. (2010) and shows the estimated worldwide concentration of PM2.5 based on satellite images averaged over the years 2001-2006. The map shows that the particulate matter concentration is especially high in desert areas, such as North and Middle Africa, the Middle East, and parts of Central Asia, but also in highly populated and industrialized regions such as East China and many parts of Europe. Moreover, it can be seen that there is a wide regional variation of particulate matter concentration worldwide, ranging from below 5 $\mu g/m^3$ up to more than 80 $\mu g/m^3$, which hints at regional differences in the effect of air quality in welfare accounting.

## 2 Utility Framework

To calculate the alternative welfare measure across countries and over time, we mainly rely on the additive utility framework described in Jones and Klenow (2016) and add a component of air quality to it. In detail, we also assume that consumption among a country's population is log-normally distributed. This leads to the linear separable flow utility per year as:

$$U(c, l, p) = \bar{u} + \log(c) + v(l) - \kappa \log(p), \tag{1}$$

which is the same as in Jones and Klenow (2016), except the term $-\kappa \log(p)$ that captures the disutility from environmental pollution, e.g. from air pollution. In detail, $\kappa$ is the disutility parameter from air pollution and $p$ is its level measured in $\mu g/m^3$. Moreover, $\log(c)$ is the sub-utility from consumption, $\bar{u}$ is a utility constant, and $v(l)$ is the sub-utility from leisure. Following the approach of Jones and Klenow (2016), $v(l)$ is defined as $v(l) = -\frac{\theta\epsilon}{1+\epsilon}(1-l)^{(\frac{1+\epsilon}{\epsilon})}$, where $\epsilon$ is the Frisch elasticity, $\theta$ is the utility weight assigned to leisure, and $l$ is leisure time. Expected lifetime utility - expected flow utility per year times the life expectancy at birth $e$ -

of a random person in country $i$ in the form of the Rawlsian utility then follows as:

$$V(e, c, l, \sigma, p) = e[\bar{u} + \log(c) + v(l) - \frac{1}{2}\sigma^2 - \kappa \log(p)], \quad (2)$$

where $\log(c) - \frac{1}{2}\sigma^2$ is the expected value of consumption given a log-normal distribution, with $\sigma^2$ as the variance of the distribution. We assume leisure and pollution to be certain, from which follows that for both variables the expected utility equals the utility of its expected value.
Consumption is the sum of private and public consumption, which takes into account that people not only derive utility from their private consumption but also from the consumption of goods provided by the government. Notice that with this additive utility function, it is assumed that air pollution does not have any direct effect on the utility of consumption and leisure, an assumption that can be questioned and that we relax in our robustness checks. Imagine a person living in an urban area with severe problems of air pollution. It seems obvious that high levels of air pollution have the potential to reduce the utility from leisure time, since they, for example, impede outdoor activities and may force people to stay indoors. If air pollution has a negative effect on the marginal utility of leisure time, this indirectly influences a person's labor supply, since it lowers the opportunity costs of working. Moreover, there might also be a direct effect of air pollution on de facto labor supply via an increase in sick days. Hanna and Oliva (2015) use data from a natural experiment on the closure of a large polluting refinery in Mexico City to show that a 20 percent decrease in local $SO_2$ emissions leads to an average increase in de facto hours worked of 3.5 percent of the local labor force.
Nevertheless, in our baseline calculations we stick to the assumption of linear separability between consumption, leisure, and air pollution to keep the model as tractable as possible and to make the results comparable to those of Jones and Klenow (2016). Moreover, it should be noted that the term of the disutility from air pollution in our specification captures the direct effects rather than the indirect ones. A potential reduction in life expectancy due to low levels of air quality is already included in $e$, whereas this does not account for different levels of subjective well-being caused by different levels of air quality.[7] Levinson (2012) concludes in his study on the link between air quality and subjective happiness that air pollution has a direct negative effect on stated well-being additionally to a potential reduction of life expectancy.

As in Jones and Klenow (2016), we chose the United States as the benchmark country and calculate the equivalent variation $\lambda_i$, which satisfies the equation:

[7]For further information about the potential impact of air pollution on health and life expectancy, see WHO (2005).

$$V(e_{us}, \lambda_i c_{us}, l_{us}, \sigma_{us}, p_{us}) = V(e_i, c_i, l_i, \sigma_i, p_i). \tag{3}$$

The equivalent variation measures the factor by which a person's consumption living in the U.S. must be adjusted to make her indifferent between living there and in country $i$. From equation 3 follows:

$$\begin{aligned}
\log(\lambda_i) = \frac{e_i - e_{us}}{e_{us}}[\bar{u} + \log(c_i) + v(l_i) - \frac{1}{2}\sigma_i^2 - \kappa \log(p_i)] & \quad \text{Flow Utility} \\
+ \log(c_i) - \log(c_{us}) & \quad \text{Consumption} \\
+ v(l_i) - v(l_{us}) & \quad \text{Leisure} \\
- \frac{1}{2}(\sigma_i^2 - \sigma_{us}^2) & \quad \text{Inequality} \\
- \kappa[\log(p_i) - \log(p_{us})] & \quad \text{Air Pollution}
\end{aligned} \tag{4}$$

In terms of consumption shares, $\frac{c_i}{y_i}$, where $y_i$ is country $i$'s GDP per capita, rather than its absolute value, this can be written as:

$$\begin{aligned}
\log(\frac{\lambda_i}{\tilde{y}_i}) = \frac{e_i - e_{us}}{e_{us}}[\bar{u} + \log(\frac{c_i}{y_i}) + v(l_i) - \frac{1}{2}\sigma_i^2 - \kappa \log(p_i)] & \quad \text{Flow Utility} \\
+ \log(\frac{c_i}{y_i}) - \log(\frac{c_{us}}{y_{us}}) & \quad \text{Consumption} \\
+ v(l_i) - v(l_{us}) & \quad \text{Leisure} \\
- \frac{1}{2}(\sigma_i^2 - \sigma_{us}^2) & \quad \text{Inequality} \\
- \kappa[\log(p_i) - \log(p_{us})] & \quad \text{Air Pollution}
\end{aligned} \tag{5}$$

with $\tilde{y}_i = \frac{y_i}{y_{us}}$ as country $i$'s GDP per capita relative to that of the U.S.

# 3 Data and Calibration

## 3.1 Data Description

Our main source of data in the calculations of welfare levels is the data provided by Jones and Klenow (2016) for the year 2007 in their supplementary material. We use this data in order to reach as much comparability of the results as possible, although meanwhile, for many of the countries in the sample, data for more recent years has become available. Since we do not have sophisticated microdata on air pollution, we restrict our calculations to the macro perspective with publicly available data on yearly country averages. We use information about air pollution provided by the World Bank. Air pollution is measured as the mean annual exposure of suspended particles measuring less than 2.5 microns in aerodynamic diameter. The concentration of air pollution is measured in $\mu g/m^3$ and weighted by the population in both urban and rural areas, which takes into account that people in rural areas typically suffer less air pollution than people living in urban ones. The data is published yearly starting in 2010 and was published only every five years between 1990 and 2005. For that reason, we use a linear interpolation to obtain the values for 2007, the year for which we calculate our welfare measure.

The main source of the Jones and Klenow data set is the Penn World Table version 8.0.[8] In detail, data on real GDP per capita, expenditure side, the share of both private and public consumption in GDP, and on the average hours worked per worker and year stems from this source.

Moreover, data from the World Development Indicators published by the World Bank on average life expectancy at birth for both sexes, absolute population, and the employment share in total population is used by Jones and Klenow to construct their data set.

Data on consumption inequality in the Jones and Klenow data set is taken from the UNU-WIDER World Income Inequality Database version 3.0 (WIID3a) and is measured as a standard Gini coefficient.[9] Under the assumption of log-normal distributed consumption, the standard deviation of consumption can be calculated from the Gini coefficient, according to:

$$\sigma = \sqrt{2} \cdot \Phi^{-1} \left( \frac{1+G}{2} \right). \tag{6}$$

The WIID database contains data on both consumption and income inequality, and consumption inequality is used whenever it is available. In the case that there is no information on consumption inequality, Jones and Klenow use data on disposable income and we also stick to this practice. We are able to calculate our welfare measure for 148 countries from all income classes for the year 2007.

Due to availability of the data on air pollution, we limit our sample to the period 1991 until 2010 when calculating growth rates of our welfare measure. Jones and Klenow (2016) calculate growth rates over the period 1980 - 2007 and also provide the underlying data, but since there is no data on air pollution for 1980, we chose the period 1991 - 2010 when calculating growth rates. Since we can not use their provided data in this case, we gather the data from the same sources as they do, but use updated versions of the Penn World Table and the UNU-WIDER World Income Inequality Database. In detail, we use the Penn World Table version 9.0 and the

[8]For detailed information, see Feenstra et al. (2016).

[9]For detailed information, see UNU-WIDER (2015).

UNU-WIDER World Income Inequality Database version 3.3 (WIID3c). Our country sample, for which we are able to calculate growth rates, shrinks to 57 countries due to data availability.

## 3.2 Calibration

In our baseline calculations, we mainly use the same calibration for the parameters as Jones and Klenow (2016) in their baseline framework for their calculations based on macrodata. The authors derive $\theta = 14.2$, $\epsilon = 1$ and $\bar{u} = 5.0$. Nevertheless, a value of $\bar{u} = 5.0$ leads to negative values of flow-utility in our calculations, which would imply that a random person in this country at that time would prefer death over life, an assumption that does not seem plausible, either in an economic or in an ethic sense. We set $\bar{u}$ to 8.28, to make sure that the lowest flow-utility in our sample (Bangladesh) is just equal to zero. Notice that $\bar{u}$ has to be changed in the calculations of welfare growth rates to avoid any negative values of the flow utility. In the case of calculating growth rates, we derive the critical $\bar{u}$ as 7.36 and set the parameter to this value. The main problem with the proper calibration of $\bar{u}$ is, in any case, that it varies with the underlying assumption of the value of a statistical life, which differs substantially across studies (Viscusi and Aldy, 2003). Even if there are sophisticated approaches to measuring the statistical value of a human's life, none of them is able to capture the inherent value of living and therefore it seems implausible to assume that anyone would choose dying over living in even the poorest country.

The parameter that needs to be calibrated in our framework is $\kappa$, the disutility parameter of air pollution. To assign a monetary value to clean air, we use the estimates on the willingness to pay for clean air from Levinson (2012), who regresses self-reported happiness from survey respondents on real-time local data on air quality controlling for weather conditions, demographic characteristics, and the respondent's income. By including both location and time fixed effects as well as their interactions and by using daily fluctuating data on air quality, the author accounts for the fact that people with a relatively higher willingness to pay for clean air self-select into areas with less air pollution, a fact that can not be accounted for in studies that calculate the willingness to pay based on data on house prices, for example. From the regression results he derives the average marginal rate of substitution between income and current local air quality. Levinson's study concludes that people are willing to forgo about 37 US dollar for an improvement in air quality of one standard deviation for one day, a value that is much larger than those from other hedonic studies.[10]

We use the coefficients on air quality, measured in logs of $\mu g$ PM10 per $m^3$ and income in logs of thousand dollars of the author's log-log regression to calculate our parameter $\kappa$ as $-\frac{\beta_1}{\beta_2} = 0.67$,

[10] See, for example, Bayer et al. (2009).

where $\beta_1$ is the regression coefficient of the pollution variable and $\beta_2$ that of the income variable, respectively. Levinson's results for the specification that we use for our calibration are shown in table 1.

Table 1: Regression results from Levinson (2012)

| | log(income), log(PM10) |
|---|---|
| PM10 daily ($\mu g/m^3$)[$\beta_1$] | $-0.044^*(0.021)$ |
| Income [$\beta_2$] | $0.065^*(0.010)$ |
| Other covariates and fixed effects | Yes |
| $R^2$ | 0.129 |
| No. obs. | 6035 |
| Years: 1984-1996, skipping 1992, 1995 | |
| WTP for a 1 $\mu g/m^3$ reduction [$-\beta_1/\beta_2$] | \$947*(483) |
| WTP for a one std. dev. reduction for one day | \$37 |

* Statistically significant at 5%. Standard errors in parentheses. The dependent variable "happiness" has a mean of 2.17 and a std. dev. of 0.63. Income is measured in 1000 \$/year, converted to 2008 \$ using the CPI-U.

Since the data on air quality we use is measured in $\mu g$ of PM2.5 per $m^3$, but the calibration relies on estimates using a concentration of PM10 in $\mu g$ per $m^3$, we convert the PM2.5 data into PM10 data. According to the WHO (2005), the common PM2.5/PM10 ratio is 0.5, which is why we multiply the raw data on air pollution by the factor two. We are aware that Levinson (2012) uses data on income, whereas in our model utility is not derived from income but from consumption. Nevertheless, we use the Levinson data for our calibration, since it is, to our knowledge the best fitting approach by now, and moreover, in the U.S. the share of private and public consumption in GDP is relatively high, so it seems reasonable to proxy consumption by income for our calibration.[11] Notice that by using perceived happiness to calibrate $\kappa$, we make sure to capture only the direct effect of air pollution on subjective well-being. With this approach, we avoid double counting negative effects of pollution on life expectancy.

Levinson's results are qualitatively in line with the findings of Welsch (2006), who uses a similar approach but on a country-wide macro level to estimate the effect of air pollution on stated well-being in ten European countries over the period 1990-1997. Besides data on nitrogen dioxide and lead, he also uses data on particulate concentration and finds a statistically significant negative effect of particulate matter concentration on stated well-being. The approach for non-market environmental valuation used in the two mentioned studies needs to be distinguished

[11] In 2007, the average share of private plus public consumption in GDP for the whole country sample excluding the U.S. is 80 percent, whereas the U.S. value is 84 percent, according to data from the Penn World Table 9.0.

from methods of revealed preferences and stated preferences that are well established in the literature. Frey et al. (2004) refer to this method as the life satisfaction approach and argue that methods of revealed preferences and stated preferences both have shortcomings. They state that in the case of the revealed preferences approach, failures in the market for the goods that are used as complements or substitutes to the non-market good that is to be valuated might bias the results, whereas the stated preferences approach might suffer from strategic behavior or limited awareness of the respondents.[12]

# 4 Empirical Results

In the following, we present the results of the calculation of our alternative welfare measure, both for levels in 2007 and growth rates over the period 1991 until 2010. Notice that all calculations are relative to the U.S. as the benchmark, so *relative welfare* in the following always means *relative to the U.S.*

## 4.1 Welfare Levels

Table A1 in the appendix shows three different welfare measures for 148 countries in 2007 and for each country the rank in a cross-country comparison with respect to the three different measures. The first two columns show simple data on real GDP per capita and the position of the country in the GDP per capita ranking. The third and the fourth columns show the welfare measure calculated according to the specification of Jones and Klenow (2016) and the respective ranking. The last two columns show welfare levels derived from our utility specification with air pollution as an additional aspect and the country ranking based on this measure. Countries are ordered according to their GDP per capita, starting with Liberia, the country with the lowest value in the sample for 2007. It can be seen that, once welfare accounts for air quality, many Central- and Western European countries seem to be worse off compared to the case when air quality is not taken into account. The same seems to be the case for many emerging countries in this sample, such as Brazil, India, China, but also for some Eastern European ones, such as Poland, Lithuania, and Hungary. Moreover, among the 50 poorest countries in the sample, with respect to their GDP per capita, 70 percent of them reveal an even lower welfare with pollution compared to the Jones and Klenow measure, a result that further strengthens one of their main findings that the poorest countries have lower welfare levels than suggested by their GDP per capita. Hence, one of the main results from Jones and Klenow (2016), namely that GDP per capita seems to overstate relative welfare of many countries with lower income levels

[12] See Bennett (2011, chapter 1) for a detailed discussion about the different approaches.

than the U.S., holds when air quality is added to the model.

The observation that air pollution might change the relative welfare position of a certain country in many cases becomes even clearer from table A2 in the appendix, which shows the decomposition of our welfare measure into the particular components, namely life expectancy (LE), consumption as a share of GDP (C/Y), leisure (L), inequality (Ineq), and pollution (Poll) for 2007. The second line for each country shows the values of the raw data, namely life expectancy, the consumption to income ratio, average annual working hours, the standard deviation of consumption, and the PM10 concentration. As can be seen, extremely high levels of air pollution of about 227 $\mu g/m^3$ in Niger, nearly 12 times the reference value of the U.S., and about 99 $\mu g/m^3$ in the Central African Republic, reduce the welfare of these two already poor countries by nearly 167 and 110 log points, respectively, whereas the sample minimum value of 10.8 $\mu g/m^3$ increases the Swedish welfare by nearly 40 log points. The negative impact of high levels of air pollution significantly reduces welfare not only in low income countries but also in some high income ones. Saudi Arabia and Qatar, both among the top five income countries in 2007, suffer even more from air pollution than most of the poorest countries in the sample.

The findings of Jones and Klenow (2016) state that, by trend, European countries perform better compared to the U.S. with respect to leisure and inequality. Nevertheless, our results show that in some cases the welfare loss from pollution outperforms the welfare gains from more leisure and less inequality, which leads to relatively lower welfare levels compared to GDP per capita levels for countries such as Austria, Germany, and Belgium, which casts doubt on the hypothesis that many Western European countries do better in terms of welfare than suggested by their income levels.

**Result 1:**

*Taking into account air quality highly decreases the welfare of most low income countries compared to both a simple GDP per capita evaluation and the Jones and Klenow welfare measure. This finding strengthens the result of Jones and Klenow (2016) that many developing countries are poorer in terms of welfare than suggested by income levels.*

**Result 2:**

*The Jones and Klenow welfare measure seems to overestimate the living standards of most Central and Western European countries. Taking their - relative to the U.S. - high levels of air pollution into account worsens their position in the welfare ranking and in some cases they even fall behind their ranking in terms of GDP per capita. This finding contradicts the result of Jones and Klenow (2016) that living standards of European countries are, on average, much* *closer to those in the U.S. than suggested by income levels.*

Overall, our welfare measure that accounts for air quality in the utility specification reveals a statistically significant correlation of 0.69 with GDP per capita (relative to the U.S.), which is much lower than the correlation of 0.81 between income and welfare calculated according to the Jones and Klenow framework.[13] Moreover, the mean absolute deviation between our measure and GDP per capita is 55.3 percent and the median absolute deviation is 59.8 percent for the year 2007.[14] As figure 4 shows, the majority of countries in our sample lie below the 45 degree line, meaning that for many countries, assessing welfare simply according to GDP per capita might overestimate their living standards.

**Result 3:**
*Our welfare measure including air pollution still has quite a high correlation with GDP per capita of 0.69 for 2007. Nevertheless, for most countries in our sample, just focusing on GDP per capita seems to overestimate their actual welfare level.*

Figure 5 shows the correlation between our welfare measure and the welfare measure calculated as in Jones and Klenow (2016). Overall, the two statistics are highly and significantly correlated in our country sample for 2007. Despite the high correlation, there are some country groups that deviate substantially from the 45 degree line. This is especially the case for most Central and Western European countries. For most Central European countries, the welfare situation worsens remarkably, once the pollution level is taken into account. Germany, for example, with a per capita GDP of about 74 percent of the U.S. level in 2007, has a welfare of 83 percent in terms of the Jones and Klenow specification, but just of about 63 percent once air pollution is included in our calculation. Similar results can be found for France, Italy, and the Netherlands. Nevertheless, people in other countries, mostly less densely populated ones such as Canada, Sweden, or New Zealand benefit from good environmental conditions in terms of low levels of air pollution.

**Result 4:**
*Our welfare measure including air pollution still has a very high correlation with welfare according to the specification of Jones and Klenow of 0.95 for 2007. Nevertheless, accounting for air quality lowers the relative welfare position of many country groups.*

[13]Notice that, although we use their data on all variables besides pollution, our correlation differs from the one that they report, which is mainly due to the different value for $\bar{u}$ that we use.

[14]As in Jones and Klenow (2016), the absolute deviation in the level case is defined as $|1 - \frac{\lambda_i}{\tilde{y}_i}| \cdot 100$.

Figure 4: Correlation of GDP p.c. and welfare with pollution (2007)

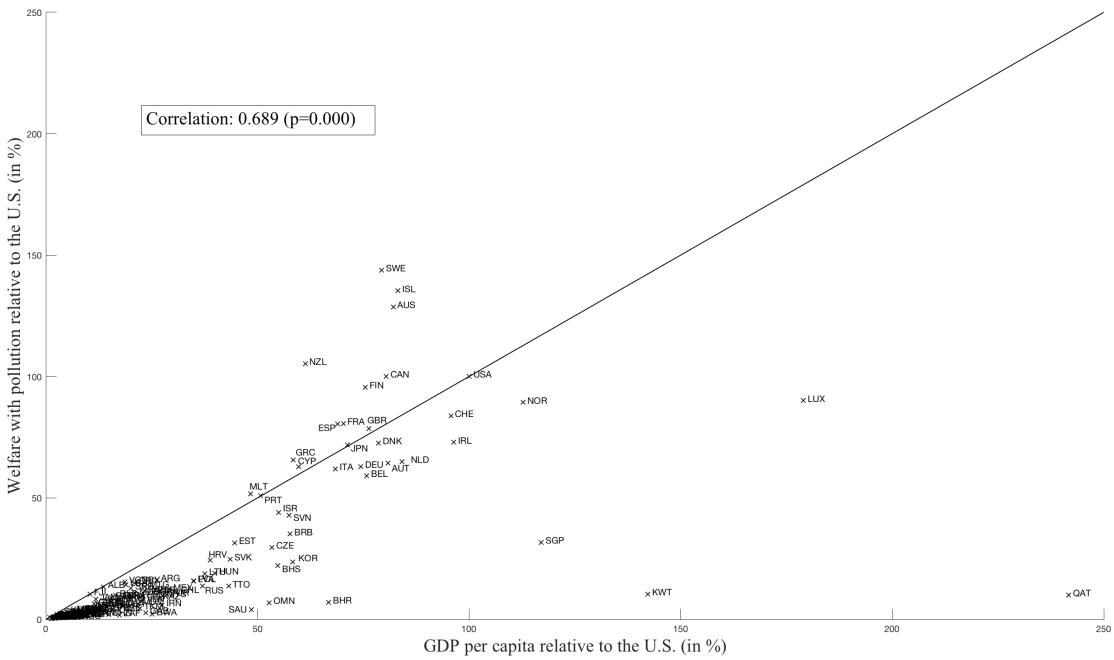
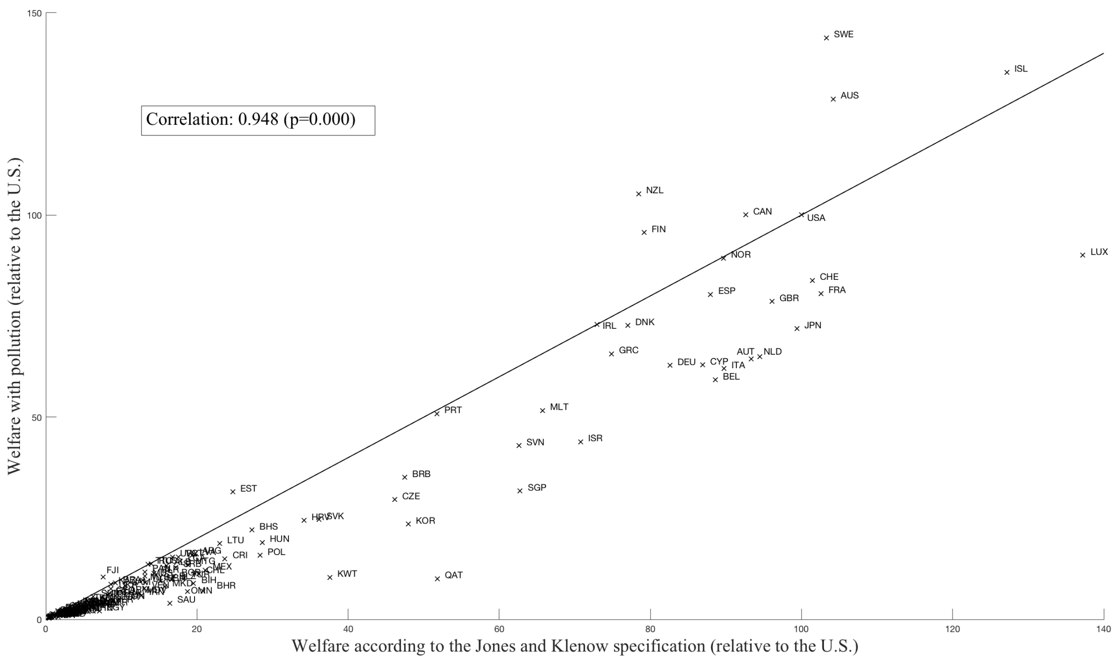



Figure 5: Correlation of welfare measures with and without pollution (2007)



## 4.2 Welfare Growth

When calculating growth rates of our welfare measure, we do not adhere to the data provided by Jones and Klenow, as explained in section 3 mainly due to availability of the data on air pollution. Moreover, differently to them, we use averages over five year periods of all variables instead of yearly data to mitigate short-term fluctuations and measurement error in the original data. In detail, we take averages of all input variables over the periods 1991-1995 and 2006-2010 and then calculate the average growth rates according to the procedure in Jones and Klenow (2016) as:

$$g_i = \frac{1}{T} \log(\lambda_i) \tag{7}$$

with $T = 3$ periods.

This means that in the following, all growth rates refer to the growth rate per period of five years. Table A3 in the appendix shows the growth rates of per capita GDP, of our welfare measure, and of the several welfare components, each per period of five years. The fourth column shows the difference between the growth rate of our welfare measure and the growth rate of per capita GDP. Negative values indicate that the country has grown less in terms of welfare than in terms of GDP per capita, but do not necessarily mean that the country has exhibited negative growth rates for either of the two measures.

As can be seen, both in terms of welfare and GDP per capita, all countries in our sample have experienced positive growth rates between the first half of the 1990s and the second half of the first decade of the 2000s. Nevertheless, in some cases there are huge differences between the growth rates of the two welfare measures. India and Vietnam, for example, both experienced high growth rates of per capita GDP, but grew about ten percent less in terms of our welfare measure, which was mainly driven by a deterioration of air quality, a result that is in line with the theoretical concept of the EKC. The increase in air pollution lowers the growth of our welfare measure by 1.7 percent per period in India and 0.7 percent per period in Vietnam, respectively. In absolute terms, the particulate matter concentration increased from 120.6 $\mu g/m^3$ to 130.1 $\mu g/m^3$ in India and from 53.8 $\mu g/m^3$ to 55.5 $\mu g/m^3$ in Vietnam between the first half of the 1990s and the second half of the first decade of the 2000s. In contrast, there are many countries whose welfare has increased at a higher rate once it is measured with our approach compared to a simple GDP per capita examination. Many European countries have exhibited growth rates of our welfare measure more than twice as high as their GDP per capita growth rates and in many cases improvements in air quality have contributed highly to that. The

Czech Republic, as an outstanding example, was able to reduce average air pollution from 61.6 $\mu g/m^3$ to less than 40 $\mu g/m^3$ during the given period. The fact that most European countries in our sample were able to improve their air quality further strengthens the finding of Jones and Klenow (2016) that European living standards have improved by more than is suggested by a simple income evaluation.

**Result 5:**
*On average, welfare of the EU-28 member states according to our measure has grown nearly 65 percent faster than GDP per capita has done between the beginning of the 1990s and the end of the first decade of the 2000s.*[15]

Figure 6 shows the correlation between GDP per capita growth rates and growth rates of our welfare measure with air pollution. The two measures reveal a correlation of 0.634, which is much lower than the value of 0.728, the correlation between GDP per capita growth and welfare calculated with our data according to the specification of Jones and Klenow (2016) without air quality.[16] The graph also shows that most of the countries in our sample lie above the 45 degree line, which means they have grown faster in terms of our welfare measure than they have done according to GDP per capita. Nevertheless, the two countries with the highest growth rates of GDP per capita in our sample, India and Vietnam, lie clearly below the 45 degree line, meaning that their fast economic growth seems to overstate the welfare improvements in these countries. As figure 7 shows, there is no clear correlation between income growth rates and over or underrating of welfare improvements. The correlation is rather weak with -0.248 and barely significant. In total, the mean absolute deviation of the two growth rates is 9.4 percent and the median absolute deviation is 9.3 percent, which shows that, on average, there are quite large differences between the two welfare assessments. Nevertheless, there is only weak evidence that in countries with high income growth rates these might overrate actual welfare improvements, which could be partly explained by a positive correlation between income growth and pollution at some stages of the development process. The graph shows that there are regional differences in this correlation, since the group of countries from Eastern Europe was able to achieve high income growth and even higher welfare growth, as most of these countries lie above the 45 degree line, while the Asian countries in the sample (besides Japan) all lie below the 45 degree line. This can be explained by the strong reductions of air pollution in many of the former

[15]There are 24 EU-28 states in our sample for which we are able to calculate growth rates of our welfare measure. Their average GDP per capita growth is 17.2 percent and their average growth of our welfare measure is 28.7 percent.

[16]Both correlations are highly significant.

Soviet states after the collapse of the Soviet Union and the approximation of many of these countries to the European Union and its environmental standards. Moreover, the integration into the European market enabled these countries to adopt more modern technologies, which helped to reduce air pollution. In contrast, most Central and Eastern Asian countries have suffered from increasing air pollution over the last decades, which is underlined by the above results.

Figure 8 additionally shows the correlation between the growth rate of our welfare measure and that of the measure calculated according to the specification of Jones and Klenow (2016). The two statistics reveal a high and statistically significant correlation of 0.879. Nevertheless, it can be seen that some countries in our sample lie clearly below the 45 degree line, indicating that welfare growth in these countries has been slower once air quality is taken into account. For other countries, especially the European ones, welfare growth over the given period is higher once the improvements in air quality are taken into account, which is not surprising, since all European countries in our sample were able to decrease their PM10 concentration between the beginning of the 1990s and the end of the first decade of the 2000s.

Due to the rather smaller sample size compared to the calculations of welfare levels, in the case of growth rates there are less clear patterns in the differences between country groups. Nevertheless, at least for the group of the EU-28 countries, we are able to derive conclusions due to good data availability for these countries.

**Result 6:**

*On average, welfare of the EU-28 member states has grown about 1 percent point faster between the beginning of the 1990s and the second half of the first decade of the 2000s, once the improvement in air quality is taken into account.*[17]

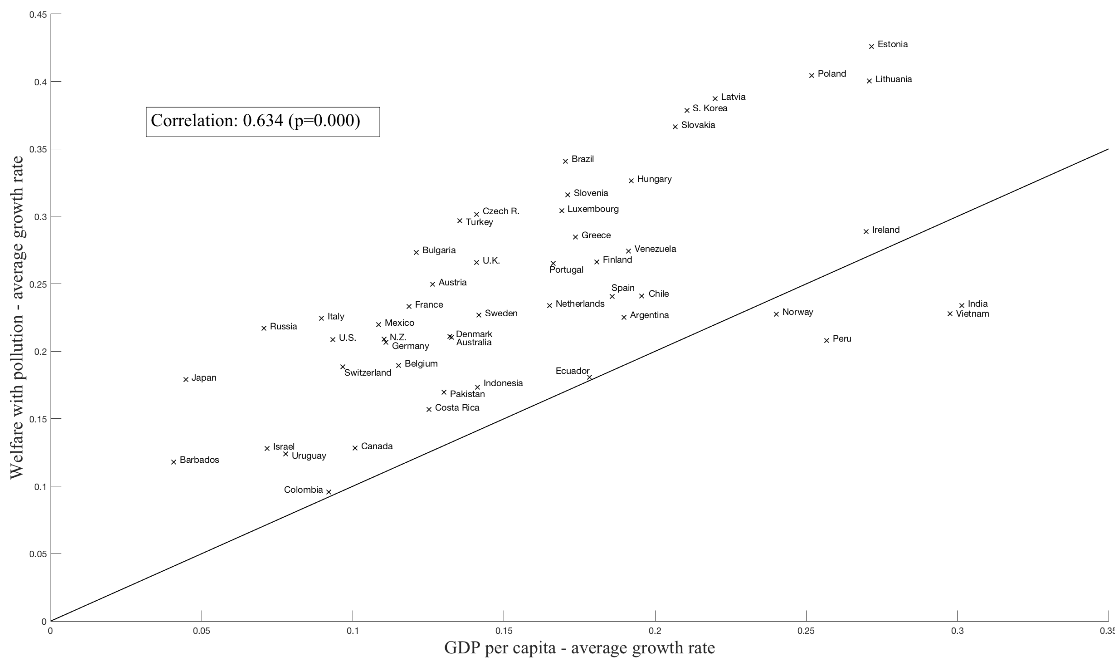
Calculating growth rates of our welfare measure can also be used to evaluate specific environmental policy measures regarding their welfare effects. As an example, take the *Action Plan on Prevention and Control of Air Pollution Introducing Ten Measures to Improve Air Quality* that was enacted by the Chinese Ministry of Ecology and Environment in 2013[18]. It aims to improve overall air quality in China over a period of five years. In particular, the concentration of particulate matter was planned to be reduced by 25 percent in the Beijing-Tianjin-Hebei Province, 20 percent in the the Yangtze River Delta and 15 percent in the Pearl River Delta.

[17]There are 24 EU-28 states in our sample for which we are able to calculate growth rates of the welfare measures with and without pollution. Their average welfare growth without pollution is 27.7 percent and with pollution this rate increases to 28.7 percent.

[18]http://english.mep.gov.cn/News_service/infocus/201309/t20130924_260707.htm.

Weighting this by the relative population shares of these three regions translates into a reduction of about five percent for the overall Chinese state[19]. Taking the data for 2013 for China[20] and assuming that there are no changes besides the reduction in the particulate matter concentration delivers an annual welfare growth of 0.7 percent (growth rate of $\lambda$) over the period of five years, which is the time frame of the action plan. Since $\lambda$ is the consumption equivalent, this means that in terms of consumption, Chinese people, on average, would be willing to accept an annual decrease of consumption by 0.7 percent if the goals of the action plan were realized. With a real GDP per capita of 11.673 USD (PPP) of which 51 percent were being consumed by either private households or the government, this translates into forgone consumption of about 30 USD (PPP) a year per capita over five years.

Figure 6: Correlation of GDP p.c. growth and welfare growth with pollution (1991-2010)




[19]Population data for China in total and by province stems from the World Bank and the National Bureau of Statistics of China.

[20]Due to lacking data on average annual working hours in China for 2013, we use the 2007 value for this variable.

Figure 7: Correlation of GDP p.c. growth and deviation from welfare measure (1991-2010)

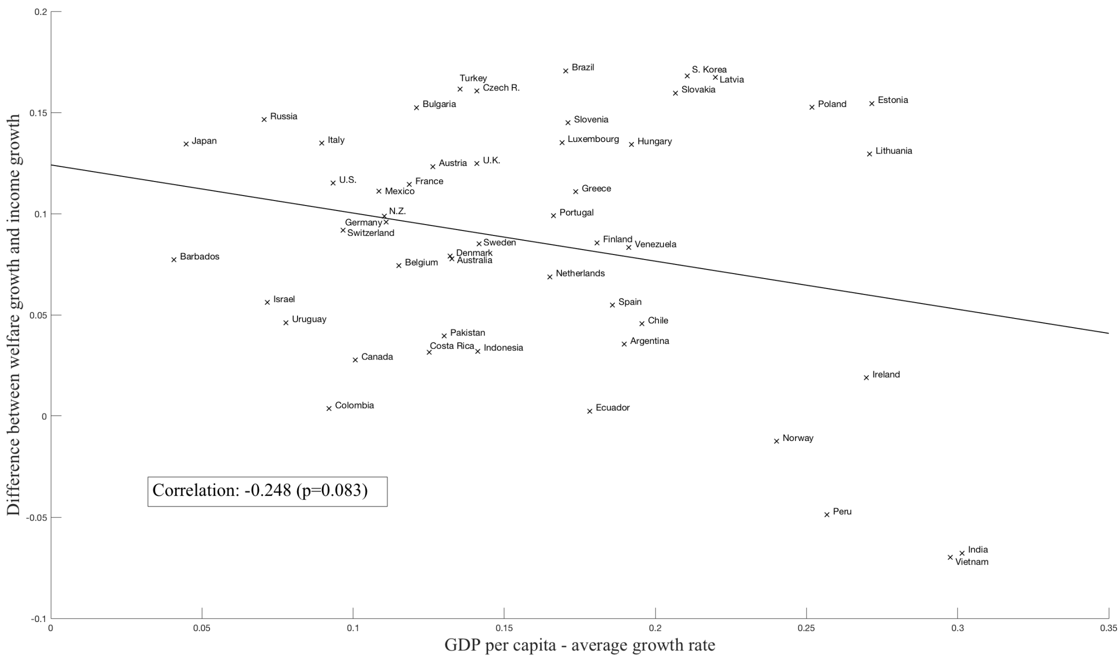
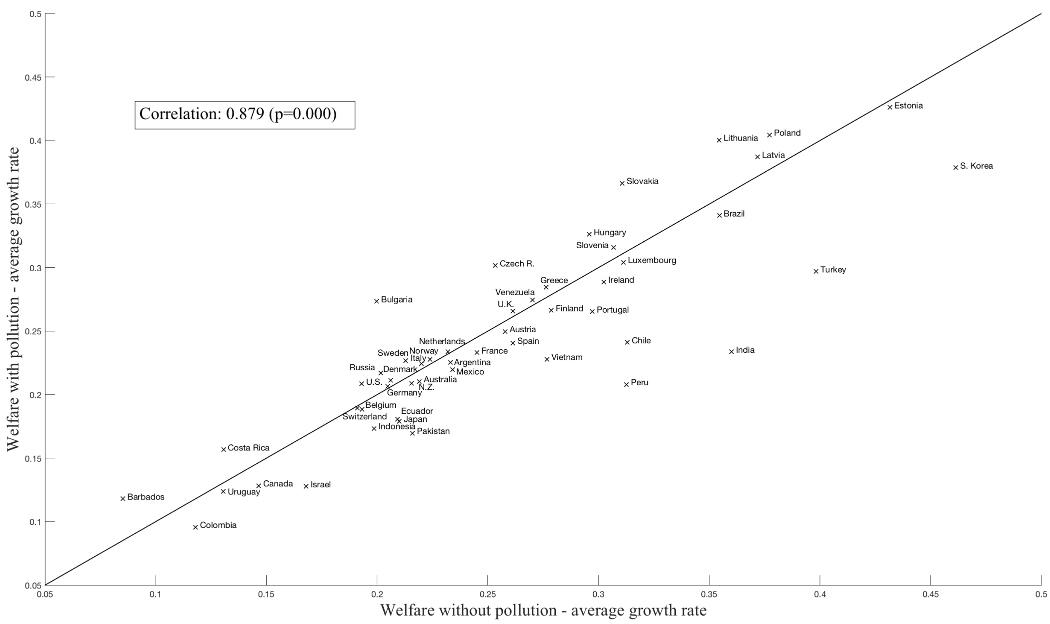



Figure 8: Correlation of welfare measure growth with and without pollution (1991-2010)




# 5 Robustness Checks

In this chapter, we show several robustness tests to check whether our results hold qualitatively if we deviate from our basic assumptions. All robustness checks are conducted both for welfare levels and welfare growth and the summary statistics are shown in tables 2 and 3, respectively.

## 5.1 Alternative Marginal Disutility from Pollution

In our baseline specification, we calibrate the marginal disutility of pollution $\kappa$ as 0.67 based on the regression coefficients of Levinson (2012) in his specification with log-income and log-pollution, as it fits to our assumptions about the utility function. As a first robustness check, we set $\kappa$ at the upper and lower bound, respectively, given the regression coefficients and their standard errors. The lower $\kappa$ is in absolute terms, the lower the marginal disutility from pollution relative to the marginal utility of income is. As can be seen in table 1, the coefficients both for log income and log pollution are statistically significant to five percent, which leads, with given coefficients and standard errors, to the 95 percent confidence intervals:

$$CI_{\beta_1} = [-0.044 - 0.021 \cdot 1.96;\ -0.044 + 0.021 \cdot 1.96] = [-0.08515;\ -0.00284] \tag{8}$$

and

$$CI_{\beta_2} = [0.065 - 0.010 \cdot 1.96;\ 0.065 + 0.021 \cdot 1.96] = [0.0454;\ 0.0846] \tag{9}$$

From that, we can calculate:

$$\kappa^{max} = -\frac{\beta_1^{min}}{\beta_2^{min}} = -\frac{-0.08515}{0.0454} = 1.87 \tag{10}$$

and

$$\kappa^{min} = -\frac{\beta_1^{max}}{\beta_2^{max}} = -\frac{-0.00284}{0.0846} = 0.03 \tag{11}$$

With the given values for $\kappa^{min}$ and $\kappa^{max}$ we recalculate our welfare measure, keeping everything else equal to our baseline specification, besides the $\bar{u}$ in the case with $\kappa^{max}$. Notice that by increasing the marginal disutility from pollution $\kappa$, the term in equation 1, the flow utility, decreases ceteris paribus. This leads, with our $\bar{u}$ from the baseline specification, to negative flow utilities for several countries, which we want to avoid as explained above. For that reason, we recalibrate $\bar{u}$ both for the calculation with $\kappa^{min}$ and $\kappa^{max}$ the same way as explained in section 3.2. It is immediately clear that the closer $\kappa$ gets to zero, the closer the utility specification gets to the case without air pollution, as in Jones and Klenow (2016), and the lower $\bar{u}$ needs to be to avoid negative flow utilities.

Table 2 shows that for the lower bound of $\kappa$ the correlation of welfare in levels with GDP per capita increases to 0.82 compared to 0.68 for the baseline specification and that the correlation with the baseline specification is very high with 0.94, meaning that our results are highly robust to decreasing the marginal disutility of pollution. With the upper bound of $\kappa$ the results deviate much more from those of the baseline specification, but notice that a $\kappa$ of 1.87 leads to a $\bar{u}$ of 14.79 necessary to avoid negative flow utilities, a value that is nearly three times the value

derived in Jones and Klenow (2016). Moreover, if we calculate the willingness to pay for a 1 $\mu g/m^3$ reduction in PM10 at the average income and average pollution level of the Levinson (2012) sample the way that he does but with the values of $\beta_1$ and $\beta_2$ that lead to our calculated $\kappa^{max}$, we end up with a value of 2622 US dollars compared to 974 US dollars for the baseline estimates of $\beta_1$ and $\beta_2$.[21] This would correspond to a willingness to pay of 103 US dollars for a one standard deviation reduction in PM10 for one day, which seems implausibly high compared to values from the literature. Given these considerations, it seems reasonable to assume that our baseline value for $\kappa$ is rather an upper bound for the marginal disutility of air pollution.
Applying the same robustness checks to welfare growth rates reveals similar results as in the case of welfare levels. As can be seen in table 3, both for the lowest and the highest estimate of $\kappa$ the results are highly correlated to those of the baseline calculations, but deviate more from the GDP per capita growth rates when $\kappa$ increases further from its baseline value.

## 5.2 Non-separable Utility Function

So far, we have assumed a linear and separable utility function as in equation 1, which means that the marginal utility of each variable is independent from all other variables. This assumption can easily be questioned. Suffering from low air quality not only influences health and life expectancy, but might also influence the marginal utility of leisure and consumption and potentially even the substitutability of the two. This might directly influence the decision about the labor supply of the households in addition to the fact that air pollution might lead to a lower labor supply due to an increase in sick days.
Based on the more general utility function in the robustness checks of Jones and Klenow (2016), we consider a general function for the flow utility with consumption, leisure, and pollution as:

$$U(c, l, p) = \bar{u} + \frac{c^{1-\gamma}(p^{-\kappa})^{1-\gamma}[1 + (\gamma - 1)v(l)]^{\gamma} - 1}{1 - \gamma}, \tag{12}$$

with $\gamma \geq 1$, which leads to consumption and leisure being substitutes.[22] Equation (12) converges to the benchmark case of equation (1) for $\gamma \to 1$. According to equation (12), the marginal utility of pollution is negative, e.g. $U_p < 0$, which is straightforward. Moreover, the marginal utility of consumption increases in the level of air pollution ($U_{cp} > 0$), while the marginal utility of leisure decreases in it ($U_{lp} < 0$). The economic interpretation is the following: The higher the level of air pollution, the more the individual prefers consumption over leisure, all else equal. This is in line with one of the theoretical arguments in Hanna and Oliva (2015),

[21] The WTP of 947 US dollars stems from the regression specification with log income and log pollution in Levinson (2012) and refers to one year.
[22] See, for example, Trabandt and Uhlig (2011) for more details about the functional form assumed in equation (12).

although they empirically find that an increase in air quality following the closure of a refinery in Mexico City led to an increase in work hours, which is equivalent to a substitution of leisure by consumption. Nevertheless, since they use census data in which households are surveyed over a rather short period of five consecutive quarters, variation in hours worked seems to be mainly due to variation in sick days rather than due to intentional changes in the labor supply. Therefore, our assumptions about the utility function are not inconsistent with their empirical results.

Multiplying equation (12) by life expectancy, applying condition (3), and rearranging gives the values of $\lambda_i$ for the case of a non-separable utility function (see Appendix for the derivation). Table 2 shows that even for values of $\gamma$ that are considerably above one, the correlation between welfare with non-separable utility and our baseline specification is close to one and highly statistically significant in the level case, meaning that our results are robust to relaxing the separability assumption. This is also underlined by figure A2 that plots the results from the separable case against those of the non-separable case with $\gamma = 2$. Moreover, also the correlation with the standard GDP per capita measure as well as the absolute deviation from it are close to the values in the separable case, which underlines the robustness of our results. Figure A3 plots the GDP per capita against our welfare measure with non-separable utility and $\gamma = 2$. It can be seen that the pattern looks very similar to figure 4 that shows the same plot but with our benchmark welfare measure with separable utility.

Regarding the results for welfare growth, switching from the separable to the non-separable case alters the results slightly more than in the case of welfare levels, but even for $\gamma$=2, the correlation between the results of both specifications is close to one and highly statistically significant even if the mean and median absolute deviation to GDP per capita growth both increase by about 14 percentage point compared to the separable case (table 3). This is underlined by figure A5 which additionally shows that all of the 63 countries for which we are able to calculate welfare growth rates are better off in the case with non-separable utility than in the separable case. Nevertheless, the scatter plot reveals a strong positive correlation.

Table 2: Robustness Checks, Welfare Levels - Summary Results

| | | *Correlation with* | | *Abs. Deviation (%)* | |
|---|---|---|---|---|---|
| | $\bar{u}$ | GDPpc | Benchmark | Mean | Median |
| Separable utility: | | | | | |
| Benchmark ($\kappa = 0.67$) | 8.28 | 0.689*** | - | 55.3 | 59.8 |
| $\kappa^{min} = 0.03$ | 4.79 | 0.821*** | 0.944*** | 24.70 | 20.93 |
| $\kappa^{max} = 1.87$ | 14.79 | 0.493*** | 0.901*** | 83.07 | 88.98 |
| Non-separable utility: | | | | | |
| $\gamma = 1.1,\ (\kappa = 0.67)$ | 8.28 | 0.690*** | 0.999*** | 55.03 | 59.88 |
| $\gamma = 1.5,\ (\kappa = 0.67)$ | 8.28 | 0.691*** | 0.989*** | 39.72 | 37.28 |
| $\gamma = 2.0,\ (\kappa = 0.67)$ | 8.28 | 0.690*** | 0.985*** | 42.00 | 39.72 |

Benchmark case refers to the baseline calculations in this paper.

Absolute deviation is measured relative to GDP per capita.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Robustness Checks, Welfare Growth - Summary Results

| | | *Correlation with* | | *Abs. Deviation (%)* | |
|---|---|---|---|---|---|
| | $\bar{u}$ | GDPpc | Benchmark | Mean | Median |
| Separable utility: | | | | | |
| Benchmark ($\kappa = 0.67$) | 7.36 | 0.634*** | - | 9.43 | 9.38 |
| $\kappa^{min} = 0.03$ | 4.83 | 0.731*** | 0.933*** | 6.11 | 5.54 |
| $\kappa^{max} = 1.87$ | 13.18 | 0.436*** | 0.924*** | 18.06 | 17.88 |
| Non-separable utility: | | | | | |
| $\gamma = 1.1,\ (\kappa = 0.67)$ | 7.36 | 0.583*** | 0.971*** | 26.61 | 28.02 |
| $\gamma = 1.5,\ (\kappa = 0.67)$ | 7.36 | 0.574*** | 0.942*** | 23.53 | 24.36 |
| $\gamma = 2.0,\ (\kappa = 0.67)$ | 7.36 | 0.566*** | 0.923*** | 23.33 | 23.99 |

Benchmark case refers to the baseline calculations in this paper.

Absolute deviation is measured relative to GDP per capita.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The robustness checks show that relaxing the assumption of linear separable utility does not alter the results qualitatively on average. However, as explained above, the non-separable utility specification changes the trade-off between the subcomponents by allowing pollution to influence their marginal utilities. This is especially relevant for countries with high levels of air pollution with respect to their welfare rank. China and India, as examples, that rank 81 and 110, respectively, out of 148 countries with regard to their GDP per capita in 2007 (relative to the U.S.), drop to rank 104 and 122 with separable utility and even further to rank 113 and 128 with non-separable utility.[23] The same is true for Qatar, the country with the highest per capita income in 2007, whose rank drops from 59 in the separable case to 65 in the non-separable case, showing that not only medium-income and low-income countries are affected by a a change in the specification. This shows that although our results are robust to relaxing the assumption about separable utility on average, for some countries their welfare ranking depends substantially on the form of the underlying utility function.

# 6 Conclusion

With this paper we contribute to the huge existing literature on alternative welfare measures by extending the recent approach from Jones and Klenow (2016) with an environmental component. In particular, we model a direct disutility from air pollution in the form of particulate matter concentration and calibrate the disutility parameter with recent estimates on the revealed willingness to pay for clean air. Based on this, we calculate welfare levels in the form of a consumption equivalent for 148 countries for the year 2007 and welfare growth over the period 1991 until 2010 for 57 countries. High concentration of particulate matter is not only a concern in developing and emerging countries, as the recent measures of the Chinese government show, but also of huge interest in many highly developed countries, as the current debate about diesel cars in Germany underlines.

We show that accounting for air quality remarkably influences many countries worldwide with respect to both their relative welfare levels and their welfare development over time. In particular, our results further strengthen one of the main findings from Jones and Klenow (2016) that many LMIC seem to be even poorer in terms of welfare than suggested by their income levels. Moreover, we can show that they have caught up less with the group of highly developed countries than has been suggested by their relatively high income growth over the last two decades. These findings shed a different light on the well-known discussion of economic convergence and highlight the importance of environmental issues to be considered from policy-makers especially in developing and emerging countries. With respect to many Western European countries, leaving out environmental aspects seems to overestimate their welfare levels, since most of these densely populated countries exhibit relatively high levels of air pollution, although most of them have been able to reduce them significantly over the last two decades. This partly tackles the findings from Jones and Klenow (2016), who state that many Western European countries are actually better off in terms of welfare than in terms of simple income.

[23] With $\gamma = 1.1$. As $\gamma$ increases further, the ranking worsens even more.

Our results are, on average, robust to different values of the air pollution disutility parameter and to relaxing the assumption of linear separable utility. Nevertheless, a nested utility function that allows air pollution to influence the marginal utility of consumption and leisure alters the results for countries with very high levels of air pollution, which seems both plausible and in line with the literature.

Our extension encourages future research to evaluate concrete policy measures as we have shown exemplarily for a recent Chinese action plan for cleaner air. Moreover, future research should focus on considering and quantifying different preferences across countries and over time regarding the trade-off between economic development and environmental degradation, a fact that is mostly ignored in the literature but yet important to derive practical policy implications. Additionally, while this paper focuses on air pollution with particulate matter, it is widely known that several other air pollutants negatively affect people's well-being. In light of the current heated debate about banning diesel vehicles from the centers of several German cities, future research should in particular try to evaluate the welfare effects of oxides of nitrogen in order to shed light on the actual costs and benefits from such interventions.

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# 7 Appendix

**Derivation of $\lambda$ in the non-separable case**

**Expected utility:**

The utility function is given by

$$U(c,l,p) = \bar{u} + \frac{c^{1-\gamma}(p^{-\kappa})^{1-\gamma}\left(1-(\gamma-1)v(l)\right)^{\gamma} - 1}{1-\gamma}$$

with $v(l)$ as defined in Jones and Klenow (2016) and leisure and pollution assumed to be constant and certain.

The expected utility can then be written as:

$$\begin{aligned} E\left[U(c,l,p)\right] &= \bar{u} + E\left[\frac{c^{1-\gamma}\left(1-(\gamma-1)v(l)\right)^{\gamma} - 1}{1-\gamma}\right] \\ &= \bar{u}\frac{E\left[c^{1-\gamma}\right](p^{-\kappa})^{1-\gamma}\left(1-(\gamma-1)v(l)\right)^{\gamma} - 1}{1-\gamma} \end{aligned}$$

As mentioned in the paper, $c$ is assumed to be log-normally distributed, i.e. $\log(c) \sim \mathcal{N}(\mu, \sigma^2)$. From that it follows that

$$\mu = E\left[\log(c)\right] = \log(c) - \frac{1}{2}\sigma^2$$

with $c$ as the arithmetic mean and $\sigma^2$ as the variance of $\log(c)$. We then use that

$$\begin{aligned} E\left[c^{1-\gamma}\right] &= e^{(1-\gamma)\mu + \frac{1}{2}(1-\gamma)^2\sigma^2} \\ &= e^{(1-\gamma)\left(\log(c) - \frac{1}{2}\sigma^2\right) + \frac{1}{2}(1-\gamma)^2\sigma^2} \end{aligned}$$

to express the expected utility as:

$$E\left[U(c,l,p)\right] = \left[\bar{u} + \frac{\left[e^{(1-\gamma)\left(\log(c) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma^2}\right](p^{-\kappa})^{1-\gamma}\left(1-(\gamma-1)v(l)\right)^{\gamma} - 1}{1-\gamma}\right]$$

**Limiting case $\gamma \to 1$**

For $\gamma \to 1$, the non-separable utility converges to the separable utility. The same is the case for the expected values. This can be shown by using l'Hôpital's rule: If $f(a) = g(a) = 0$, then

$$\lim_{x \to a} \frac{f(x)}{g(x)} = \lim_{x \to a} \frac{f\prime(x)}{g\prime(x)}$$

Applying this to the utility function yields:

$$\lim_{\gamma \to 1} \frac{c^{1-\gamma}(p^{-\kappa})^{1-\gamma}\left(1-(\gamma-1)v(l)\right)^{\gamma}-1}{1-\gamma}$$
$$= \lim_{\gamma \to 1} \frac{e^{\log\left(c^{1-\gamma}(p^{-\kappa})^{1-\gamma}(1-(\gamma-1)v(l))^{\gamma}\right)}-1}{1-\gamma}$$
$$= \lim_{\gamma \to 1} \frac{e^{(1-\gamma)(\log(c)-\kappa\log(p))\gamma\log(1-(\gamma-1)v(l))}-1}{1-\gamma}$$

Taking the derivative of the nominator and the denominator yields:

$$= \lim_{\gamma \to 1} \frac{e^{(1-\gamma)(\log(c)-\kappa\log(p))}(-\log(c)+\kappa\log(p))e^{\gamma\log(1-(\gamma-1)v(l))}}{-1} + \frac{e^{(1-\gamma)(\log(c)-\kappa\log(p))}e^{\gamma\log(1-(\gamma-1)v(l))}\left(\log(1-(\gamma-1)v(l)) - \frac{\gamma}{1-(\gamma-1)v(l)}v(l)\right)}{-1}$$
$$= \frac{e^{0}(-\log(c)+\kappa\log(p))e^{1\log(1)} + e^{0}e^{1\log(1)}\left(\log(1)-1v(l)\right)}{-1}$$
$$= \frac{-\log(c)+\kappa\log(p)-v(l)}{-1} = \log(c)-\kappa\log(p)+v(l)$$

Applying the same rule to the expected utility yields:

$$E\left[U(c,l,p)\right] = \log(c) - \frac{1}{2}\sigma^2 - \kappa\log(p) + v(l)$$

which is the expected value of our separable utility function.

**Calculating the Equivalent Variation**

Based on the above, we write expected utility for each country $i$ and the U.S. as

$$U_i(e_i, c_i, l_i, \sigma_i, p_i) = e_i \left[ \bar{u} + \frac{\left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] (p_i^{-\kappa})^{1-\gamma} \left(1 - (\gamma - 1)v(l_i)\right)^{\gamma} - 1}{1-\gamma} \right]$$

$$U_{us}(e_{us}, c_{us}, l_{us}, \sigma_{us}, p_{us}) = e_{us} \left[ \bar{u} + \frac{\left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] (p_{us}^{-\kappa})^{1-\gamma} \left(1 - (\gamma - 1)v(l_{us})\right)^{\gamma} - 1}{1-\gamma} \right]$$

We then set

$$U_i(e_i, c_i, l_i, \sigma_i, p_i) = U_{us}(e_{us}, \lambda_i c_{us}, l_{us}, \sigma_{us}, p_{us})$$

and solve for $\lambda$:

$$\begin{aligned}
& e_i \left[ \bar{u} + \frac{\left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] (p_i^{-\kappa})^{1-\gamma} \left(1 - (\gamma - 1)v(l_i)\right)^{\gamma} - 1}{1-\gamma} \right] \\
&= e_{us} \left[ \bar{u} + \frac{\left[ e^{(1-\gamma)\left(\log(\lambda_i c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] (p_{us}^{-\kappa})^{1-\gamma} \left(1 - (\gamma - 1)v(l_{us})\right)^{\gamma} - 1}{1-\gamma} \right] \\
&= e_{us} \left[ \bar{u} + \frac{\left[ e^{(1-\gamma)\log(\lambda_i)} e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] (p_{us}^{-\kappa})^{1-\gamma} \left(1 - (\gamma - 1)v(l_{us})\right)^{\gamma} - 1}{1-\gamma} \right] \\
&= e_{us} \left[ \bar{u} + \frac{\lambda_i^{1-\gamma} \left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] (p_{us}^{-\kappa})^{1-\gamma} \left(1 - (\gamma - 1)v(l_{us})\right)^{\gamma} - 1}{1-\gamma} \right]
\end{aligned}$$

Then,

$$e_i \left[ \bar{u} + \frac{\left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] \left(p_i^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_i)\right)^{\gamma} - 1}{1-\gamma} \right]$$

$$= e_{us} \left[ \bar{u} + \frac{\lambda_i^{1-\gamma} \left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] \left(p_{us}^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_{us})\right)^{\gamma} - 1}{1-\gamma} \right]$$

$$\Leftrightarrow e_i\bar{u} + e_i \left[ \frac{\left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] \left(p_i^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_i)\right)^{\gamma}}{1-\gamma} - \frac{1}{1-\gamma} \right]$$

$$= e_{us}\bar{u} + e_{us} \left[ \frac{\lambda_i^{1-\gamma} \left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] \left(p_{us}^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_{us})\right)^{\gamma}}{1-\gamma} - \frac{1}{1-\gamma} \right]$$

$$\Leftrightarrow (e_i - e_{us}) \left( \bar{u} - \frac{1}{1-\gamma} \right) + e_i \left[ \frac{\left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] \left(p_i^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_i)\right)^{\gamma}}{1-\gamma} \right]$$

$$= e_{us} \left[ \frac{\lambda_i^{1-\gamma} \left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] \left(p_{us}^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_{us})\right)^{\gamma}}{1-\gamma} \right]$$

$$\Leftrightarrow \left[ \frac{(e_i - e_{us})\left(\bar{u}(1-\gamma) - 1\right) + e_i \left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] \left(p_i^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_i)\right)^{\gamma}}{1-\gamma} \right]$$

$$= e_{us} \left[ \frac{\lambda_i^{1-\gamma} \left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] \left(p_{us}^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_{us})\right)^{\gamma}}{1-\gamma} \right]$$

$$\Leftrightarrow \lambda_i^{1-\gamma} = \left[ \frac{(e_i - e_{us})\left(\bar{u}(1-\gamma) - 1\right) + e_i \left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] \left(p_i^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_i)\right)^{\gamma}}{e_{us} \left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] \left(p_{us}^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_{us})\right)^{\gamma}} \right]$$

$$\Leftrightarrow \lambda_i = \left[ \frac{(e_i - e_{us})\left(\bar{u}(1-\gamma) - 1\right) + e_i \left[ e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2} \right] \left(p_i^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_i)\right)^{\gamma}}{e_{us} \left[ e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2} \right] \left(p_{us}^{-\kappa}\right)^{1-\gamma} \left(1-(\gamma-1)v(l_{us})\right)^{\gamma}} \right]^{\frac{1}{1-\gamma}}$$

#### Calculating the Compensating Variation

The compensating variation is derived by solving

$$U_i(e_i, \lambda_i c_i, l_i, \sigma_i, p_i) = U_{us}(e_{us}, c_{us}, l_{us}, \sigma_{us}, p_{us})$$

for $\lambda_i$

Analogously to the equivalent variation, it follows that

$$\lambda_i = \left[ \frac{(e_{us} - e_i)\left(\bar{u}(1-\gamma) - 1\right) + e_{us}\left[e^{(1-\gamma)\left(\log(c_{us}) - \frac{1}{2}\sigma_{us}^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_{us}^2}\right](p_{us}^{-\kappa})^{1-\gamma}\left(1 - (\gamma - 1)v(l_{us})\right)^{\gamma}}{e_i\left[e^{(1-\gamma)\left(\log(c_i) - \frac{1}{2}\sigma_i^2\right) + \frac{1}{2}(1-\gamma)^2\sigma_i^2}\right](p_i^{-\kappa})^{1-\gamma}\left(1 - (\gamma - 1)v(l_i)\right)^{\gamma}} \right]^{\frac{1}{1-\gamma}}$$

Figure A1: Worldwide PM2.5 concentration ($\mu g/m^3$) - Averaged over 2001-2006

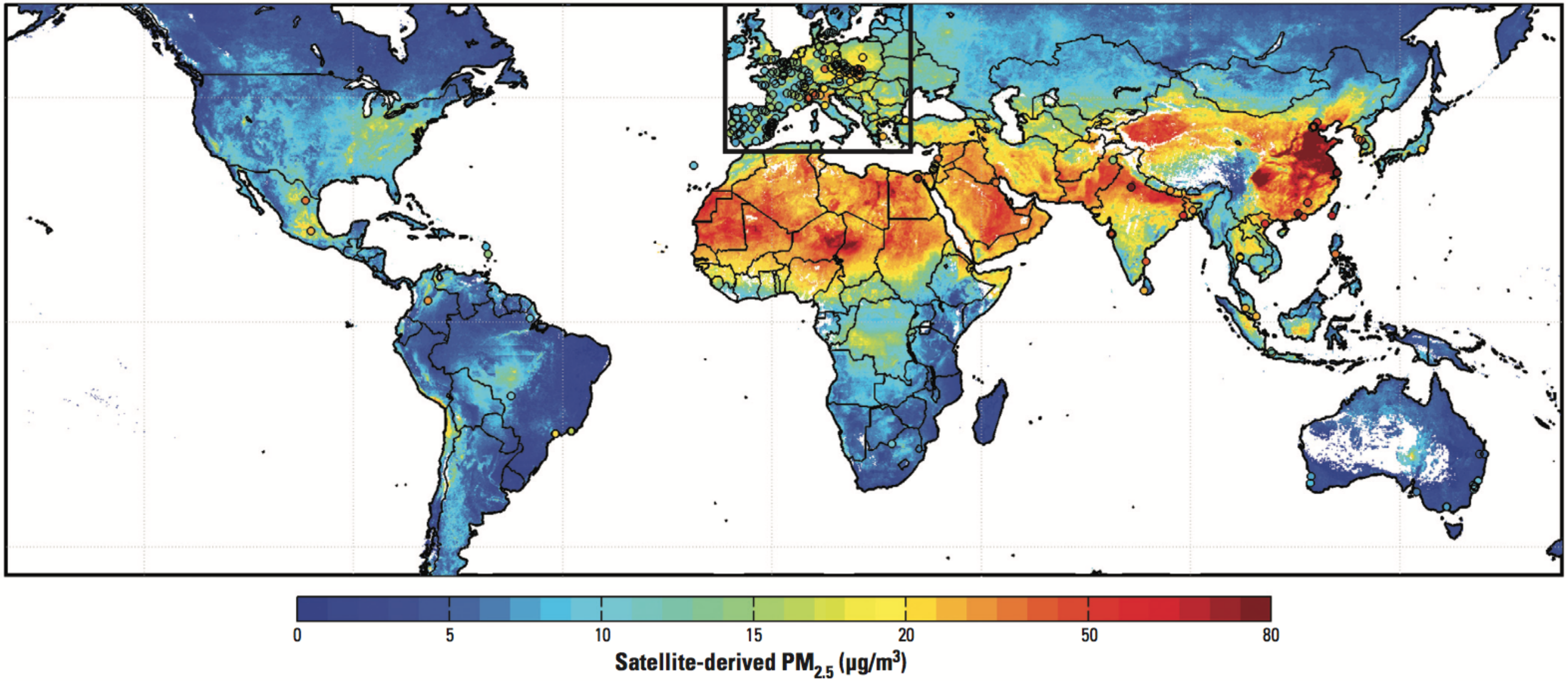


**Figure 4.** Global satellite-derived $PM_{2.5}$ averaged over 2001–2006. White space indicates water or locations containing < 50 measurements. Circles correspond to values and locations of comparison sites outside Canada and the United States; the black box outlines European sites.

Source: van Donkelaar et. al (2010).

Table A1: Different welfare measures relative to the U.S. (2007)

| Country | GDP pc | Rank | Welfare JK | Rank | Welfare w. poll. | Rank |
|---|---|---|---|---|---|---|
| Liberia | 0.9 | 148 | 0.48 | 144 | 0.89 | 126 |
| Niger | 1.2 | 147 | 0.44 | 145 | 0.27 | 148 |
| Ethiopia | 1.4 | 146 | 0.56 | 140 | 0.53 | 143 |
| Cent. Afr. Rep. | 1.4 | 145 | 0.34 | 148 | 0.41 | 147 |
| Malawi | 1.6 | 144 | 0.41 | 146 | 0.51 | 144 |
| Sierra Leone | 1.7 | 143 | 0.39 | 147 | 0.62 | 138 |
| Madagascar | 1.7 | 142 | 0.97 | 124 | 0.94 | 125 |
| Burkina Faso | 2 | 141 | 0.57 | 139 | 0.46 | 146 |
| Togo | 2 | 140 | 0.73 | 131 | 0.65 | 134 |
| Mali | 2 | 139 | 0.48 | 143 | 0.47 | 145 |
| Guinea | 2.1 | 138 | 0.53 | 141 | 0.64 | 135 |
| Comoros | 2.1 | 137 | 1.10 | 123 | 1.25 | 117 |
| Tanzania | 2.2 | 136 | 0.65 | 133 | 0.82 | 129 |
| Rwanda | 2.3 | 135 | 0.61 | 136 | 0.54 | 140 |
| Nepal | 2.3 | 134 | 1.18 | 121 | 0.53 | 142 |
| Uganda | 2.4 | 133 | 0.60 | 138 | 0.54 | 141 |
| Lesotho | 2.8 | 132 | 0.61 | 137 | 0.97 | 124 |
| Kenya | 2.8 | 131 | 0.76 | 128 | 1.13 | 121 |
| Benin | 2.8 | 130 | 0.76 | 129 | 0.67 | 133 |
| Bangladesh | 3 | 129 | 1.68 | 115 | 0.62 | 136 |
| Cote d'Ivoire | 3.2 | 128 | 0.76 | 130 | 0.89 | 127 |
| Senegal | 3.3 | 127 | 1.13 | 122 | 1.06 | 123 |
| S. Tome Princ. | 3.5 | 126 | 2.14 | 110 | 2.45 | 100 |
| Zambia | 3.8 | 125 | 0.53 | 142 | 0.78 | 130 |
| Cameroon | 4.1 | 124 | 0.73 | 132 | 0.61 | 139 |
| Cambodia | 4.1 | 123 | 1.37 | 118 | 1.23 | 118 |
| Ghana | 4.2 | 122 | 1.79 | 114 | 1.53 | 111 |
| Chad | 4.2 | 121 | 0.62 | 134 | 0.62 | 137 |
| Nigeria | 4.3 | 120 | 0.77 | 127 | 0.74 | 132 |
| Mauritania | 4.6 | 119 | 1.29 | 120 | 0.82 | 128 |
| Sudan | 4.7 | 118 | 1.87 | 112 | 1.18 | 119 |

| Country | GDP pc | Rank | Welfare JK | Rank | Welfare w. poll. | Rank |
|---|---|---|---|---|---|---|
| Lao | 4.7 | 117 | 1.84 | 113 | 1.34 | 115 |
| Tajikistan | 4.9 | 116 | 2.94 | 106 | 1.60 | 110 |
| Kyrgyzstan | 4.9 | 115 | 3.12 | 105 | 3.08 | 95 |
| Djibouti | 5.1 | 114 | 1.37 | 119 | 1.13 | 120 |
| Pakistan | 5.3 | 113 | 2.59 | 108 | 1.28 | 116 |
| Vietnam | 5.9 | 112 | 3.51 | 102 | 1.93 | 108 |
| Moldova | 6.3 | 111 | 4.15 | 97 | 3.53 | 90 |
| India | 6.3 | 110 | 2.25 | 109 | 1.11 | 122 |
| Honduras | 6.5 | 109 | 5.70 | 89 | 2.87 | 98 |
| Philippines | 7.2 | 108 | 3.35 | 104 | 2.41 | 101 |
| Morocco | 7.3 | 107 | 4.02 | 98 | 3.00 | 97 |
| Angola | 7.5 | 106 | 0.62 | 135 | 0.75 | 131 |
| Cape Verde | 7.6 | 105 | 6.37 | 87 | 3.25 | 94 |
| Swaziland | 7.9 | 104 | 0.93 | 125 | 1.41 | 114 |
| Indonesia | 8 | 103 | 3.86 | 99 | 3.72 | 87 |
| Bolivia | 8.1 | 102 | 2.92 | 107 | 1.93 | 107 |
| Zimbabwe | 8.3 | 101 | 0.89 | 126 | 1.41 | 113 |
| Sri Lanka | 8.3 | 100 | 6.78 | 86 | 3.66 | 89 |
| Syria | 8.3 | 99 | 7.48 | 84 | 3.43 | 92 |
| Iraq | 8.3 | 98 | 3.63 | 101 | 1.47 | 112 |
| Paraguay | 8.5 | 97 | 4.61 | 95 | 3.33 | 93 |
| Guatemala | 8.8 | 96 | 5.41 | 92 | 3.07 | 96 |
| Bhutan | 9.7 | 95 | 3.69 | 100 | 1.96 | 106 |
| Egypt | 9.8 | 94 | 7.13 | 85 | 2.12 | 103 |
| Mongolia | 10 | 93 | 4.18 | 96 | 3.70 | 88 |
| Jordan | 10.1 | 92 | 8.95 | 76 | 4.77 | 82 |
| Fiji | 10.4 | 91 | 7.61 | 82 | 10.44 | 56 |
| Uzbekistan | 10.5 | 90 | 5.62 | 90 | 3.48 | 91 |
| Namibia | 11.1 | 89 | 2.02 | 111 | 1.96 | 105 |
| Georgia | 11.4 | 88 | 8.29 | 79 | 6.37 | 75 |
| Jamaica | 11.8 | 87 | 10.44 | 71 | 8.40 | 67 |
| Armenia | 12.3 | 86 | 10.10 | 72 | 6.55 | 73 |

| Country | GDP pc | Rank | Welfare JK | Rank | Welfare w. poll. | Rank |
|---|---|---|---|---|---|---|
| Suriname | 13 | 85 | 6.30 | 88 | 5.66 | 79 |
| Albania | 13.7 | 84 | 15.97 | 58 | 13.29 | 48 |
| Ecuador | 14 | 83 | 8.23 | 81 | 6.05 | 76 |
| Tunisia | 14.4 | 82 | 9.68 | 73 | 4.99 | 81 |
| China | 14.8 | 81 | 5.33 | 93 | 1.98 | 104 |
| Bosnia Herz. | 15.5 | 80 | 19.56 | 46 | 8.87 | 65 |
| Peru | 15.9 | 79 | 8.23 | 80 | 4.05 | 84 |
| Colombia | 16.4 | 78 | 7.50 | 83 | 5.46 | 80 |
| Belize | 16.5 | 77 | 16.65 | 56 | 9.91 | 60 |
| Ukraine | 16.9 | 76 | 8.63 | 77 | 7.61 | 70 |
| Macedonia | 17.3 | 75 | 15.75 | 59 | 8.13 | 68 |
| Dominican Rep | 17.3 | 74 | 13.14 | 64 | 9.17 | 63 |
| Azerbaijan | 17.4 | 73 | 5.27 | 94 | 3.84 | 86 |
| South Africa | 17.4 | 72 | 1.57 | 116 | 1.81 | 109 |
| Thailand | 18.1 | 71 | 9.23 | 74 | 5.79 | 78 |
| Brazil | 18.3 | 70 | 9.20 | 75 | 9.02 | 64 |
| St. Vincent | 18.7 | 69 | 17.52 | 52 | 15.46 | 41 |
| Saint Lucia | 18.9 | 68 | 17.78 | 51 | 14.37 | 44 |
| Serbia | 20.1 | 67 | 17.19 | 53 | 12.87 | 49 |
| Costa Rica | 21 | 66 | 23.70 | 40 | 15.00 | 43 |
| Mauritius | 21.1 | 65 | 13.13 | 65 | 10.66 | 55 |
| Uruguay | 21.6 | 64 | 16.78 | 55 | 15.43 | 42 |
| Maldives | 21.8 | 63 | 12.32 | 70 | 6.39 | 74 |
| Turkmenistan | 22.2 | 62 | 5.44 | 91 | 4.56 | 83 |
| Lebanon | 22.9 | 61 | 15.14 | 60 | 9.48 | 62 |
| Venezuela | 22.9 | 60 | 13.06 | 67 | 7.66 | 69 |
| Panama | 23.3 | 59 | 13.11 | 66 | 11.73 | 51 |
| Montenegro | 23.4 | 58 | 18.79 | 48 | 13.54 | 47 |
| Gabon | 23.6 | 57 | 3.39 | 103 | 2.66 | 99 |
| Bulgaria | 24.4 | 56 | 16.95 | 54 | 10.73 | 54 |
| Botswana | 25.1 | 55 | 1.57 | 117 | 2.16 | 102 |
| Belarus | 25.5 | 54 | 14.30 | 61 | 11.39 | 52 |

| Country | GDP pc | Rank | Welfare JK | Rank | Welfare w. poll. | Rank |
|---|---|---|---|---|---|---|
| Argentina | 26.2 | 53 | 19.69 | 45 | 16.11 | 38 |
| Kazakhstan | 26.7 | 52 | 8.62 | 78 | 8.72 | 66 |
| Iran | 27.5 | 51 | 12.69 | 69 | 5.94 | 77 |
| Malaysia | 27.6 | 50 | 12.78 | 68 | 9.65 | 61 |
| Turkey | 28.6 | 49 | 18.33 | 50 | 10.27 | 58 |
| Mexico | 29.1 | 48 | 21.06 | 42 | 12.22 | 50 |
| Chile | 30.9 | 47 | 20.24 | 44 | 11.28 | 53 |
| Latvia | 34.9 | 46 | 19.36 | 47 | 15.84 | 40 |
| Poland | 35 | 45 | 28.34 | 37 | 15.87 | 39 |
| Russia | 37 | 44 | 13.95 | 62 | 13.73 | 45 |
| Lithuania | 37.6 | 43 | 23.01 | 41 | 18.76 | 37 |
| Croatia | 38.8 | 42 | 34.19 | 35 | 24.44 | 33 |
| Hungary | 39.9 | 41 | 28.65 | 36 | 19.02 | 36 |
| Trin. & Tob. | 43.2 | 40 | 13.55 | 63 | 13.65 | 46 |
| Slovakia | 43.6 | 39 | 36.14 | 34 | 24.70 | 32 |
| Estonia | 44.6 | 38 | 24.73 | 39 | 31.56 | 30 |
| Malta | 48.4 | 37 | 65.75 | 25 | 51.64 | 24 |
| Saudi Arabia | 48.6 | 36 | 16.41 | 57 | 3.99 | 85 |
| Portugal | 50.7 | 35 | 51.74 | 29 | 50.88 | 25 |
| Oman | 52.8 | 34 | 18.77 | 49 | 6.91 | 72 |
| Czech Rep. | 53.4 | 33 | 46.15 | 32 | 29.63 | 31 |
| Bahamas | 54.8 | 32 | 27.26 | 38 | 22.10 | 35 |
| Israel | 55 | 31 | 70.76 | 24 | 43.91 | 26 |
| Slovenia | 57.5 | 30 | 62.60 | 27 | 42.96 | 27 |
| Barbados | 57.7 | 29 | 47.47 | 31 | 35.14 | 28 |
| South Korea | 58.3 | 28 | 47.95 | 30 | 23.57 | 34 |
| Greece | 58.5 | 27 | 74.87 | 22 | 65.67 | 17 |
| Cyprus | 59.7 | 26 | 86.91 | 17 | 62.96 | 20 |
| New Zealand | 61.3 | 25 | 78.46 | 20 | 105.24 | 4 |
| Bahrain | 66.8 | 24 | 20.79 | 43 | 7.06 | 71 |
| Italy | 68.4 | 23 | 89.73 | 13 | 62.00 | 22 |
| Spain | 69 | 22 | 87.97 | 16 | 80.35 | 12 |

| Country | GDP pc | Rank | Welfare JK | Rank | Welfare w. poll. | Rank |
|---|---|---|---|---|---|---|
| France | 70.3 | 21 | 102.59 | 5 | 80.57 | 11 |
| Japan | 71.3 | 20 | 99.38 | 8 | 71.86 | 16 |
| Germany | 74.4 | 19 | 82.62 | 18 | 62.84 | 21 |
| Finland | 75.5 | 18 | 79.16 | 19 | 95.65 | 7 |
| Belgium | 75.8 | 17 | 88.61 | 15 | 59.23 | 23 |
| UK | 76.3 | 16 | 96.12 | 9 | 78.61 | 13 |
| Denmark | 78.6 | 15 | 77.03 | 21 | 72.68 | 15 |
| Sweden | 79.4 | 14 | 103.28 | 4 | 143.82 | 1 |
| Canada | 80.4 | 13 | 92.63 | 12 | 100.01 | 5 |
| Austria | 80.8 | 12 | 93.35 | 11 | 64.43 | 19 |
| Australia | 82.1 | 11 | 104.21 | 3 | 128.66 | 3 |
| Iceland | 83.2 | 10 | 127.17 | 2 | 135.28 | 2 |
| Netherlands | 84.2 | 9 | 94.50 | 10 | 64.93 | 18 |
| Switzerland | 95.7 | 8 | 101.45 | 6 | 83.85 | 10 |
| Ireland | 96.4 | 7 | 72.94 | 23 | 72.88 | 14 |
| United States | 100.00 | 6 | 100.00 | 7 | 100.00 | 6 |
| Norway | 112.8 | 5 | 89.70 | 14 | 89.33 | 9 |
| Singapore | 117.1 | 4 | 62.77 | 26 | 31.73 | 29 |
| Kuwait | 142.3 | 3 | 37.57 | 33 | 10.42 | 57 |
| Luxembourg | 179 | 2 | 137.24 | 1 | 90.08 | 8 |
| Qatar | 241.7 | 1 | 51.80 | 28 | 10.08 | 59 |

The countries are ordered according to their GDP pc relative to the U.S.

Welfare JK is the welfare measure according to Jones and Klenow (2016)

Table A2: Decomposition of welfare measure with pollution (2007)
Second lines show the raw data of the subcomponents

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Liberia | 0.9 | 0.894 | -0.007 | -0.533 | 0.437 | 0.074 | 0.000 | 0.014 |
| | | | | 53.9 | 1.308 | 586 | 0.658 | 18.98 |
| Niger | 1.2 | 0.269 | -1.496 | 0.000 | 0.093 | 0.077 | 0.000 | -1.665 |
| | | | | 52.8 | 0.927 | 570 | 0.658 | 227.12 |
| Cent. Afr. Rep. | 1.4 | 0.413 | -1.221 | -0.304 | 0.168 | 0.016 | 0.000 | -1.101 |
| | | | | 45.5 | 1 | 788 | 0.658 | 98.71 |
| Ethiopia | 1.4 | 0.533 | -0.967 | -0.254 | 0.019 | 0.016 | 0.069 | -0.816 |
| | | | | 56.7 | 0.861 | 790 | 0.543 | 64.73 |
| Malawi | 1.6 | 0.505 | -1.153 | -0.333 | -0.053 | 0.034 | -0.075 | -0.726 |
| | | | | 50.9 | 0.801 | 728 | 0.763 | 56.66 |
| Madagascar | 1.7 | 0.941 | -0.591 | -0.238 | 0.143 | 0.006 | -0.088 | -0.415 |
| | | | | 65.4 | 0.975 | 817 | 0.78 | 35.82 |
| Sierra Leone | 1.7 | 0.620 | -1.009 | -0.583 | 0.160 | 0.056 | -0.043 | -0.599 |
| | | | | 45.8 | 0.992 | 656 | 0.721 | 46.99 |
| Mali | 2 | 0.468 | -1.453 | -0.313 | 0.020 | 0.089 | -0.060 | -1.188 |
| | | | | 49.7 | 0.862 | 522 | 0.744 | 112.14 |
| Togo | 2 | 0.654 | -1.117 | -0.355 | 0.192 | 0.008 | 0.000 | -0.963 |
| | | | | 55.6 | 1.024 | 814 | 0.658 | 80.40 |
| Burk. Faso | 2 | 0.460 | -1.469 | -0.244 | 0.044 | 0.014 | -0.051 | -1.231 |
| | | | | 53.5 | 0.883 | 792 | 0.732 | 119.50 |
| Comoros | 2.1 | 1.249 | -0.519 | -0.472 | 0.329 | 0.080 | 0.000 | -0.455 |
| | | | | 59.5 | 1.174 | 561 | 0.658 | 38.01 |
| Guinea | 2.1 | 0.638 | -1.191 | -0.424 | -0.066 | 0.046 | -0.038 | -0.710 |
| | | | | 52.2 | 0.791 | 690 | 0.713 | 55.35 |
| Tanzania | 2.2 | 0.815 | -0.993 | -0.463 | -0.012 | -0.002 | 0.010 | -0.527 |
| | | | | 54.9 | 0.835 | 840 | 0.642 | 42.22 |
| Nepal | 2.3 | 0.533 | -1.462 | -0.110 | 0.023 | 0.055 | -0.181 | -1.248 |
| | | | | 67 | 0.865 | 657 | 0.892 | 122.66 |
| Rwanda | 2.3 | 0.543 | -1.443 | -0.316 | 0.121 | -0.002 | -0.179 | -1.068 |
| | | | | 53.7 | 0.954 | 840 | 0.889 | 93.97 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Uganda | 2.4 | 0.538 | -1.496 | -0.350 | 0.072 | 0.046 | -0.093 | -1.171 |
| | | | | 51.7 | 0.908 | 688 | 0.787 | 109.39 |
| Benin | 2.8 | 0.673 | -1.426 | -0.394 | -0.035 | 0.046 | -0.009 | -1.034 |
| | | | | 54.4 | 0.816 | 689 | 0.671 | 89.39 |
| Kenya | 2.8 | 1.127 | -0.910 | -0.616 | 0.104 | 0.059 | -0.158 | -0.300 |
| | | | | 54.4 | 0.938 | 644 | 0.865 | 30.21 |
| Lesotho | 2.8 | 0.972 | -1.058 | -0.927 | 0.463 | 0.045 | 0.000 | -0.639 |
| | | | | 45.2 | 1.343 | 694 | 0.658 | 49.88 |
| Bangladesh | 3 | 0.623 | -1.572 | -0.125 | -0.125 | 0.080 | 0.035 | -1.437 |
| | | | | 67.7 | 0.746 | 559 | 0.603 | 162.07 |
| Cote d'Ivoire | 3.2 | 0.890 | -1.280 | -0.570 | 0.095 | 0.062 | -0.149 | -0.718 |
| | | | | 52.7 | 0.929 | 629 | 0.855 | 56.06 |
| Senegal | 3.3 | 1.056 | -1.139 | -0.467 | 0.127 | 0.050 | -0.078 | -0.771 |
| | | | | 58 | 0.959 | 676 | 0.767 | 60.58 |
| S. Tome Princ. | 3.5 | 2.451 | -0.356 | -0.493 | 0.347 | 0.073 | 0.000 | -0.283 |
| | | | | 63.6 | 1.196 | 590 | 0.658 | 29.46 |
| Zambia | 3.8 | 0.785 | -1.577 | -0.733 | -0.012 | 0.043 | -0.167 | -0.708 |
| | | | | 46.2 | 0.835 | 703 | 0.876 | 55.24 |
| Cambodia | 4.1 | 1.231 | -1.203 | -0.416 | -0.007 | -0.006 | -0.085 | -0.688 |
| | | | | 61.1 | 0.839 | 851 | 0.777 | 53.63 |
| Cameroon | 4.1 | 0.607 | -1.910 | -0.458 | 0.006 | 0.040 | -0.086 | -1.412 |
| | | | | 49.8 | 0.85 | 714 | 0.778 | 156.08 |
| Chad | 4.2 | 0.621 | -1.912 | -0.508 | -0.246 | 0.051 | 0.000 | -1.210 |
| | | | | 48.4 | 0.661 | 670 | 0.658 | 115.86 |
| Ghana | 4.2 | 1.525 | -1.013 | -0.432 | 0.086 | 0.031 | 0.000 | -0.698 |
| | | | | 62.3 | 0.921 | 743 | 0.658 | 54.39 |
| Nigeria | 4.3 | 0.737 | -1.764 | -0.561 | 0.030 | 0.086 | -0.126 | -1.194 |
| | | | | 50 | 0.871 | 529 | 0.828 | 113.14 |
| Mauritania | 4.6 | 0.816 | -1.729 | -0.392 | -0.055 | 0.086 | -0.043 | -1.326 |
| | | | | 57.5 | 0.8 | 533 | 0.721 | 137.49 |
| Lao | 4.7 | 1.337 | -1.257 | -0.295 | -0.235 | 0.008 | 0.015 | -0.749 |
| | | | | 65.7 | 0.668 | 810 | 0.635 | 58.67 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Sudan | 4.7 | 1.179 | -1.383 | -0.432 | 0.131 | 0.103 | 0.000 | -1.184 |
| | | | | 60.2 | 0.963 | 448 | 0.658 | 111.55 |
| Kyrgyzstan | 4.9 | 3.078 | -0.465 | -0.355 | 0.162 | 0.038 | 0.000 | -0.310 |
| | | | | 67.9 | 0.994 | 716 | 0.658 | 30.65 |
| Tajikistan | 4.9 | 1.604 | -1.117 | -0.310 | 0.131 | 0.089 | 0.033 | -1.060 |
| | | | | 66.3 | 0.963 | 519 | 0.605 | 92.83 |
| Djibouti | 5.1 | 1.130 | -1.507 | -0.545 | 0.049 | 0.085 | -0.072 | -1.024 |
| | | | | 56.4 | 0.887 | 540 | 0.76 | 88.04 |
| Pakistan | 5.3 | 1.280 | -1.421 | -0.322 | 0.014 | 0.095 | 0.057 | -1.266 |
| | | | | 64.5 | 0.857 | 493 | 0.564 | 125.80 |
| Vietnam | 5.9 | 1.930 | -1.117 | -0.096 | -0.270 | -0.021 | -0.007 | -0.724 |
| | | | | 74.2 | 0.645 | 893 | 0.668 | 56.51 |
| India | 6.3 | 1.109 | -1.737 | -0.303 | -0.183 | 0.051 | -0.013 | -1.290 |
| | | | | 64.1 | 0.704 | 670 | 0.677 | 130.50 |
| Moldova | 6.3 | 3.525 | -0.581 | -0.367 | 0.252 | 0.082 | -0.077 | -0.471 |
| | | | | 68.1 | 1.087 | 550 | 0.766 | 38.92 |
| Honduras | 6.5 | 2.868 | -0.818 | -0.191 | 0.228 | 0.050 | 0.000 | -0.905 |
| | | | | 72 | 1.061 | 677 | 0.658 | 73.83 |
| Philippines | 7.2 | 2.410 | -1.095 | -0.323 | -0.019 | 0.068 | -0.146 | -0.674 |
| | | | | 67.8 | 0.829 | 609 | 0.852 | 52.49 |
| Morocco | 7.3 | 2.999 | -0.890 | -0.231 | -0.139 | 0.068 | -0.074 | -0.514 |
| | | | | 71 | 0.735 | 606 | 0.762 | 41.43 |
| Angola | 7.5 | 0.753 | -2.299 | -0.592 | -0.773 | 0.012 | -0.106 | -0.839 |
| | | | | 49.4 | 0.39 | 798 | 0.803 | 67.03 |
| Cape Verde | 7.6 | 3.247 | -0.850 | -0.164 | 0.130 | 0.034 | 0.000 | -0.851 |
| | | | | 73 | 0.962 | 729 | 0.658 | 68.14 |
| Swaziland | 7.9 | 1.411 | -1.722 | -1.098 | 0.168 | 0.090 | -0.247 | -0.636 |
| | | | | 46.8 | 1 | 516 | 0.963 | 49.61 |
| Indonesia | 8 | 3.722 | -0.765 | -0.392 | -0.079 | 0.032 | 0.015 | -0.342 |
| | | | | 67.7 | 0.781 | 737 | 0.635 | 32.14 |
| Bolivia | 8.1 | 1.933 | -1.433 | -0.378 | 0.072 | 0.059 | -0.312 | -0.875 |
| | | | | 65.3 | 0.908 | 643 | 1.028 | 70.61 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Iraq | 8.3 | 1.468 | -1.733 | -0.247 | -0.262 | 0.108 | 0.000 | -1.331 |
| | | | | 67.9 | 0.65 | 421 | 0.658 | 138.60 |
| Syria | 8.3 | 3.427 | -0.885 | -0.084 | -0.056 | 0.104 | 0.024 | -0.873 |
| | | | | 75.3 | 0.799 | 444 | 0.62 | 70.40 |
| Sri Lanka | 8.3 | 3.657 | -0.820 | -0.123 | -0.060 | 0.077 | 0.027 | -0.741 |
| | | | | 74.3 | 0.796 | 570 | 0.615 | 57.98 |
| Zimbabwe | 8.3 | 1.411 | -1.772 | -1.159 | 0.154 | -0.050 | -0.095 | -0.622 |
| | | | | 45.8 | 0.986 | 969 | 0.789 | 48.63 |
| Paraguay | 8.5 | 3.329 | -0.937 | -0.214 | -0.018 | 0.025 | -0.208 | -0.523 |
| | | | | 71.7 | 0.83 | 759 | 0.921 | 41.99 |
| Guatemala | 8.8 | 3.074 | -1.052 | -0.268 | 0.252 | 0.081 | -0.270 | -0.847 |
| | | | | 70.1 | 1.087 | 556 | 0.986 | 67.83 |
| Bhutan | 9.7 | 1.956 | -1.601 | -0.362 | -0.166 | 0.045 | -0.002 | -1.116 |
| | | | | 65.8 | 0.716 | 697 | 0.661 | 100.87 |
| Egypt | 9.8 | 2.124 | -1.529 | -0.160 | -0.035 | 0.082 | 0.044 | -1.461 |
| | | | | 72.2 | 0.816 | 549 | 0.587 | 167.84 |
| Mongolia | 10 | 3.697 | -0.995 | -0.418 | -0.206 | 0.053 | 0.037 | -0.461 |
| | | | | 67.1 | 0.688 | 667 | 0.599 | 38.35 |
| Jordan | 10.1 | 4.773 | -0.750 | -0.193 | 0.182 | 0.108 | -0.041 | -0.806 |
| | | | | 72.9 | 1.014 | 420 | 0.718 | 63.77 |
| Fiji | 10.4 | 10.435 | 0.003 | -0.479 | 0.321 | 0.067 | 0.000 | 0.094 |
| | | | | 68.8 | 1.165 | 612 | 0.658 | 16.88 |
| Uzbekistan | 10.5 | 3.484 | -1.103 | -0.395 | 0.080 | 0.050 | 0.024 | -0.861 |
| | | | | 67.4 | 0.915 | 677 | 0.62 | 69.23 |
| Namibia | 11.1 | 1.961 | -1.734 | -0.581 | -0.093 | 0.051 | -0.483 | -0.628 |
| | | | | 60.2 | 0.77 | 669 | 1.183 | 49.04 |
| Georgia | 11.4 | 6.367 | -0.583 | -0.217 | 0.060 | 0.064 | -0.069 | -0.420 |
| | | | | 72.8 | 0.897 | 627 | 0.755 | 36.08 |
| Jamaica | 11.8 | 8.401 | -0.340 | -0.277 | 0.417 | 0.002 | -0.085 | -0.397 |
| | | | | 72 | 1.282 | 829 | 0.776 | 34.85 |
| Armenia | 12.3 | 6.549 | -0.630 | -0.196 | 0.086 | 0.062 | 0.000 | -0.583 |
| | | | | 73.3 | 0.921 | 633 | 0.658 | 45.88 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Suriname | 13 | 5.663 | -0.831 | -0.364 | -0.208 | 0.100 | 0.000 | -0.358 |
| | | | | 69.5 | 0.686 | 468 | 0.658 | 32.93 |
| Albania | 13.7 | 13.294 | -0.030 | -0.066 | 0.094 | 0.091 | 0.072 | -0.221 |
| | | | | 76.5 | 0.928 | 506 | 0.538 | 26.87 |
| Ecuador | 14 | 6.047 | -0.840 | -0.116 | -0.126 | 0.058 | -0.261 | -0.394 |
| | | | | 75 | 0.745 | 646 | 0.977 | 34.73 |
| Tunisia | 14.4 | 4.993 | -1.059 | -0.142 | -0.139 | 0.070 | -0.056 | -0.792 |
| | | | | 74.2 | 0.735 | 601 | 0.738 | 62.49 |
| China | 14.8 | 1.982 | -2.011 | -0.143 | -0.440 | -0.067 | -0.156 | -1.204 |
| | | | | 72.6 | 0.544 | 1009 | 0.863 | 114.85 |
| Bosnia Herz. | 15.5 | 8.866 | -0.559 | -0.131 | 0.290 | 0.120 | 0.057 | -0.896 |
| | | | | 75 | 1.129 | 343 | 0.564 | 72.85 |
| Peru | 15.9 | 4.054 | -1.367 | -0.174 | -0.168 | 0.038 | -0.179 | -0.883 |
| | | | | 73.1 | 0.714 | 719 | 0.889 | 71.46 |
| Colombia | 16.4 | 5.464 | -1.099 | -0.207 | -0.055 | 0.027 | -0.389 | -0.476 |
| | | | | 72.8 | 0.8 | 756 | 1.1 | 39.18 |
| Belize | 16.5 | 9.912 | -0.510 | -0.130 | 0.173 | 0.056 | 0.000 | -0.609 |
| | | | | 75.1 | 1.005 | 652 | 0.658 | 47.72 |
| Ukraine | 16.9 | 7.605 | -0.798 | -0.470 | 0.007 | 0.006 | 0.086 | -0.427 |
| | | | | 68.2 | 0.851 | 815 | 0.511 | 36.45 |
| Dominican Rep | 17.3 | 9.172 | -0.635 | -0.258 | 0.097 | 0.059 | 0.000 | -0.533 |
| | | | | 72.5 | 0.931 | 644 | 0.658 | 42.61 |
| Macedonia | 17.3 | 8.126 | -0.756 | -0.170 | 0.101 | 0.108 | 0.000 | -0.795 |
| | | | | 74.1 | 0.935 | 421 | 0.658 | 62.78 |
| South Africa | 17.4 | 1.814 | -2.261 | -1.003 | -0.053 | 0.061 | -0.428 | -0.837 |
| | | | | 51 | 0.801 | 636 | 1.135 | 66.82 |
| Azerbaijan | 17.4 | 3.837 | -1.512 | -0.309 | -0.610 | 0.004 | -0.009 | -0.588 |
| | | | | 69.7 | 0.459 | 822 | 0.671 | 46.23 |
| Thailand | 18.1 | 5.794 | -1.139 | -0.180 | -0.207 | -0.043 | -0.099 | -0.610 |
| | | | | 73.5 | 0.687 | 951 | 0.794 | 47.78 |
| Brazil | 18.3 | 9.023 | -0.707 | -0.278 | -0.069 | -0.023 | -0.158 | -0.180 |
| | | | | 72.1 | 0.789 | 898 | 0.865 | 25.30 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| St. Vincent | 18.7 | 15.458 | -0.190 | -0.357 | 0.476 | 0.004 | 0.000 | -0.313 |
| | | | | 71.5 | 1.36 | 821 | 0.658 | 30.81 |
| Saint Lucia | 18.9 | 14.372 | -0.274 | -0.221 | 0.275 | 0.008 | 0.000 | -0.336 |
| | | | | 73.7 | 1.113 | 812 | 0.658 | 31.86 |
| Serbia | 20.1 | 12.865 | -0.446 | -0.232 | 0.135 | 0.078 | 0.000 | -0.428 |
| | | | | 73.4 | 0.967 | 566 | 0.658 | 36.48 |
| Costa Rica | 21 | 14.999 | -0.337 | 0.051 | 0.142 | 0.027 | -0.130 | -0.426 |
| | | | | 78.8 | 0.974 | 754 | 0.833 | 36.41 |
| Mauritius | 21.1 | 10.657 | -0.683 | -0.264 | -0.079 | 0.027 | -0.001 | -0.367 |
| | | | | 72.6 | 0.781 | 751 | 0.659 | 33.36 |
| Uruguay | 21.6 | 15.432 | -0.336 | -0.101 | -0.029 | 0.023 | -0.093 | -0.136 |
| | | | | 75.9 | 0.821 | 766 | 0.787 | 23.72 |
| Maldives | 21.8 | 6.390 | -1.227 | -0.101 | -0.410 | 0.068 | -0.043 | -0.742 |
| | | | | 75.4 | 0.561 | 605 | 0.721 | 58.01 |
| Turkmenistan | 22.2 | 4.559 | -1.583 | -0.578 | -0.392 | 0.010 | 0.000 | -0.623 |
| | | | | 64.6 | 0.571 | 807 | 0.658 | 48.67 |
| Venezuela | 22.9 | 7.665 | -1.094 | -0.191 | -0.267 | 0.059 | -0.018 | -0.677 |
| | | | | 73.6 | 0.647 | 644 | 0.685 | 52.77 |
| Lebanon | 22.9 | 9.476 | -0.882 | -0.292 | 0.004 | 0.078 | 0.000 | -0.672 |
| | | | | 71.9 | 0.848 | 569 | 0.658 | 52.34 |
| Panama | 23.3 | 11.735 | -0.686 | -0.115 | -0.247 | 0.059 | -0.208 | -0.175 |
| | | | | 75.5 | 0.66 | 645 | 0.921 | 25.13 |
| Montenegro | 23.4 | 13.537 | -0.547 | -0.201 | 0.015 | 0.086 | 0.000 | -0.448 |
| | | | | 74 | 0.858 | 533 | 0.658 | 37.58 |
| Gabon | 23.6 | 2.663 | -2.182 | -0.636 | -0.738 | 0.059 | 0.000 | -0.867 |
| | | | | 60.9 | 0.404 | 644 | 0.658 | 69.80 |
| Bulgaria | 24.4 | 10.733 | -0.821 | -0.259 | 0.025 | -0.002 | 0.045 | -0.630 |
| | | | | 72.7 | 0.866 | 842 | 0.586 | 49.19 |
| Botswana | 25.1 | 2.158 | -2.454 | -1.027 | -0.574 | -0.008 | -0.333 | -0.511 |
| | | | | 52.1 | 0.476 | 859 | 1.048 | 41.29 |
| Belarus | 25.5 | 11.390 | -0.806 | -0.406 | -0.071 | 0.018 | 0.122 | -0.469 |
| | | | | 70.2 | 0.787 | 780 | 0.434 | 38.79 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Argentina | 26.2 | 16.113 | -0.486 | -0.147 | -0.107 | 0.048 | 0.000 | -0.280 |
| | | | | 75.1 | 0.759 | 684 | 0.658 | 29.32 |
| Kazakhstan | 26.7 | 8.719 | -1.119 | -0.591 | -0.258 | 0.008 | 0.049 | -0.327 |
| | | | | 66.5 | 0.653 | 810 | 0.579 | 31.45 |
| Iran | 27.5 | 5.943 | -1.532 | -0.254 | -0.334 | 0.076 | -0.034 | -0.985 |
| | | | | 71.9 | 0.605 | 581 | 0.708 | 83.15 |
| Malaysia | 27.6 | 9.649 | -1.051 | -0.215 | -0.403 | 0.048 | -0.063 | -0.419 |
| | | | | 73.4 | 0.565 | 684 | 0.748 | 35.99 |
| Turkey | 28.6 | 10.268 | -1.024 | -0.250 | -0.042 | 0.084 | -0.059 | -0.757 |
| | | | | 72.8 | 0.81 | 543 | 0.742 | 59.33 |
| Mexico | 29.1 | 12.218 | -0.868 | -0.090 | -0.041 | -0.008 | -0.123 | -0.605 |
| | | | | 76 | 0.811 | 859 | 0.824 | 47.42 |
| Chile | 30.9 | 11.276 | -1.008 | 0.033 | -0.255 | -0.025 | -0.199 | -0.562 |
| | | | | 78.5 | 0.655 | 908 | 0.912 | 44.48 |
| Latvia | 34.9 | 15.843 | -0.790 | -0.390 | 0.092 | -0.080 | 0.001 | -0.412 |
| | | | | 71 | 0.926 | 1037 | 0.657 | 35.64 |
| Poland | 35 | 15.872 | -0.791 | -0.141 | -0.008 | 0.006 | 0.022 | -0.669 |
| | | | | 75.2 | 0.838 | 817 | 0.624 | 52.13 |
| Russia | 37 | 13.733 | -0.991 | -0.600 | -0.130 | 0.006 | 0.057 | -0.324 |
| | | | | 67.5 | 0.742 | 816 | 0.564 | 31.32 |
| Lithuania | 37.6 | 18.763 | -0.695 | -0.413 | 0.087 | 0.012 | 0.038 | -0.419 |
| | | | | 70.9 | 0.922 | 802 | 0.597 | 36.04 |
| Croatia | 38.8 | 24.442 | -0.462 | -0.125 | -0.081 | 0.067 | 0.078 | -0.401 |
| | | | | 75.7 | 0.779 | 615 | 0.526 | 35.06 |
| Hungary | 39.9 | 19.020 | -0.741 | -0.268 | -0.011 | 0.002 | 0.097 | -0.561 |
| | | | | 73.2 | 0.836 | 829 | 0.489 | 44.46 |
| Trin. Tobago | 43.2 | 13.653 | -1.152 | -0.494 | -0.433 | 0.020 | 0.000 | -0.244 |
| | | | | 69.1 | 0.548 | 780 | 0.658 | 27.81 |
| Slovakia | 43.6 | 24.699 | -0.568 | -0.219 | -0.019 | 0.038 | 0.129 | -0.496 |
| | | | | 74.2 | 0.829 | 716 | 0.419 | 40.38 |
| Estonia | 44.6 | 31.564 | -0.346 | -0.327 | -0.083 | -0.053 | -0.006 | 0.123 |
| | | | | 72.8 | 0.778 | 974 | 0.667 | 16.17 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Malta | 48.4 | 51.643 | 0.065 | 0.106 | 0.016 | 0.029 | 0.110 | -0.196 |
| | | | | 79.4 | 0.859 | 749 | 0.462 | 25.91 |
| Saudi Arabia | 48.6 | 3.994 | -2.499 | -0.170 | -0.768 | 0.067 | 0.000 | -1.628 |
| | | | | 73.2 | 0.392 | 615 | 0.658 | 214.91 |
| Portugal | 50.7 | 50.877 | 0.003 | 0.033 | -0.001 | -0.037 | 0.012 | -0.004 |
| | | | | 78.3 | 0.844 | 935 | 0.64 | 19.51 |
| Oman | 52.8 | 6.910 | -2.034 | -0.209 | -0.694 | 0.062 | 0.000 | -1.193 |
| | | | | 73.1 | 0.422 | 630 | 0.658 | 112.99 |
| Czech Republic | 53.4 | 29.634 | -0.589 | -0.067 | -0.146 | -0.021 | 0.124 | -0.478 |
| | | | | 76.7 | 0.73 | 892 | 0.43 | 39.31 |
| Bahamas | 54.8 | 22.099 | -0.908 | -0.201 | 0.044 | -0.021 | -0.419 | -0.311 |
| | | | | 74.4 | 0.883 | 891 | 1.127 | 30.71 |
| Israel | 55 | 43.912 | -0.225 | 0.177 | -0.026 | 0.004 | 0.011 | -0.391 |
| | | | | 80.6 | 0.823 | 821 | 0.641 | 34.55 |
| Slovenia | 57.5 | 42.959 | -0.292 | 0.052 | -0.138 | 0.010 | 0.137 | -0.352 |
| | | | | 78.6 | 0.736 | 804 | 0.398 | 32.64 |
| Barbados | 57.7 | 35.143 | -0.496 | -0.109 | 0.147 | -0.004 | -0.178 | -0.352 |
| | | | | 76.1 | 0.979 | 848 | 0.888 | 32.64 |
| South Korea | 58.3 | 23.574 | -0.905 | 0.085 | -0.290 | -0.117 | 0.076 | -0.659 |
| | | | | 79.3 | 0.632 | 1120 | 0.531 | 51.31 |
| Greece | 58.5 | 65.668 | 0.116 | 0.111 | 0.067 | -0.030 | 0.055 | -0.088 |
| | | | | 79.4 | 0.904 | 914 | 0.568 | 22.09 |
| Cyprus | 59.7 | 62.955 | 0.053 | 0.076 | 0.146 | 0.029 | 0.092 | -0.290 |
| | | | | 78.9 | 0.978 | 745 | 0.499 | 29.77 |
| New Zealand | 61.3 | 105.244 | 0.540 | 0.179 | -0.018 | -0.023 | 0.058 | 0.345 |
| | | | | 80.2 | 0.83 | 902 | 0.563 | 11.65 |
| Bahrain | 66.8 | 7.062 | -2.247 | -0.140 | -0.910 | 0.016 | 0.000 | -1.212 |
| | | | | 74.6 | 0.34 | 786 | 0.658 | 116.27 |
| Italy | 68.4 | 62.000 | -0.098 | 0.234 | -0.153 | 0.023 | 0.065 | -0.267 |
| | | | | 81.3 | 0.725 | 767 | 0.551 | 28.79 |
| Spain | 69 | 80.350 | 0.152 | 0.218 | -0.130 | 0.025 | 0.049 | -0.010 |
| | | | | 80.9 | 0.742 | 760 | 0.579 | 19.69 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| France | 70.3 | 80.567 | 0.136 | 0.212 | -0.085 | 0.062 | 0.106 | -0.158 |
| | | | | 80.8 | 0.776 | 629 | 0.471 | 24.50 |
| Japan | 71.3 | 71.863 | 0.008 | 0.318 | -0.155 | -0.028 | 0.063 | -0.191 |
| | | | | 82.5 | 0.724 | 912 | 0.554 | 25.73 |
| Germany | 74.4 | 62.843 | -0.169 | 0.117 | -0.195 | 0.046 | 0.088 | -0.225 |
| | | | | 79.5 | 0.695 | 687 | 0.506 | 27.04 |
| Finland | 75.5 | 95.649 | 0.237 | 0.111 | -0.223 | 0.008 | 0.117 | 0.224 |
| | | | | 79.3 | 0.676 | 810 | 0.446 | 13.94 |
| Belgium | 75.8 | 59.230 | -0.247 | 0.115 | -0.175 | 0.055 | 0.110 | -0.351 |
| | | | | 79.5 | 0.709 | 657 | 0.461 | 32.59 |
| U.K. | 76.3 | 78.611 | 0.030 | 0.114 | 0.016 | 0.012 | 0.044 | -0.157 |
| | | | | 79.4 | 0.859 | 799 | 0.588 | 24.44 |
| Denmark | 78.6 | 72.677 | -0.078 | 0.029 | -0.193 | 0.004 | 0.129 | -0.048 |
| | | | | 78.2 | 0.697 | 821 | 0.418 | 20.81 |
| Sweden | 79.4 | 143.825 | 0.594 | 0.241 | -0.187 | 0.010 | 0.135 | 0.395 |
| | | | | 80.9 | 0.701 | 807 | 0.404 | 10.82 |
| Canada | 80.4 | 100.011 | 0.218 | 0.220 | -0.171 | -0.021 | 0.042 | 0.148 |
| | | | | 80.8 | 0.712 | 893 | 0.59 | 15.58 |
| Austria | 80.8 | 64.431 | -0.226 | 0.151 | -0.187 | -0.004 | 0.119 | -0.305 |
| | | | | 80 | 0.701 | 844 | 0.441 | 30.45 |
| Australia | 82.1 | 128.657 | 0.449 | 0.266 | -0.160 | -0.015 | 0.070 | 0.288 |
| | | | | 81.3 | 0.72 | 876 | 0.541 | 12.67 |
| Iceland | 83.2 | 135.281 | 0.486 | 0.253 | 0.074 | -0.090 | 0.108 | 0.141 |
| | | | | 81.1 | 0.91 | 1061 | 0.466 | 15.75 |
| Netherlands | 84.2 | 64.926 | -0.260 | 0.158 | -0.246 | 0.034 | 0.101 | -0.307 |
| | | | | 80.1 | 0.661 | 732 | 0.481 | 30.52 |
| Switzerland | 95.7 | 83.854 | -0.132 | 0.274 | -0.349 | -0.048 | 0.077 | -0.086 |
| | | | | 81.7 | 0.596 | 964 | 0.529 | 22.01 |
| Ireland | 96.4 | 72.876 | -0.280 | 0.085 | -0.455 | -0.021 | 0.082 | 0.030 |
| | | | | 79 | 0.536 | 896 | 0.519 | 18.57 |
| United States | 100 | 100.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | 77.8 | 0.845 | 836 | 0.658 | 19.40 |

| Country | GDP pc | Welfare w. poll. | Log Ratio | LE | C/Y | L | Ineq | Poll |
|---|---|---|---|---|---|---|---|---|
| Norway | 112.8 | 89.335 | -0.233 | 0.188 | -0.599 | 0.018 | 0.100 | 0.061 |
| | | | | 80.4 | 0.464 | 780 | 0.483 | 17.73 |
| Singapore | 117.1 | 31.727 | -1.306 | 0.154 | -0.685 | -0.180 | 0.000 | -0.595 |
| | | | | 80.4 | 0.426 | 1251 | 0.658 | 46.73 |
| Kuwait | 142.3 | 10.424 | -2.614 | -0.172 | -0.990 | -0.015 | 0.000 | -1.437 |
| | | | | 74.3 | 0.314 | 877 | 0.658 | 162.05 |
| Luxembourg | 179 | 90.081 | -0.687 | 0.167 | -0.509 | -0.100 | 0.107 | -0.351 |
| | | | | 80.1 | 0.508 | 1086 | 0.468 | 32.59 |
| Qatar | 241.7 | 10.083 | -3.177 | -0.009 | -1.421 | -0.100 | 0.000 | -1.646 |
| | | | | 77.6 | 0.204 | 1087 | 0.658 | 220.62 |

The countries are ordered according to their GDP pc relative to the U.S.

LE: Life Expectancy; C/Y Consumption share in GDP; L: Leisure; Ineq: Inequality; Poll: Pollution

Table A3: Welfare growth 1991-2010

| Country | $\widehat{\text{GDP}}$ pc | $\widehat{\text{Welfare}}$ | Diff | $\widehat{\text{LE}}$ | $\widehat{\text{C/Y}}$ | $\widehat{\text{L}}$ | $\widehat{\text{Ineq}}$ | $\widehat{\text{Poll}}$ |
|---|---|---|---|---|---|---|---|---|
| Barbados | 0.041 | 0.118 | 0.077 | 0.043 | 0.091 | -0.030 | -0.049 | 0.062 |
| | | | | 71.8 ; 74.5 | 0.89 ; 1.04 | 0.85 ; 0.81 | 0.67 ; 0.86 | 41.7 ; 31.6 |
| Japan | 0.045 | 0.179 | 0.134 | 0.056 | 0.098 | 0.029 | -0.002 | -0.001 |
| | | | | 79.4 ; 82.6 | 0.63 ; 0.74 | 0.79 ; 0.83 | 0.57 ; 0.58 | 25.2 ; 25.4 |
| Russia | 0.071 | 0.217 | 0.147 | 0.029 | 0.110 | -0.008 | 0.047 | 0.038 |
| | | | | 66.0 ; 67.9 | 0.67 ; 0.75 | 0.81 ; 0.80 | 0.86 ; 0.67 | 37.8 ; 32.0 |
| Israel | 0.072 | 0.128 | 0.056 | 0.065 | 0.090 | -0.012 | -0.015 | 0.000 |
| | | | | 77.1 ; 81.0 | 0.77 ; 0.81 | 0.84 ; 0.83 | 0.62 ; 0.69 | 35.1 ; 35.1 |
| Uruguay | 0.078 | 0.124 | 0.046 | 0.043 | 0.071 | 0.004 | -0.017 | 0.022 |
| | | | | 73.1 ; 76.1 | 0.83 ; 0.82 | 0.83 ; 0.83 | 0.77 ; 0.83 | 26.1 ; 23.7 |
| Italy | 0.090 | 0.224 | 0.135 | 0.068 | 0.108 | -0.001 | 0.007 | 0.043 |
| | | | | 77.7 ; 81.6 | 0.71 ; 0.75 | 0.86 ; 0.86 | 0.62 ; 0.58 | 35.0 ; 29.0 |
| Colombia | 0.092 | 0.096 | 0.004 | 0.044 | 0.073 | -0.015 | -0.031 | 0.024 |
| | | | | 68.9 ; 72.9 | 0.85 ; 0.80 | 0.84 ; 0.82 | 0.95 ; 1.04 | 41.5 ; 37.3 |
| U.S. | 0.093 | 0.209 | 0.115 | 0.053 | 0.113 | 0.006 | -0.002 | 0.039 |
| | | | | 75.5 ; 78.1 | 0.77 ; 0.82 | 0.81 ; 0.82 | 0.69 ; 0.70 | 22.1 ; 18.7 |
| Switzerland | 0.097 | 0.189 | 0.092 | 0.070 | 0.061 | 0.008 | 0.019 | 0.030 |
| | | | | 78.0 ; 81.9 | 0.64 ; 0.57 | 0.81 ; 0.82 | 0.64 ; 0.55 | 25.2 ; 22.0 |
| Canada | 0.101 | 0.128 | 0.028 | 0.062 | 0.083 | -0.004 | -0.020 | 0.007 |
| | | | | 77.7 ; 80.9 | 0.75 ; 0.72 | 0.82 ; 0.82 | 0.54 ; 0.64 | 15.7 ; 15.3 |
| Mexico | 0.109 | 0.220 | 0.111 | 0.043 | 0.114 | -0.006 | 0.038 | 0.030 |
| | | | | 72.0 ; 75.7 | 0.80 ; 0.81 | 0.79 ; 0.79 | 1.00 ; 0.88 | 51.6 ; 45.1 |
| N.Z. | 0.110 | 0.209 | 0.099 | 0.076 | 0.129 | -0.013 | -0.004 | 0.022 |
| | | | | 76.4 ; 80.4 | 0.75 ; 0.79 | 0.82 ; 0.80 | 0.60 ; 0.62 | 12.5 ; 11.4 |
| Germany | 0.111 | 0.207 | 0.096 | 0.068 | 0.097 | 0.009 | -0.005 | 0.038 |
| | | | | 75.9 ; 79.6 | 0.74 ; 0.70 | 0.86 ; 0.87 | 0.49 ; 0.52 | 32.2 ; 27.2 |
| Belgium | 0.115 | 0.189 | 0.074 | 0.059 | 0.105 | -0.005 | -0.002 | 0.032 |
| | | | | 76.5 ; 79.8 | 0.74 ; 0.72 | 0.88 ; 0.87 | 0.47 ; 0.48 | 37.7 ; 32.6 |
| France | 0.119 | 0.233 | 0.114 | 0.071 | 0.124 | 0.004 | 0.010 | 0.024 |
| | | | | 77.3 ; 81.2 | 0.75 ; 0.77 | 0.86 ; 0.87 | 0.58 ; 0.53 | 27.3 ; 24.5 |
| Bulgaria | 0.121 | 0.273 | 0.152 | 0.022 | 0.156 | -0.003 | 0.004 | 0.096 |
| | | | | 71.3 ; 73.0 | 0.77 ; 0.85 | 0.86 ; 0.86 | 0.62 ; 0.60 | 77.4 ; 50.7 |

| Country | $\widehat{\text{GDP pc}}$ | $\widehat{\text{Welfare}}$ | Diff | $\widehat{\text{LE}}$ | $\widehat{\text{C/Y}}$ | $\widehat{\text{L}}$ | $\widehat{\text{Ineq}}$ | $\widehat{\text{Poll}}$ |
|---|---|---|---|---|---|---|---|---|
| Costa Rica | 0.125 | 0.157 | 0.032 | 0.025 | 0.117 | -0.011 | -0.025 | 0.050 |
| | | | | 76.2 ; 78.5 | 0.89 ; 0.87 | 0.77 ; 0.76 | 0.81 ; 0.89 | 42.4 ; 33.9 |
| Austria | 0.126 | 0.250 | 0.123 | 0.074 | 0.127 | 0.002 | 0.013 | 0.034 |
| | | | | 76.1 ; 80.3 | 0.72 ; 0.72 | 0.83 ; 0.83 | 0.55 ; 0.47 | 35.3 ; 30.4 |
| Pakistan | 0.130 | 0.170 | 0.039 | 0.018 | 0.140 | -0.005 | -0.001 | 0.018 |
| | | | | 60.9 ; 64.6 | 0.88 ; 0.90 | 0.81 ; 0.80 | 0.56 ; 0.56 | 135 ; 124 |
| Denmark | 0.132 | 0.211 | 0.079 | 0.063 | 0.117 | -0.003 | -0.001 | 0.035 |
| | | | | 75.2 ; 78.5 | 0.70 ; 0.67 | 0.85 ; 0.84 | 0.44 ; 0.45 | 24.3 ; 20.8 |
| Australia | 0.133 | 0.210 | 0.078 | 0.073 | 0.120 | -0.003 | 0.002 | 0.019 |
| | | | | 77.6 ; 81.4 | 0.73 ; 0.70 | 0.81 ; 0.80 | 0.61 ; 0.60 | 13.5 ; 12.4 |
| Turkey | 0.135 | 0.297 | 0.162 | 0.097 | 0.160 | 0.018 | 0.022 | 0.001 |
| | | | | 65.9 ; 73.5 | 0.77 ; 0.83 | 0.84 ; 0.86 | 0.86 ; 0.78 | 61.4 ; 61.3 |
| U.K. | 0.141 | 0.266 | 0.125 | 0.059 | 0.170 | 0.000 | 0.002 | 0.035 |
| | | | | 76.5 ; 79.8 | 0.79 ; 0.86 | 0.84 ; 0.84 | 0.63 ; 0.62 | 28.4 ; 24.4 |
| Czech R. | 0.141 | 0.302 | 0.161 | 0.068 | 0.125 | 0.016 | -0.007 | 0.099 |
| | | | | 72.6 ; 76.9 | 0.77 ; 0.74 | 0.81 ; 0.83 | 0.40 ; 0.45 | 61.6 ; 39.7 |
| Indonesia | 0.141 | 0.173 | 0.032 | 0.035 | 0.149 | -0.010 | -0.015 | 0.016 |
| | | | | 64.3 ; 67.8 | 0.71 ; 0.73 | 0.79 ; 0.78 | 0.58 ; 0.66 | 33.3 ; 31.1 |
| Sweden | 0.142 | 0.227 | 0.085 | 0.058 | 0.134 | -0.001 | 0.001 | 0.034 |
| | | | | 78.2 ; 81.1 | 0.71 ; 0.69 | 0.84 ; 0.84 | 0.45 ; 0.45 | 12.6 ; 10.8 |
| Netherlands | 0.165 | 0.234 | 0.069 | 0.054 | 0.155 | -0.013 | 0.005 | 0.033 |
| | | | | 77.2 ; 80.3 | 0.69 ; 0.67 | 0.86 ; 0.85 | 0.52 ; 0.50 | 35.3 ; 30.6 |
| Portugal | 0.166 | 0.265 | 0.099 | 0.070 | 0.196 | -0.007 | 0.003 | 0.003 |
| | | | | 74.6 ; 78.6 | 0.79 ; 0.86 | 0.82 ; 0.82 | 0.67 ; 0.65 | 19.6 ; 19.3 |
| Luxembourg | 0.169 | 0.304 | 0.135 | 0.083 | 0.186 | 0.002 | -0.002 | 0.036 |
| | | | | 76.0 ; 80.1 | 0.61 ; 0.64 | 0.86 ; 0.86 | 0.49 ; 0.50 | 38.2 ; 32.6 |
| Brazil | 0.170 | 0.341 | 0.171 | 0.072 | 0.159 | 0.011 | 0.048 | 0.051 |
| | | | | 66.7 ; 72.7 | 0.80 ; 0.77 | 0.79 ; 0.81 | 1.15 ; 1.01 | 30.3 ; 24.2 |
| Slovenia | 0.171 | 0.316 | 0.145 | 0.088 | 0.160 | -0.004 | 0.005 | 0.066 |
| | | | | 73.5 ; 78.8 | 0.79 ; 0.77 | 0.85 ; 0.85 | 0.46 ; 0.43 | 43.3 ; 32.3 |
| Greece | 0.174 | 0.285 | 0.111 | 0.043 | 0.210 | -0.006 | 0.007 | 0.030 |
| | | | | 77.4 ; 79.9 | 0.82 ; 0.92 | 0.83 ; 0.83 | 0.64 ; 0.61 | 25.7 ; 22.5 |

| Country | $\widehat{\text{GDP pc}}$ | $\widehat{\text{Welfare}}$ | Diff | $\widehat{\text{LE}}$ | $\widehat{\text{C/Y}}$ | $\widehat{\text{L}}$ | $\widehat{\text{Ineq}}$ | $\widehat{\text{Poll}}$ |
|---|---|---|---|---|---|---|---|---|
| Ecuador | 0.178 | 0.181 | 0.002 | 0.041 | 0.151 | -0.049 | 0.019 | 0.019 |
| | | | | 70.4 ; 74.7 | 0.82 ; 0.75 | 0.80 ; 0.75 | 0.99 ; 0.93 | 35.5 ; 32.7 |
| Finland | 0.181 | 0.266 | 0.086 | 0.072 | 0.189 | -0.001 | -0.010 | 0.016 |
| | | | | 75.8 ; 79.5 | 0.68 ; 0.69 | 0.84 ; 0.84 | 0.40 ; 0.47 | 15.0 ; 14.0 |
| Spain | 0.186 | 0.241 | 0.055 | 0.065 | 0.176 | -0.019 | 0.008 | 0.010 |
| | | | | 77.6 ; 81.2 | 0.77 ; 0.74 | 0.88 ; 0.85 | 0.63 ; 0.58 | 20.5 ; 19.6 |
| Argentina | 0.190 | 0.225 | 0.035 | 0.042 | 0.168 | -0.006 | -0.002 | 0.023 |
| | | | | 72.2 ; 75.2 | 0.85 ; 0.80 | 0.84 ; 0.83 | 0.82 ; 0.82 | 32.2 ; 29.1 |
| Venezuela | 0.191 | 0.274 | 0.083 | 0.032 | 0.148 | -0.011 | 0.062 | 0.043 |
| | | | | 70.4 ; 73.5 | 0.73 ; 0.64 | 0.82 ; 0.81 | 0.93 ; 0.71 | 60.8 ; 50.3 |
| Hungary | 0.192 | 0.326 | 0.134 | 0.065 | 0.178 | -0.001 | 0.001 | 0.084 |
| | | | | 69.4 ; 73.6 | 0.87 ; 0.83 | 0.85 ; 0.85 | 0.49 ; 0.48 | 65.0 ; 44.9 |
| Chile | 0.196 | 0.241 | 0.046 | 0.063 | 0.162 | 0.006 | 0.019 | -0.010 |
| | | | | 74.0 ; 79.6 | 0.78 ; 0.70 | 0.80 ; 0.81 | 1.03 ; 0.97 | 42.1 ; 43.9 |
| Slovakia | 0.207 | 0.366 | 0.160 | 0.041 | 0.240 | 0.010 | -0.013 | 0.088 |
| | | | | 71.9 ; 74.6 | 0.79 ; 0.87 | 0.83 ; 0.84 | 0.36 ; 0.46 | 59.7 ; 40.5 |
| S. Korea | 0.211 | 0.379 | 0.168 | 0.094 | 0.226 | 0.049 | 0.008 | 0.001 |
| | | | | 72.6 ; 79.8 | 0.60 ; 0.63 | 0.73 ; 0.77 | 0.61 ; 0.57 | 51.3 ; 51.0 |
| Latvia | 0.220 | 0.387 | 0.167 | 0.073 | 0.245 | 0.018 | -0.025 | 0.075 |
| | | | | 67.2 ; 72.2 | 0.83 ; 0.89 | 0.80 ; 0.82 | 0.56 ; 0.68 | 50.2 ; 36.0 |
| Norway | 0.240 | 0.228 | -0.012 | 0.061 | 0.138 | -0.005 | 0.002 | 0.031 |
| | | | | 77.3 ; 80.6 | 0.59 ; 0.43 | 0.85 ; 0.84 | 0.47 ; 0.46 | 20.4 ; 17.8 |
| Poland | 0.252 | 0.404 | 0.153 | 0.054 | 0.266 | 0.011 | -0.007 | 0.081 |
| | | | | 71.4 ; 75.6 | 0.82 ; 0.86 | 0.81 ; 0.82 | 0.53 ; 0.57 | 75.9 ; 53.1 |
| Peru | 0.257 | 0.208 | -0.049 | 0.049 | 0.213 | -0.027 | -0.005 | -0.022 |
| | | | | 67.0 ; 73.2 | 0.85 ; 0.75 | 0.80 ; 0.78 | 0.87 ; 0.88 | 60.1 ; 66.2 |
| Ireland | 0.270 | 0.289 | 0.019 | 0.084 | 0.172 | -0.015 | 0.020 | 0.027 |
| | | | | 75.3 ; 80.0 | 0.70 ; 0.52 | 0.84 ; 0.82 | 0.66 ; 0.56 | 21.0 ; 18.6 |
| Lithuania | 0.271 | 0.400 | 0.129 | 0.039 | 0.292 | -0.004 | -0.004 | 0.077 |
| | | | | 69.4 ; 72.0 | 0.89 ; 0.95 | 0.84 ; 0.83 | 0.63 ; 0.64 | 51.4 ; 36.6 |
| Estonia | 0.272 | 0.426 | 0.154 | 0.103 | 0.258 | 0.009 | 0.008 | 0.048 |
| | | | | 68.0 ; 73.9 | 0.83 ; 0.79 | 0.81 ; 0.82 | 0.62 ; 0.58 | 20.1 ; 16.3 |

| Country | $\widehat{\text{GDP pc}}$ | $\widehat{\text{Welfare}}$ | Diff | $\widehat{\text{LE}}$ | $\widehat{\text{C/Y}}$ | $\widehat{\text{L}}$ | $\widehat{\text{Ineq}}$ | $\widehat{\text{Poll}}$ |
|---|---|---|---|---|---|---|---|---|
| Vietnam | 0.298 | 0.228 | -0.070 | 0.011 | 0.195 | 0.039 | -0.010 | -0.007 |
| | | | | 71.3 ; 74.7 | 0.96 ; 0.71 | 0.68 ; 0.70 | 0.62 ; 0.66 | 53.8 ; 55.5 |
| India | 0.301 | 0.234 | -0.068 | 0.014 | 0.244 | 0.011 | -0.018 | -0.017 |
| | | | | 59.4 ; 65.7 | 0.84 ; 0.71 | 0.78 ; 0.80 | 0.60 ; 0.68 | 120.6; 130.1 |

The countries are ordered according to their GDP per capita growth.

Growth rates computed based on the averages of the periods 1991-1995 and 2006-2010.

LE: Life Expectancy; C/Y: Consumption share in GDP; L: Leisure; Ineq: Inequality; Poll: Pollution

Figure A2: Robustness check: Welfare with separable vs. non-separable utility

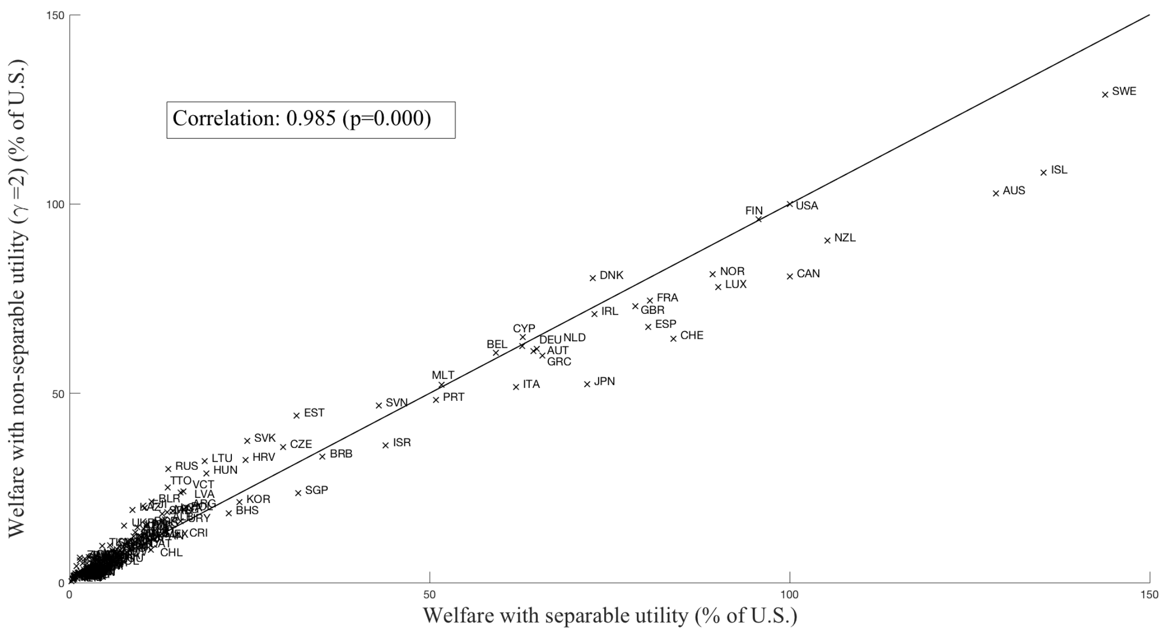


Figure A3: Robustness check: GDP p.c. vs. welfare with non-separable utility

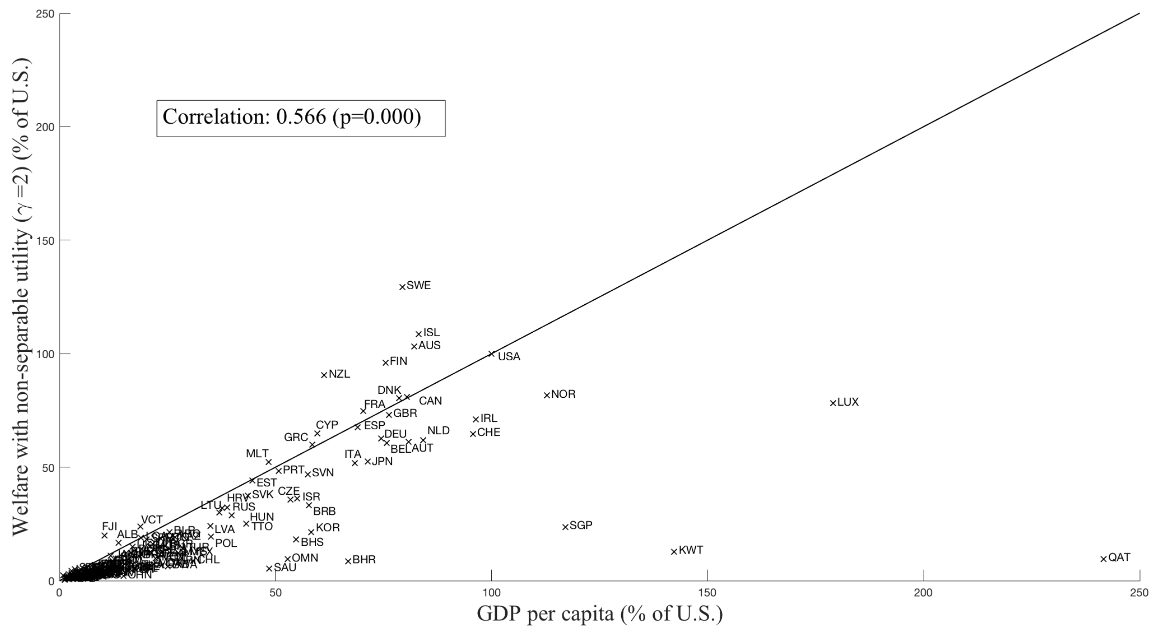

Figure A4: Robustness check: Welfare growth separable vs. non-separable utility

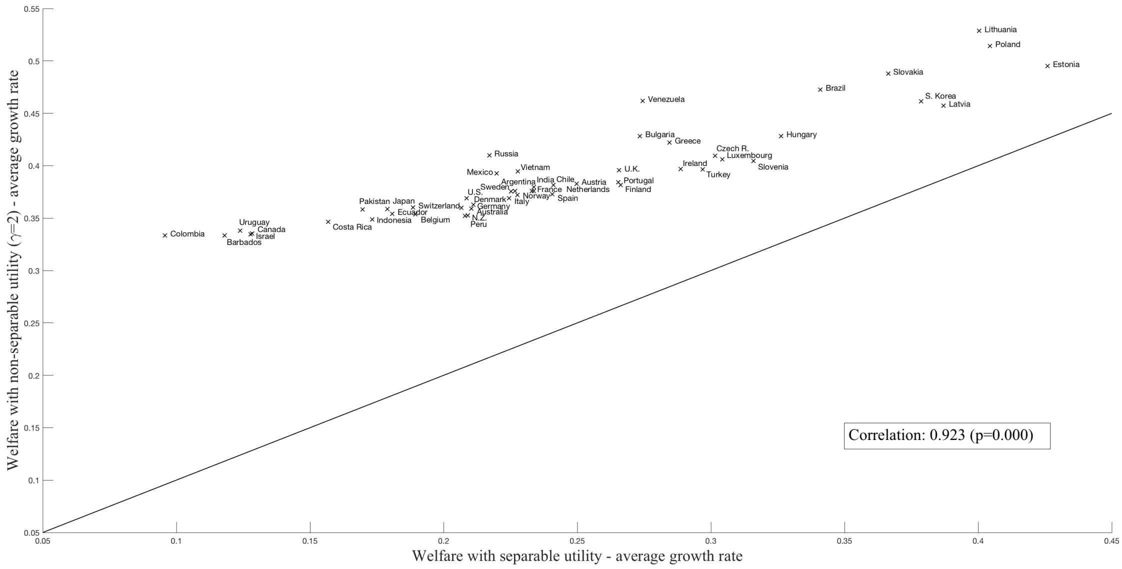


Figure A5: Robustness check: GDP p.c. growth vs. welfare growth with non-separable utility