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ADJUSTING NATIONAL ACCOUNTING FOR HEALTH:
IS THE BUSINESS CYCLE COUNTERCYCLICAL?

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Adjusting National Accounting for Health: Is the Business Cycle Countercyclical?
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ABSTRACT

Many national accounts of economic output and prosperity, such as gross domestic product (GDP) or net domestic product (NDP), offer an incomplete picture by ignoring, for example, the value of leisure, home production, and the value of health. Previous discussed shortcomings of such accounts have focused on how unobserved dimensions affect GDP levels but not their cyclicality, which affects the measurement of the business cycle. This paper proposes a new methodology to measure economic fluctuations that incorporates monetized changes in health of the population in the United States and globally during the past 50 years. In particular, we incorporate in GDP the dollar value of mortality, treating it as depreciation in human capital analogous to how net domestic product (NDP) treats depreciation of physical capital. Because mortality tends to be procyclical, we find that adjusting for mortality reduces the measured deviations of GDP from trend during the past 50 years by about 30% both in the United States and internationally.

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1. Introduction

It has long been recognized that gross domestic product (GDP) is an incomplete measure of economic output. Among other things, GDP excludes the value of leisure, home production, and health. Yet GDP and net domestic product (NDP) prevail as measures of economic output. This is in part for a pragmatic reason; alternative approaches cannot be adopted in a simple and transparent manner across time and countries. The measure of an economy's well-being has enormous implications not only for attempts to understand fluctuations, but also for its impact on national policies that are grounded in the belief that currently measured recessions are welfare reducing and booms are welfare enhancing.

An important dimension of an economy's welfare concerns the health of its population. Indeed, recent research indicates that, in terms of overall trends, health has been one of the most important components of the advances in U.S. welfare during the last century (Murphy and Topel 2006). In this paper, we analyze whether incorporating health into measures of short-term macroeconomic fluctuations in GDP or NDP—i.e., deviations from trends—alters assessments of the magnitude of macroeconomic fluctuations.

We incorporate health into macroeconomic fluctuation measures by valuing in U.S. dollars any cyclical changes in health surrounding booms and recessions. In particular, we incorporate mortality into output measures as depreciation in human capital in a way analogous to how NDP treats physical depreciation. We then construct mortality-adjusted GDP and NDP measures to reexamine the U.S. and international fluctuations during the past 50 years. We find that mortality covaries positively with traditional GDP and NDP measures over time across ages and countries, extending an existing literature on the positive covariance between mortality and employment (Ruhm 2000). When we monetize these counter-cyclical levels of health, we find that they are quantitatively important and the U.S. fluctuations look milder than traditionally presumed with GDP or NDP. We find that incorporating the value of mortality potentially reverses one third of "recessions" during the past 50 years, and that adjusting for mortality reduces measured output volatility in both the United States and in the group of developed countries considered by about 30%.

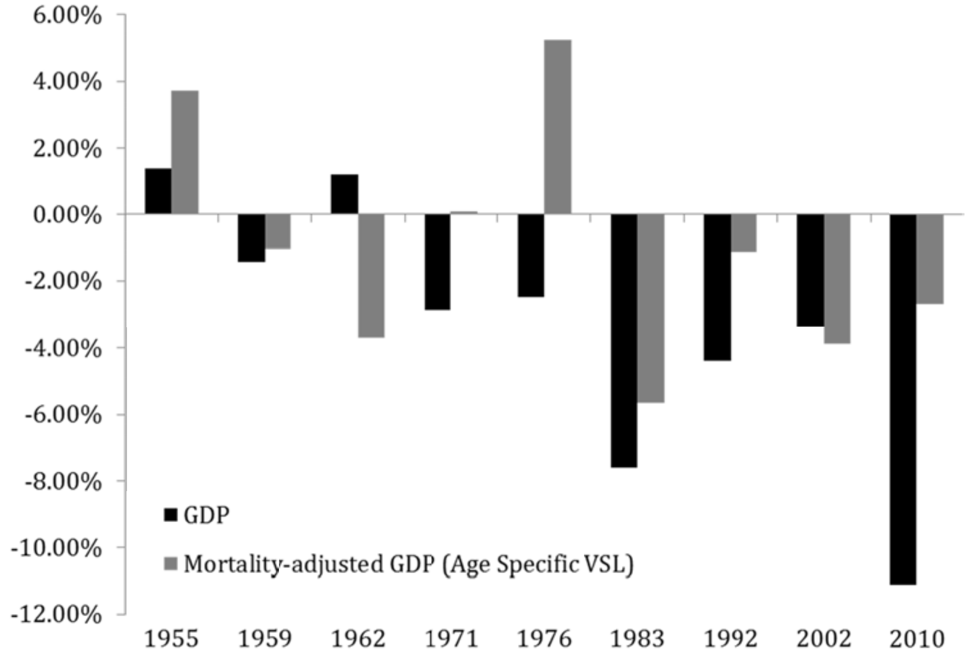
To illustrate the quantitative magnitude of the value of mortality in a year, consider 2010, when there were approximately 2.5 million deaths in the United States. The Environmental Protection Agency and U.S. Department of Transportation estimates the value of a life at roughly $9 million (in 2010 dollars) in recent regulatory impact analyses (Viscusi 2014, U.S. Department of Transportation 2013). This implies a mortality cost of approximately $22.5 trillion in 2010. The GDP of the United States that year was approximately $15.8 trillion. Although there is ongoing debate regarding whether the monetary value of life for older individuals should be larger or smaller than that of younger individuals, the magnitudes of these back-of-the-envelope calculations suggest they are of first order importance.

The importance of health lost in a year relative to GDP carries over when we look at changes in deviations from trend which we henceforth refer to as "fluctuations." [1] To illustrate our main results, figure 1 compares the severity of the nine U.S. recessions between 1950 and 2010 as measured by both GDP and our mortality-adjusted GDP, which as noted takes into account depreciation in human capital.[2] We measure the magnitude of each recession as the peak to trough relative to GDP, as dated by the National Bureau of Economic Research (NBER 2013). Each bar represents the difference in actual output at the end of recession minus the implied trend output level between the years 1950 to 2010. In every recession other than in 1962 and 2002, adjusting for the value of mortality suggests that the total output fluctuations were milder than what is implied by unadjusted GDP because of the positive correlation between mortality and traditional GDP. A remarkable result is that offsets in health were large enough to essentially reverse one third of these recessions. From the perspective of total economic output, including full depreciation, these "recessions" were not associated with a decline in total output after adjusting for health.

[1] Our paper looks at all deviations from trend, regardless of their frequency. It is beyond the scope of this paper (and our data) to further subdivide the deviations into, say, low frequencies, medium frequencies, seasonal frequencies, etc.

[2] In addition to calculating mortality adjusted GDP we also calculated mortality adjusted NDP. We replicated the proceeding analysis using both GDP and NDP and found quantitatively similar results. We report the results for GDP rather than NDP to facilitate comparisons across countries.

FIGURE 1: RECESSION – PEAK TO TROUGH (% OF GDP)



Notes on Figures 1 and 3:

- Each bar measures the difference in actual output at the end of recession minus the trend output level. The difference in output is normalized by the trend GDP level in the corresponding year. Output is measured in constant U.S. dollars (2000 base).
- We compute trend GDP and mortality adjusted GDP by assuming both GDP and the value of mortality grow at some constant, but potentially different rates. Trend mortality adjusted GDP and GDP are computed using the average GDP and value of mortality growth rates over the period 1950 to 2010. See footnote 11 for further details.
- Recessions are dated as per the NBER. Consequently, it is possible that the peak to trough for any given recession, as measured using GDP, is positive (e.g., 1955 and 1962 recessions).
- Real GDP data is from the U.S. Bureau of Economic Analysis and the World Bank.
- We calculate the value of mortality in the year 2000 using the age specific value of statistical life estimates from Aldy and Viscusi (2008) (See section IV of Aldy and Viscusi 2008 for further details). The VSL in other years is scaled by trend per capita GDP as discussed in Section 3.

As illustrated in Figure 1, our main finding is that incorporating health makes fluctuations less significant. We believe, therefore, that more research is warranted on the cyclicality of unmeasured components of national output.

Our paper relates to several other strands of work. Cutler and Richardson (1997), Nordhaus (2002), and Murphy and Topel (2006) have documented the central role of health in overall economic well-being gains in the United States. Becker et al. (2005) have examined the impact of valuing health for world inequality and economic convergence. Jones and Klenow (2010) have examined the impact of including other nonmarket measures into international comparisons of welfare. This literature may be interpreted as addressing the value of the overall trends in health and other measures. In contrast, our research relates to the behavior of *deviations from trends* over time by assessing the cyclical nature of health and how it relates to standard measurements of fluctuations.

The paper is organized as follows. Section 2 illustrates how physical depreciation is handled in NDP measures and outlines how human capital depreciation can be handled in an analogous manner. Section 3 describes how we construct the mortality adjusted GDP series. Section 4 adjusts recessions in the United States and abroad for human capital depreciation, looking at how peak-to-trough changes are affected. Section 5 provides estimates for how the cyclicality of the U.S. and international output measures are altered by including the depreciation of health. Finally, Section 6 concludes by outlining research issues we believe need to be addressed. These include more complete measures of the cyclical nature of human capital fluctuations, such as changes in fertility (entry versus exits from the health capital stock) and educational investments (appreciation versus depreciation of the stock). We argue that these unobserved components of human capital are likely to be counter-cyclical, thereby reinforcing the documented counter-cyclical value of health examined here.

2. Human and Physical Capital Depreciation in the National Accounts

Part of measuring economic activity over a specific time frame (hereafter, a calendar year) involves recognizing the value of capital is different at the end of the time frame than it was at the beginning. Structures have been built or destroyed, water has been polluted or cleaned, etc. For many purposes it is desirable to have measures of economic activity that include the net change in the capital stock.

For this reason, national accounts include estimates of physical investment: the value of additions to the nation's private physical capital stock. In the expenditure account, physical investment is sometimes measured net of depreciation, that is, the "depreciation" value of the destruction, aging, or economic obsolescence of pre-existing physical assets is subtracted from the value of new assets created during the year.[3] In the income account, the same depreciation (as used in the expenditure account) is excluded from the incomes of the owners of domestic physical capital. Either way, the result is NDP, or Net (of depreciation) Domestic Product.

It is also understood that there are valuable human and environmental assets and that, in principle, their accumulation and depreciation would be counted too (Hartwick 1990, Nordhaus and Kokkelenberg 1999, Jorgenson 2009). Human and environmental capital data has traditionally been lacking, but economists are making progress, for example, including environmental depreciation in their measures of economic activity (Carson 1994). Ideally, national accounts would include the creation and destruction of human assets in the same way as it includes the creation and destruction of physical assets. For the purpose of measuring macroeconomic fluctuations, these measures will only be important if they are correlated with the cycle because if they are not, traditional measures are sufficient in measuring deviations. The purpose of our paper is to measure economic activity over time in a way that begins to include the depreciation of human capital by estimating the amount of deprecation and subtracting it from estimates of national product that are gross of human depreciation.

The BEA's ideal method for measuring depreciation – the loss in an asset's value solely from the passage of time – is to infer an age-value profile from purchase price data in a well-function resale market for used assets (Fraumeni 1997). Depreciation over the year would then be inferred by moving each asset one year further down the profile. For example, if two-year old automobiles sell for 90 percent of the price of one-year old automobiles, then automobiles would be assumed to depreciate 10 percent during their second year.

In practice, physical asset resale market data is imperfect for this purpose. The assets sold in the resale market are not a random sample of the assets in existence the year

[3] The BEA defines depreciation as "the decline in value due to wear and tear, obsolescence, accidental damage, and aging." (Fraumeni, 1997).

before. For example, some automobiles are totaled as the result of accidents, etc., and thereby excluded from resale markets but their destruction is nonetheless depreciation.[4] When the resale data is poor enough, as it is for a great many of the physical assets tracked in the national accounts, a depreciation schedule is parameterized and calibrated for each type of asset and then assumed to apply to all investments of that type (Fraumeni 1997). Geometric depreciation is commonly used for physical assets. Earlier versions of the national accounts sometimes used a one-hoss-shay schedule based on data on normal asset lifetimes: no depreciation during the normal asset life and then 100 percent depreciation when the asset life is reached.

We don't have a resale market in humans, so we follow the parametric approaches that have been used to estimate physical depreciation. We take an approach which calibrates a parametric age profile to recognize that the value lost at a person's death depends on the age of the person who died (Murphy and Topel 2006; Aldy and Viscusi 2008). Specifically we use existing age specific value of statistical life (VSL) tables to calculate the value of depreciation in the human capital stock resulting from death.

3. Constructing Mortality Adjusted GDP Series

We define mortality adjusted GDP as the value of GDP minus the value of lost life (mortality) over the corresponding period. The value of mortality reflects the total value of life lost in the corresponding period due to death. We compute the value of mortality as the sum of the number of deaths in the period weighted by the corresponding VSL.

We use two VSL methodologies to compute the value of mortality. The first method uses the VSL estimates from Aldy and Viscusi (2008) who use a minimum distance estimator in conjunction with hedonic wage regressions to estimate the VSL conditional on ages 18-62.[5] We extrapolate their estimates for the non-working age populations.

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[4] The BEA usually measures expected or "normal" depreciation rather than actual depreciation. For example, automobile depreciation in the national accounts does not reflect the actual number of car crashes during the year but rather a normal rate. However, special disaster loss charges are included in the national accounts when a natural or man-made disaster's destruction exceeds 0.1 percent of GDP.

[5] See section IV of Aldy and Viscusi 2008 for further details.

Following Viscusi and Hersch (2008) we calculate the VSL for individuals over the age of 63 by treating the VSL as the present discounted value of future value of statistical life years (VSLY).[6] For individuals under the age of 18, we assume a constant VSL of $3.43mm (which corresponds to the estimated VSL for 18 year olds).[7] The second VSL methodology uses the age and gender specific VSL profiles from Murphy and Topel (2006). Murphy and Topel calibrates an age-profile for the VSL for a life-cycle model which incorporates multiple dimensions of health. The VSL profile is then calibrated using consumption and income data and scaled according to existing EPA VSL estimates.

Figure 2 plots our extrapolated VSL profile from Aldy and Viscusi (2008) along with the VSL profile from Murphy and Topel (2006). Both age-VSL profiles follow an inverse U shape. The Murphy and Topel age-VSL profile places a higher value on younger individuals and lower value on elderly individuals than the corresponding Aldy and Viscusi profile. In choosing between the Aldy and Viscusi and Murphy and Topel estimates we face the trade-off of using an extrapolated age-VSL profile estimated from observed data versus a complete age-VSL profile constructed from economic theory. Regardless of which age-VSL profile we use to compute mortality adjusted GDP, the primary results remain the same: mortality adjustment dampens the observed fluctuations and overall volatility of measured output.

Both the Aldy and Viscusi and Murphy and Topel age-VSL profiles are calibrated to the year 2000. To calculate the value of life in other years we simply scale the VSL by the

[6] Viscusi and Hersch (2008) treat VSL as the discounted constant stream of future VSLY. Using the VSL estimates from Aldy and Viscusi (2008) we calculate the VSLY at age t as

$$VSLY(t) = \frac{rVSL(t)}{1-(1+r)^{-L(t)}}$$

where $L(t)$ is the remaining life expectancy in years at age t (as per the CDC National Vital Statistics Report and the Social Security Administration) and r is the discount rate (assumed to be 3%). We construct the VSL for ages 63+ using the implied VSLY for 62 year olds.

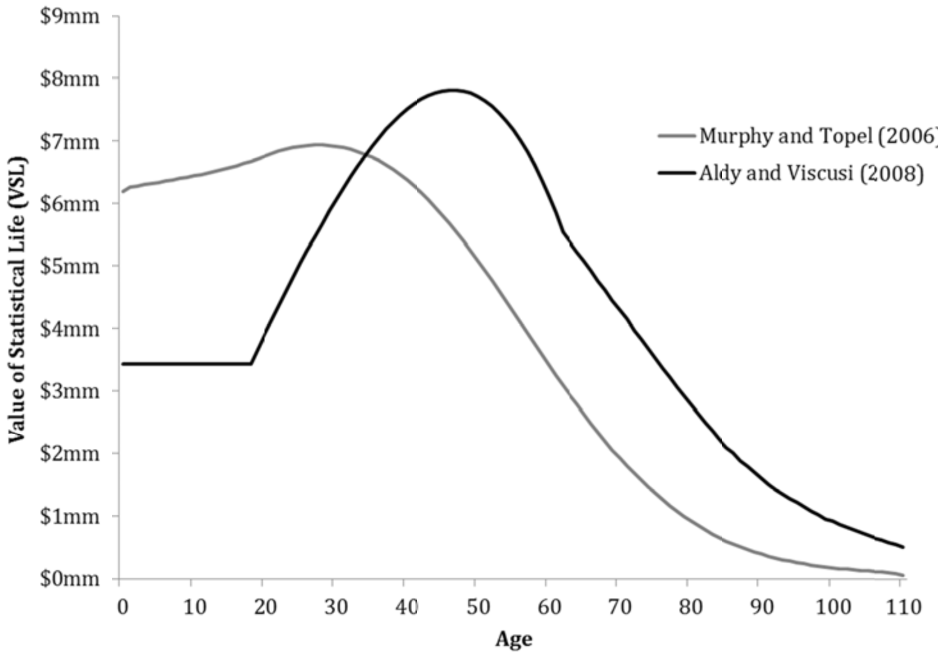
[7] As a robustness check, we replicate the proceeding analysis by assuming a VSL of zero for individuals 0-17 and find quantitatively similar results.

trend GDP per capita in the given year relative to the trend GDP per capita in 2000[8]. This methodology implicitly assumes the elasticity of VSL with respect to income is one. While there is some debate in the literature about the elasticity of VSL with respect to income, our unit elastic assumption is in line with prior research and current guidelines. Viscusi and Aldy (2003) and Doucouliagos et. al (2014) estimate an elasticity of roughly 0.5 while research from Kneiser et. al (2010) and Costa and Kahn (2004) estimate the elasticity is closer to 1.5. We specify a VSL income elasticity of one which is in accordance with current guidelines set by the U.S. Department of Transportation (2013) and the estimates from Miller (2000). [9]

[8] Trend GDP is calculated using the Hodrick Prescott Filter with a smoothing parameter of 6.5

[9] See the U.S. Department of Transportation Memorandum (2013) for further discussion regarding the elasticity of the VSL with respect to income.

FIGURE 2: VALUE OF A STATISTICAL LIFE BY AGE



Notes on Figure 2:

- Due to data availability issues, we extrapolate the VSL estimates from Aldy and Viscusi (2008) for ages 0-17 and greater than 63. Following Viscusi and Hersch (2008) we calculate the VSL for individuals over the age of 63 by treating the VSL as the present discounted value of future value of statistical life years (VSLY). For individuals under the age of 18, we assume a constant VSL of $3.43mm (which corresponds to the estimated VSL for 18 year olds).
- The figure reports the age-VSL profile for males from Murphy and Topel (2006).

The proceeding analysis is easily replicated with any VSL profile. With more extensive data one could allow for heterogeneous values of life beyond controlling for age and sex. Valuing a death at the corresponding average VSL conditional on age could be problematic to the extent the value of life for an individual at margin of living and dying is less than the average value of a statistical life. However, such issues are not unique to calculating human depreciation. Due to data availability and for purposes of calculating human depreciation in a manner analogous to physical capital depreciation, we calculate human deprecation conditional on age.

4. Adjusting Individual Recessions for Changes in the Value of Health

This section performs an analysis of the degree to which the cyclical nature of health affects the measurement of individual recessions in the U.S. and internationally. We consider the peak-to-trough of the measured GDP levels and adjust them for the value of health destroyed in these recessions.

Figures 1 and 3 indicate the peak to trough of the nine U.S. recessions occurring over the period 1950-2010. We calculate peak to trough as the difference in actual output at the end of recession minus the output level implied by the trend. The difference in output is normalized by the implied trend GDP level in the corresponding year. We compute trend GDP and mortality adjusted GDP by assuming both GDP and the value of mortality grow at some constant, but potentially different rates.[10] Figure 1 is calculated using the Aldy and Viscusi (2008) age-VSL profile while figure 3 is calculated using the age and gender specific VSL estimates from Murphy and Topel (2006). Under both measures mortality adjustment essentially negates the 1955 and 1976 U.S. "recessions". Although comparable, mortality adjustment appears to have a slightly bigger impact when calculated using the Aldy and Viscusi age-VSL profile than when calculated using the Murphy and Topel age and gender specific VSL profile. This is likely due to the fact that the Aldy and Viscusi age-VSL profile puts a higher value on individuals over the age 35 than the Murphy and Topel profile. Due to the comparability of the results and for convenience, the remaining analysis is conducted using the Aldy and Viscusi age-VSL profile.

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[10] We calculate peak to trough for mortality adjusted GDP as

$$\text{Peak to Trough} = \frac{N_t - N_t^T}{N_t^T}$$

where N_t is the actual level of mortality adjusted GDP at the end of the recession (time t) and N_t^T is the trend level of mortality adjusted GDP. Trend mortality adjusted GDP is computed as

$$N_t^T = Y_{t-\tau}(1 + \overline{\Delta\%Y})^\tau - M_{t-\tau}(1 + \overline{\Delta\%M})^\tau$$

where $Y_{t-\tau}$ and $M_{t-\tau}$ are the pre-recession levels of GDP and value of mortality, $\overline{\Delta\%Y}$ and $\overline{\Delta\%M}$ are the average GDP and value of mortality growth rates over the period 1950-2010, and τ is the length of the recession. The peak to trough calculations for unadjusted GDP are calculated in an analogous manner.

FIGURE 1: RECESSION – PEAK TO TROUGH (% OF GDP)

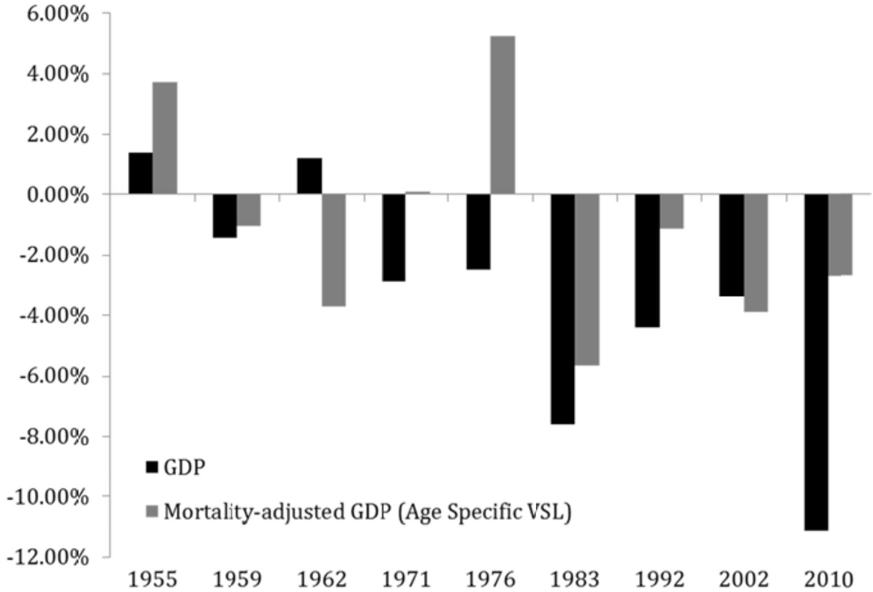
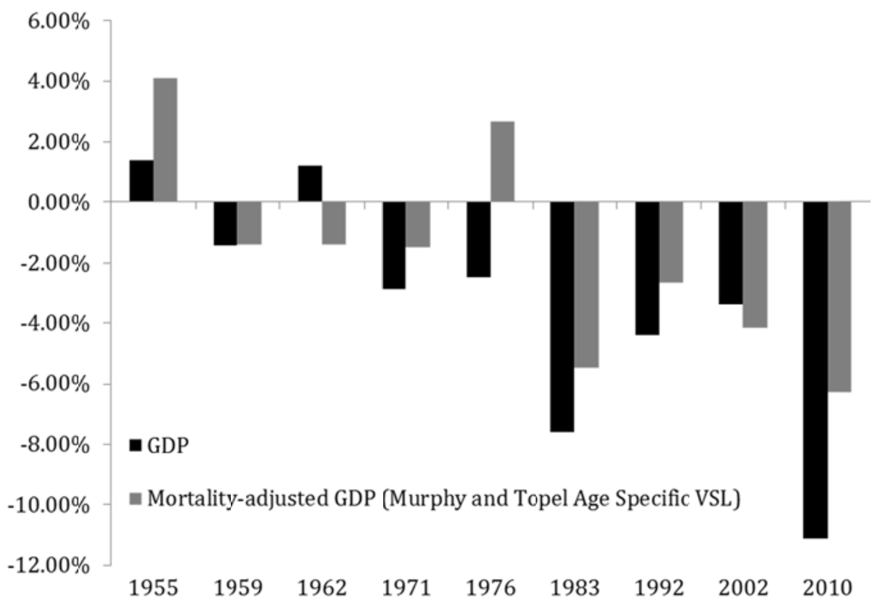


FIGURE 3: RECESSION – PEAK TO TROUGH (% OF GDP)



Notes on Figures 1 and 3:

- Each bar measures the difference in actual output at the end of recession minus the trend output level. The difference in output is normalized by the trend GDP level in the corresponding year.
- Trend mortality adjusted GDP and GDP are computed using the average GDP and value of mortality growth rates over the period 1950 to 2010. See footnote 11 for further details.
- Recessions are dated as per the NBER. Consequently, it is possible for the peak to trough of any given recession, as measured using GDP, to be positive (i.e. 1955 and 1962 recessions).

The implications of mortality adjustment when measuring economic output are not unique to the United States. We replicate the preceding peak to trough analysis for our unbalanced sample of twenty-one other developed countries covering the period 1960-2010. Recessions across countries are dated using an algorithm in-line with Jorda, Schularick, and Taylor (2011), Claessens, Kose, and Terrones (2011) and Bry and Boschan (1971)[11]. The value of mortality is calculated across countries by scaling Aldy and Viscusi's (2008) VSL estimates by trend GDP per capita[12]

$$\mathrm{VSL}_{a,i,t} = \mathrm{VSL}_a^{AV} \frac{\mathrm{GDPPC}_{i,t}}{\mathrm{GDPPC}_{US,2000}}$$

Where $VSL_{a,i,t}$ is the value of a statistical life for an individual at age a, time t in country i and VSL_a^{AV} is the value of a statistical life as per Aldy and Viscusi (2008). As discussed in Section 3 this methodology implies an income VSL elasticity of one which is line with the across-country elasticity estimates from Miller (2000).

Although not uniformly, figure 4 and table 1 indicate that the general finding, that recessions appear less severe when adjusting for mortality, seems to persist across countries. The first row of table 1 indicates that in Australia output fell, on average, by 2.90% below trend during recessions when measured using GDP. When measured using mortality-adjusted GDP, Australian output, on average, only fell by 1.24% below trend during recessions. For uniformity and ease of exposition we calculate the peak to trough of each recession in each country using the same methodology as described above. This approach computes trend GDP and mortality adjusted GDP under the assumption that both mortality and GDP grow at constant rates within a given country. Overall, we find that adjusting for mortality reduces the depth of the recession, on average, by over three absolute percentage points of GDP and essentially negated one in four recessions in our sample.

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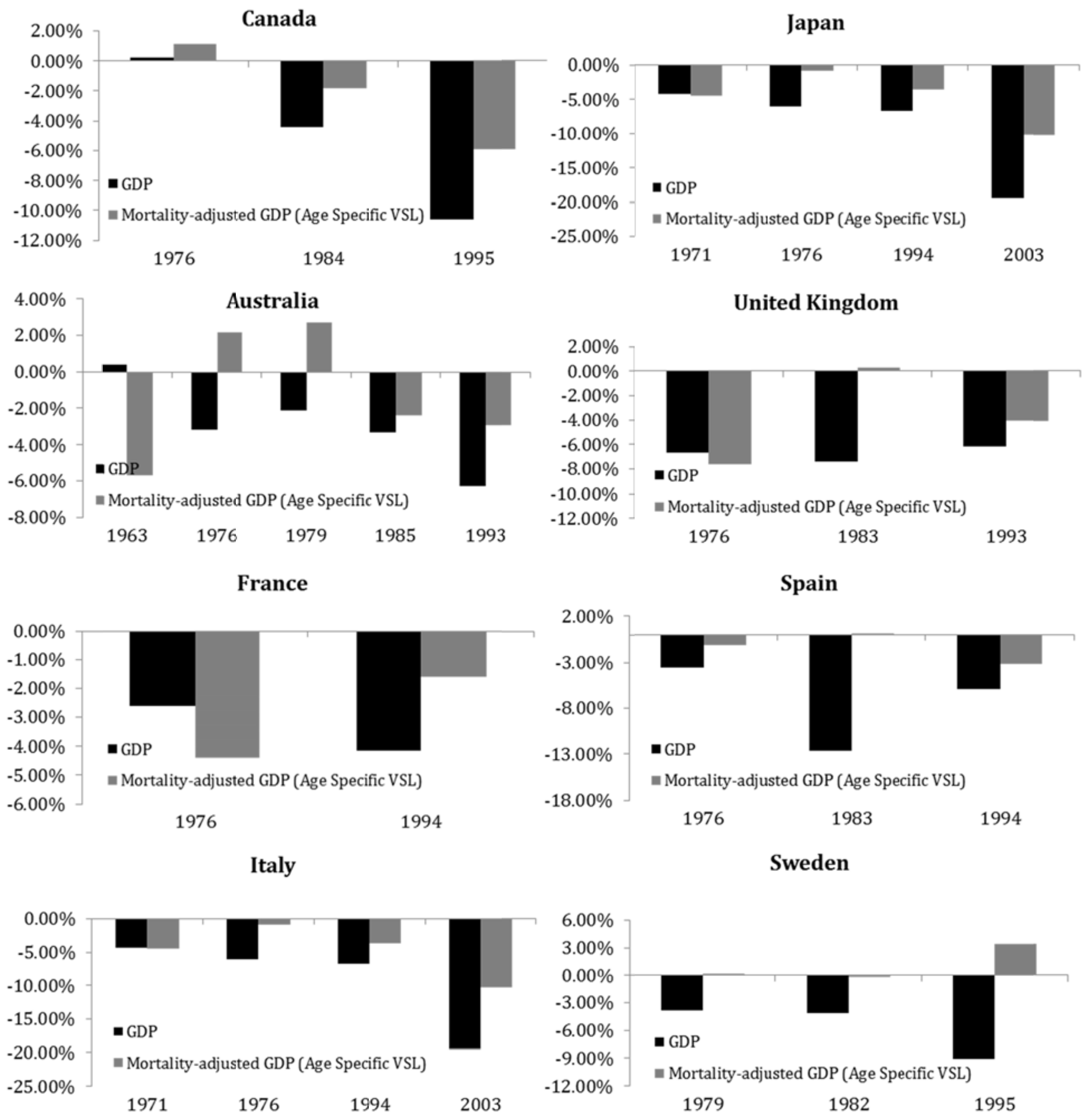
[11] Peaks are defined as the year preceding a year over year decline in real per capita GDP with the year(s) proceeding the peak defined as a recession. The end of the recession is marked by the year in which real GDP per capita exceeds the real GDP per capita level in the peak year prior to the start of the recession.

[12] Trend GDP is calculated using the Hodrick Prescott Filter with a smoothing parameter of 6.5

Figure 4: Recession – Peak to Trough (% of GDP)



Notes on Figure 4:

- Each bar measures the difference in actual output at the end of recession minus the implied trend output level. The difference in output is normalized by the trend GDP level in the corresponding year.
- Trend mortality adjusted GDP and GDP are computed using the average GDP and value of mortality growth rates over the period 1950 to 2010 (see table 1 notes and footnote 11 for further details).

TABLE 1: AVERAGE RECESSION DEPTH (AVERAGE PEAK TO TROUGH, % OF GDP)

Country	GDP	Mortality-adjusted GDP (Age Specific VSL)
Australia	-2.90%	-1.24%
Austria	-2.34%	-1.37%
Belgium	-3.42%	-2.21%
Canada	-4.93%	-2.21%
Denmark	-1.40%	-3.50%
Finland	-8.35%	2.63%
France	-3.40%	-3.01%
Hungary	-5.65%	2.92%
Iceland	-6.21%	-3.52%
Ireland	-2.90%	-0.23%
Israel	-9.06%	-6.04%
Italy	-3.47%	-1.92%
Japan	-9.13%	-4.83%
Luxembourg	-9.99%	-3.58%
Netherlands	-3.82%	-2.89%
New Zealand	-1.09%	1.26%
Norway	-4.72%	-2.37%
Portugal	-8.52%	-0.41%
Spain	-7.38%	-1.45%
Sweden	-5.67%	1.14%
U.K.	-6.74%	-3.78%
U.S.	-3.41%	-1.00%

Notes on Table 1

- The peak to trough of each recession is calculated as the difference in actual output at the end of recession minus the trend output level. The difference in output is normalized by the trend GDP level in the corresponding year.
- Trend mortality adjusted GDP and GDP are computed using the average GDP and value of mortality growth rates over the period 1950 to 2010. See footnote 11 for further details. Due to concerns about compounding trend estimation error, recessions lasting greater than 10 years are dropped from the data set when computing the average peak to trough.
- For each country table 1 displays the average peak to trough across all defined recessions in the respective country.
- U.S. recessions are defined as per the NBER. Non-U.S. recessions are defined using the algorithm described previously
- Data for the U.S., Ireland, Israel and New Zealand covers the periods (1950-2010), (1970-2009), (1983-2009), and (1977-2008) respectively. Data for Austria, Denmark, France, Iceland and Sweden covers the period (1960-2010). Data for all other countries is from 1960-2009.
- Countries were selected based on the availability (at least 25 continuous years) of mortality data from Mortality.org and population and GDP data from the World Bank.

5. Adjusting the Cyclicality of GDP Measurements to Changes in Health

In this section we adjust the U.S. and international fluctuations to include the value of mortality. We first extend the existing evidence related to mortality and employment in the U.S. to the business cycle, as well as extend that analysis across ages and countries. We then incorporate these estimates into adjusting the cyclicality of standard GDP fluctuations. Our main finding is that adjusting for mortality reduces the measured output volatility by about 30% in the U.S. and internationally.

5.1. Mortality and fluctuations

If unmeasured components such as health remained constant over time, calculating mortality-adjusted GDP would offer little value from a macroeconomic policy perspective in terms of analyzing fluctuations. However, we extend previous work by showing that the value of mortality is pro-cyclical, exhibiting a strong positive correlation with GDP. Previous literature identifies the negative relationship between mortality and employment. Without taking an explicit stance on the causality of the relationship, we extend their results, showing that there is a positive relationship between mortality and GDP which may have equally or even more important implications when monetized using our methods.

We examine the relationship between mortality and GDP further by regressing log mortality on log GDP as displayed in table 2. The estimated relationship between log mortality and log GDP is positive and significant in each specification. When we examine mortality by age group, the results indicate that mortality among the elderly may propel the positive relationship between total mortality and output. This finding is in accordance with the earlier findings from Stevens et al. (2011), which find that overall positive relationship between unemployment and mortality is generated by the elderly population.

TABLE 2: REGRESSION OF LOG MORTALITY ON LOG GDP

Age Group	(1)	(2)	(3)	(4)
All	0.4071*** (0.0772)	0.2670*** (0.0825)	0.2337*** (0.0859)	0.2135** (0.0894)
65+	0.7567*** (0.1155)	0.3228*** (0.1045)	0.2911*** (0.1040)	0.2293** (0.1045)
25-64	0.1006 (0.1507)	0.1429 (0.0943)	0.1495 (0.0941)	0.1874* (0.0967)
0-24	0.1942 (0.1893)	0.2066 (0.1316)	0.2004 (0.1315)	0.1627 (0.1363)
Time Trend	X	X		X
AR(1) Correction		X		
First Differences			X	X

Notes on Table 2:

- Each age group coefficient is estimated in a separate regression with log age-group mortality as the dependent variable. Reported coefficients are the coefficients on log GDP. “AR(1) correction” indicates Prais-Winsten AR(1) regressions.
- One, two and three stars indicate significance at 10, 5 and 1 percent levels.
- The data set spans 1950-2010 with annual observations.

5.2 Adjusting U.S. macroeconomic fluctuations for health

At first glance, mortality-adjusted GDP and GDP exhibit similar patterns over the past fifty years in the U.S. However, upon further examination, there are several distinct differences between the GDP and mortality-adjusted GDP. We compare and contrast mortality unadjusted and adjusted GDP by formally decomposing them both into their trend and deviations from trend.

We decompose log GDP and the log value of mortality into additive trend and deviation from trend components using both a linear trend and the Hodrick Prescott Filter to calculate the corresponding trends. GDP, Y_t, and the value mortality (the number of deaths multiplied by the corresponding VSL), M_t, can be written in terms of their trend and cyclical components such that

$$Y_t = \exp(y_t^T + y_t^C), \;\; M_t = \exp(m_t^T + m_t^C)$$

where

$$\mathrm{E}[Y_t | y_t^T] = \exp(y_t^T), \;\; \mathrm{E}[M_t | m_t^T] = \exp(m_t^T)$$

As discussed previously, mortality adjusted GDP, N_t, is defined as GDP in a given year minus the corresponding value of mortality

$$N_t = Y_t - M_t$$

We define the cyclical component of mortality-adjusted GDP and GDP, N_t^C and Y_t^C respectively, as deviations from trend

$$N_t^C = N_t - \left[\exp\left(y_t^T\right) - \exp\left(m_t^T\right)\right]$$
$$Y_t^C = Y_t - \exp\left(y_t^T\right)$$

Note that we refer to these type of deviations from trend as "fluctuations" in mortality-adjusted GDP and GDP. Assuming that both y_t^C and m_t^C follow a log linear trend, we regress the $\ln Y_t$ and $\ln M_t$ on a time trend to recover the cyclical and trend components of both

GDP as well as value of mortality.[13] We also estimate the cyclical and trend components of GDP and mortality using the Hodrick Prescott filter.

Figure 5 plots the estimated cyclical components of GDP and NDP as a fraction of GDP, denoted NY_t^C and YY_t^C respectively.

$$NY_t^C = N_t^C \exp(-y_t^T)$$
$$YY_t^C = Y_t^C \exp(-y_t^T)$$

Though the two series exhibit a strong positive correlation over the past fifty years, the cyclical component of GDP appears more volatile than that of mortality-adjusted GDP, especially prior to 1990. Statistically speaking, the measured volatility of GDP is almost 1.5 times that of mortality-adjusted GDP, 4.42% relative to 3.12%. Table 3 summarizes the volatility of GDP as calculated using the two decomposition methods (log linear trend and the Hodrick Prescott Filter). Note that since the trend component, as calculated as per the Hodrick Prescott Filter, fluctuates over time, we calculate the volatility of the trend component about a log linear trend. Under all three measures, the volatility of output decreases when we adjust for mortality.

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[13] Formally, we assume that y_t^C and m_t^C are normally distributed such that

$$\ln Y_t = y_t^T + y_t^C = a_y + b_y t - Var(\varepsilon_y^C)/2 + \varepsilon_{y,t}^C$$
$$\ln M_t = m_t^T + m_t^C = a_m + b_m t - Var(\varepsilon_m^C)/2 + \varepsilon_{m,t}^C$$

The trend and cyclical components are estimated from the regression results as

$$\widehat{y_t^C} = \widehat{\varepsilon_{y,t}^C} - Var(\widehat{\varepsilon_y^C})/2$$
$$\widehat{y_t^T} = \widehat{a_y} + \widehat{b_y} t$$
$$\widehat{m_t^C} = \widehat{\varepsilon_{m,t}^C} - Var(\widehat{\varepsilon_m^C})/2$$
$$\widehat{m_t^T} = \widehat{a_m} + \widehat{b_m} t$$

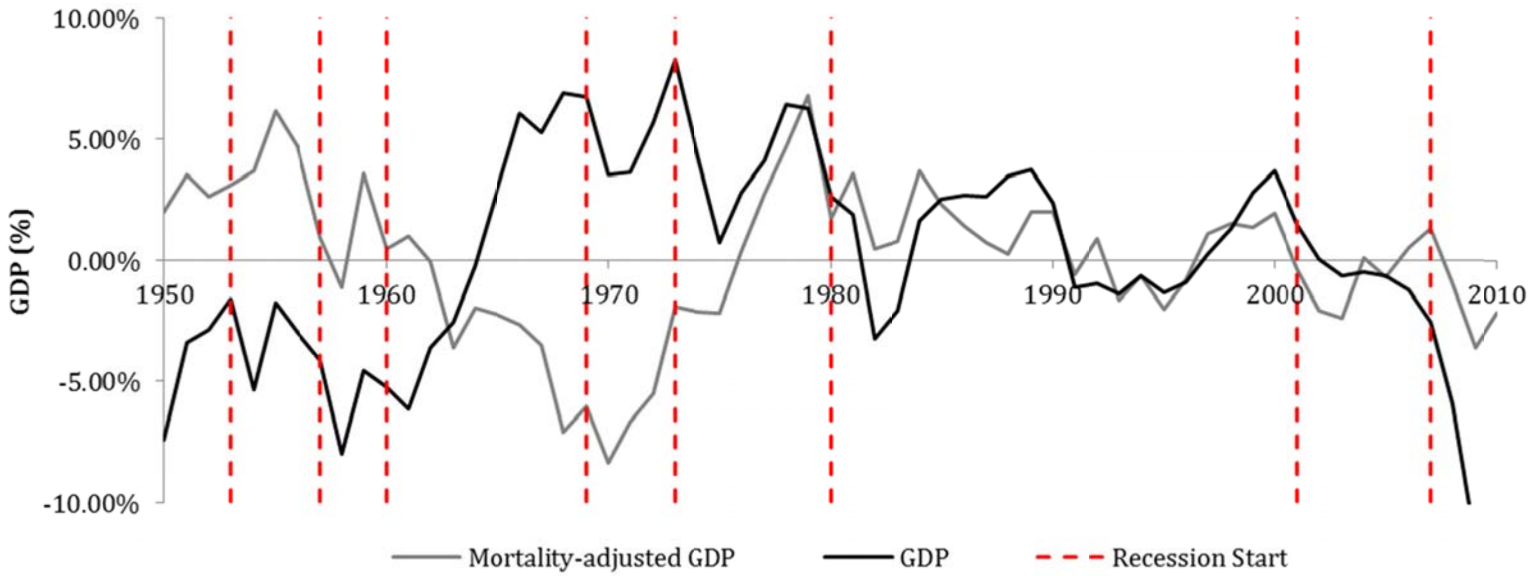
TABLE 3: VOLATILITY OF MEASURED OUTPUT

Measure	Std. Dev. of the Cycle	Std. Dev. of the Cycle	Std. Dev. of the Trend
GDP	4.42%	1.45%	4.07%
Mortality-adjusted GDP	3.12%	1.30%	2.63%
Log Linear Trend	X		
Hodrick Prescott Filter		X	X

Notes on Table 3:

- The cyclical and trend components of GDP and mortality $(y_t^C, y_t^T, m_t^T, m_t^C)$ are estimated using a log linear trend and the Hodrick Prescott Filter.
- The standard deviation of the trend component expresses the standard deviation of the trend (as calculated using the Hodrick Prescott Filter) about a linear time trend.
- Mortality-adjusted GDP is calculated using the age specific VSL estimates from Aldy and Viscusi (2008) described in Section 3.
- The data set spans 1950-2010 with annual observations

FIGURE 5: CYCLICAL COMPONENTS OF GDP AND MORTALITY-ADJUSTED GDP



Notes on Figure 5:

- The cyclical and trend components of GDP and mortality are estimated using a log linear trend.
- Mortality-adjusted GDP is calculated using the age specific VSL estimates from Aldy and Viscusi (2008) as described in Section 3.

5.3 Adjusting international fluctuations for health

This section extends the previous analysis for the U.S. to the twenty-one other industrialized countries. Our analysis confirms previous findings suggesting that the positive relationship mortality and GDP extends beyond the United States to other industrial countries though the relationship is fairly heterogeneous. Our results suggest that the implications of adjusting fluctuations for mortality may actually be more important for other parts of the industrialized world relative to the United States.

Previous research focused on the pro-cyclicality of mortality by examining the relationship between the mortality and unemployment rates across countries. Using panel data from 21 OECD countries, Gerdtham and Ruhm (2006) find that mortality rates are negatively correlated with unemployment rates. We find qualitatively similar results when examining the relationship between mortality and GDP overall though we find there is substantial heterogeneity across countries which reinforces the need for mortality adjustment in national accounts.

Using our panel of twenty-two countries over the period 1960-2010, we regress the log of a country's total mortality on log GDP while controlling for country time and fixed effects. The results of the regressions of log mortality on log GDP are displayed in table 4. Although the estimated relationship between log mortality and log GDP is positive in three specifications, and positive and significant in two of the specifications, the pooled country elasticity estimates are substantially lower than the corresponding U.S. estimates in table 2. We run additional specifications where we allow the effect of log GDP on log mortality to vary at the country level while still using country fixed and trend effects. The estimated mortality/GDP elasticity estimates are positive and significant for over half of the countries in the sample. However, the relationship between GDP and mortality is heterogeneous across countries with estimated elasticities ranging from -0.30 to 0.80.

TABLE 4: REGRESSION OF LOG MORTALITY ON LOG GDP

	(1)	(2)	(3)	(4)
Log GDP	0.0910*** (0.0143)	0.0525** (0.0239)	0.0051 (0.0316)	-0.0236 (0.0352)
Time Trend	X	X		X
AR(1) Correction		X		
First Differences			X	X

Notes on Table 4:

- Reported coefficients are the coefficients on log GDP. "AR(1) correction" indicates Prais-Winsten AR(1) regressions.
- One, two and three stars indicate significance at 10, 5 and 1 percent levels.
- All specifications include country specific dummy variables. When included, time trends are country specific
- Data for the Ireland, Israel and New Zealand covers the periods (1950-2010), (1970-2009), (1983-2009), and (1977-2008) respectively. Data for Austria, Denmark, France, Iceland, Sweden and the U.S. covers the period (1960-2010). Data for all other countries is from 1960-2009. Observations are annual.
- Countries were selected based on the availability (at least 25 continuous years) of mortality data from Mortality.org and population and GDP data from the World Bank.

Following Section 5.2, we formally decompose mortality-adjusted GDP and GDP into their trend and deviation from trend components for each country in our sample.[14] Figures 6-8 summarize the volatility of GDP as calculated using the two decomposition methods (log linear trend and the Hodrick Prescott Filter). The gray and black bars plot the standard deviation of the cyclical component of mortality-adjusted GDP and GDP respectively over the past fifty years. Since the trend component, as calculated as per the Hodrick Prescott Filter, fluctuates over time, we calculate the volatility of the trend component about a log

[14] Mortality-adjusted GDP is calculated using the gender and age specific VSL estimates from Aldy and Viscusi (2008) described in Section 3.

linear trend in figure 8. Mortality adjustment reduces the magnitude of deviations from a log linear trend for 17 of the 22 countries in the sample. However, when calculating a business cycle as per the Hodrick Prescott Filter, mortality adjustment reduces the variance of the cyclical component of GDP for only four of the countries in the sample. Figures 7 and 8 indicate that mortality adjustment appears to have a bigger impact on the volatility of the trend component of GDP relative to the cyclical component of GDP. This suggests that the low frequency procyclical movements in mortality are what helps buffer the business cycle. The international results indicate the importance of understanding the effect mortality and other unmeasured components of output have on fluctuations extends beyond the U.S.

FIGURE 6: VOLATILITY OF GDP VS MORTALITY-ADJUSTED GDP (LOG LINEAR TREND)

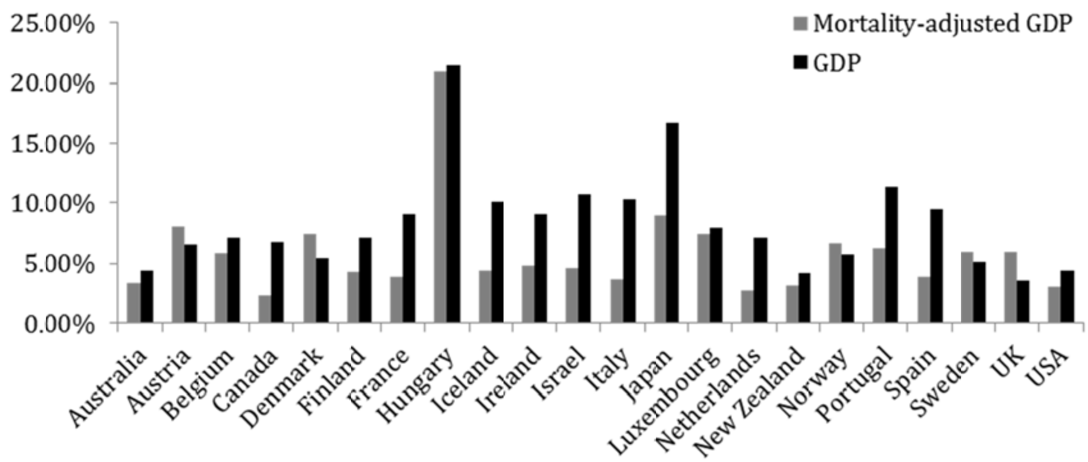


FIGURE 7: VOLATILITY OF GDP VS MORTALITY-ADJUSTED GDP (CYCLICAL COMPONENT –HP FILTER)

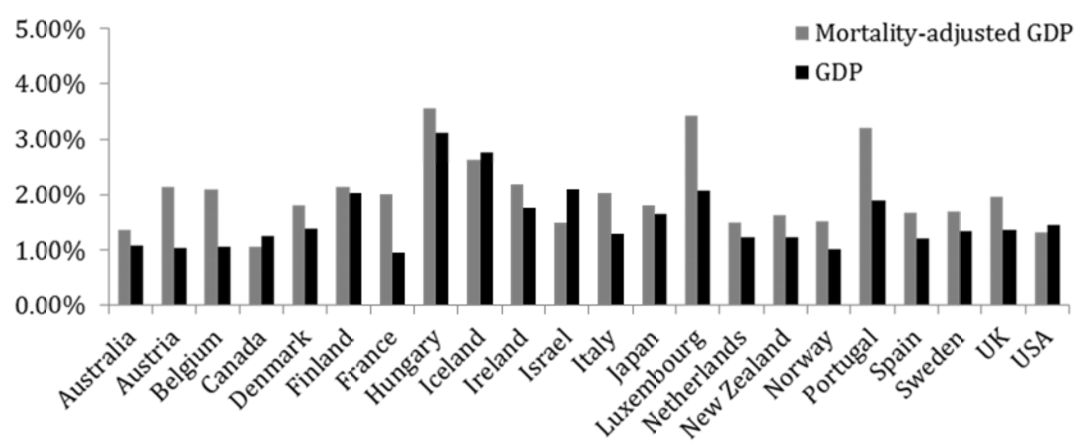
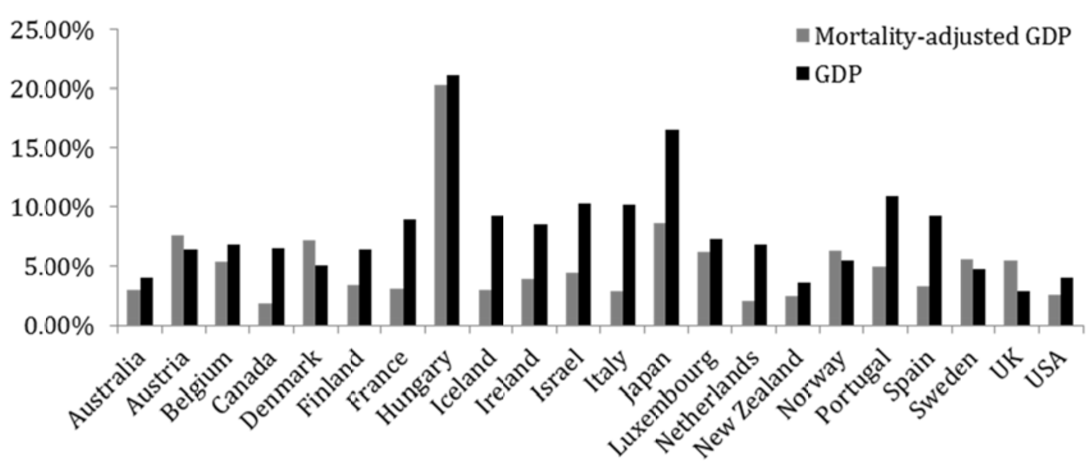


FIGURE 8: VOLATILITY OF GDP VS MORTALITY-ADJUSTED GDP (TREND COMPONENT –HP FILTER)



6. Concluding Remarks

We examined the macroeconomic fluctuations in the United States and globally during the past 50 years taking into account the depreciation of health (human capital) in GDP measures. Because mortality tends to be pro-cyclical, fluctuations in standard GDP are in part offset by human depreciation; booms are not as valuable because of greater mortality, and recessions are not as bad because of lower mortality. Consequently, the fluctuations in the United States and elsewhere appear milder than commonly measured. We found that many "recessions" during the past 50 years were not actually recessions, and that adjusting for mortality, on average, reduces the severity of both U.S. and international recessions by more than 2% of GDP and reduces measured fluctuations around trend by 30%.

Our analysis raises important issues for more fully incorporating human capital components into output measures. Our measure of mortality adjusted GDP only accounted for deaths, thereby implicitly only considering a diminishing rather than a potentially appreciating stock of human capital. Further analysis should consider replenishments of the stock in terms of fertility and immigration/emigration. It should also consider appreciation through human capital investments such as education. Previous empirical work remains inconclusive regarding the cyclicality of fertility rates given that they depend on counteracting income and substitution effects induced by the business cycle (Butz and Ward 1979; Mocan 1990; Ahn and Mira 2002). Incorporating births presents further challenges as it is not obvious how to incorporate the value of a new life. Does one include the parents' value, the child's, or both? Similar challenges exist in valuing net immigration in assessing the value of resident aliens versus citizens. Dellas and Sakellaris (2003) have documented the counter-cyclical nature of formal human capital investments. These should be incorporated into fluctuations measures as appreciation during recessions and thus may offset traditional measures, just as our mortality-based analysis did. Nevertheless, we view this effort as too speculative at this point both in methods and data availability, particularly so valuing newborns through potentially cyclical fertility. Furthermore, one may note here that our approach is consistent with current government practice in valuing human life, e.g.

in assessing EPA or FDA policies, which also only focuses on the value of the lives lost as opposed to valuing those still alive.

Future analysis should also consider the full life cycle of depreciation in human capital. Our analysis depreciated the human capital stock only at death, as opposed to depreciating or appreciating a life still not lost. Future research should also investigate whether gradual depreciation in human capital affects our results on how fluctuations in mortality and market GDP are correlated. For a given age-profile of the value of a human life, the analog to depreciation profiles of physical assets, one may envision valuing the current human capital stock based on the age distribution in the population. This will be contingent on morbidity patterns by age. Cyclical patterns in morbidity, for example caused by mental health or heart disease, may amplify fluctuations and should also be incorporated.

Our main argument is that there are clear ways of extending traditional measures of fluctuations and the effects of policies aimed at curbing them, beyond simply counting market transactions. More work is needed to make such extensions operational.

In general, the existing evidence on the cyclicality of human capital may suggest that unobserved components of value are also indeed counter-cyclical, in which case they reinforce rather than counteract the documented counter-cyclical value of health examined here. Examining the cyclicality of previously unmeasured components differs from previous research that has focused on missing components in the level of economic output. However, what matters for assessing the value of policies trying to mitigate fluctuations is not the level of the unmeasured components of output (such as leisure, health, and education, for example), but their cyclicality. If unmeasured components do not vary with the measured components, the much of the costs of fluctuations is captured by measured GDP. We believe, therefore, that more research is warranted on the quantitative importance of fluctuations in unmeasured components of national output.

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