

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

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Abstract:

National accounts of economic output and prosperity, such as gross domestic product (GDP) or net domestic product (NDP), offer an incomplete picture of economic well-being. Building on previous work to improve estimates of the *levels* of economic output at a given point in time, this paper proposes a new methodology to measure economic *fluctuations* over time that incorporates monetized changes in health. We apply the new methods to U.S. and global national accounts over the past 50 years. In particular, we incorporate into an expanded measure of GDP the dollar losses associated with mortality. We treat mortality and morbidity as depreciation of human capital analogous to how net domestic product (NDP) treats depreciation of physical capital. 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 costly because of lower mortality. Consequently, when the depreciation in health is monetized and incorporated into the business cycle, fluctuations in the United States and elsewhere appear milder than commonly measured. We find that several “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 results offer new perspectives on Keynesian style fiscal- and monetary policies intended to counteract the cycle: boosting output in recessions could generate another burst in mortality.

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), which nets out physical depreciation, 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 counter-cyclical 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 contrast to this literature on the trends in health and output, this paper is the first to 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.

To illustrate the quantitative magnitude of the value of mortality in a year and its potential impact on NDP measures incorporating human capital depreciation, consider 2010, when there were approximately 2.5 million deaths in the U.S. 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 depreciation of human capital of approximately \$22.5 trillion in 2010. The GDP of the U.S. that year was approximately \$15.8 trillion. Although there is ongoing debate regarding whether the magnitude of the monetary value of a life, and how it varies by age, the magnitudes of these back-of-the-envelope calculations suggest mortality is of first-order importance for NDP measures incorporating human capital depreciation.

We find that GDP and NDP measures for the U.S. and international fluctuations during the past 50 years are greatly altered by incorporating health depreciation. The main contributions of this paper are to provide a methodology by which mortality and morbidity can be incorporated into national accounts, showing that mortality is quantitatively important for dampening and even offsetting the business cycles around the world, and arguing that this raises new questions about the value of counter-cyclical fiscal and monetary policies.

Previous research documents that there exists a positive relationship between mortality and employment in the U.S. (Ruhm 2000) and internationally (Gerdtham and Ruhm 2006). In line with the previous literature, we find that mortality covaries positively with traditional GDP and NDP measures over time in a number of countries. We provide methods to monetize these counter-cyclical levels of health so that they can be incorporated into the business cycle. We find that accounting for health is quantitatively important and makes fluctuations in aggregate economic output look milder than traditionally presumed with GDP or NDP. In particular, we find that incorporating the value of mortality potentially even 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 roughly 30%.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 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

¹ Recent research (Arthi et al 2017) disputes the use of state-panel data, as in Ruhm 2000, to measure the cyclical mortality because of the difficulty with measuring and accounting for migration. Note that, in contrast to the state-panel studies, we are using national data and measuring the business cycle according to aggregate Gross Domestic Product.

² In addition to calculating mortality-adjusted GDP we also calculated mortality-adjusted NDP. We replicated the preceding 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.

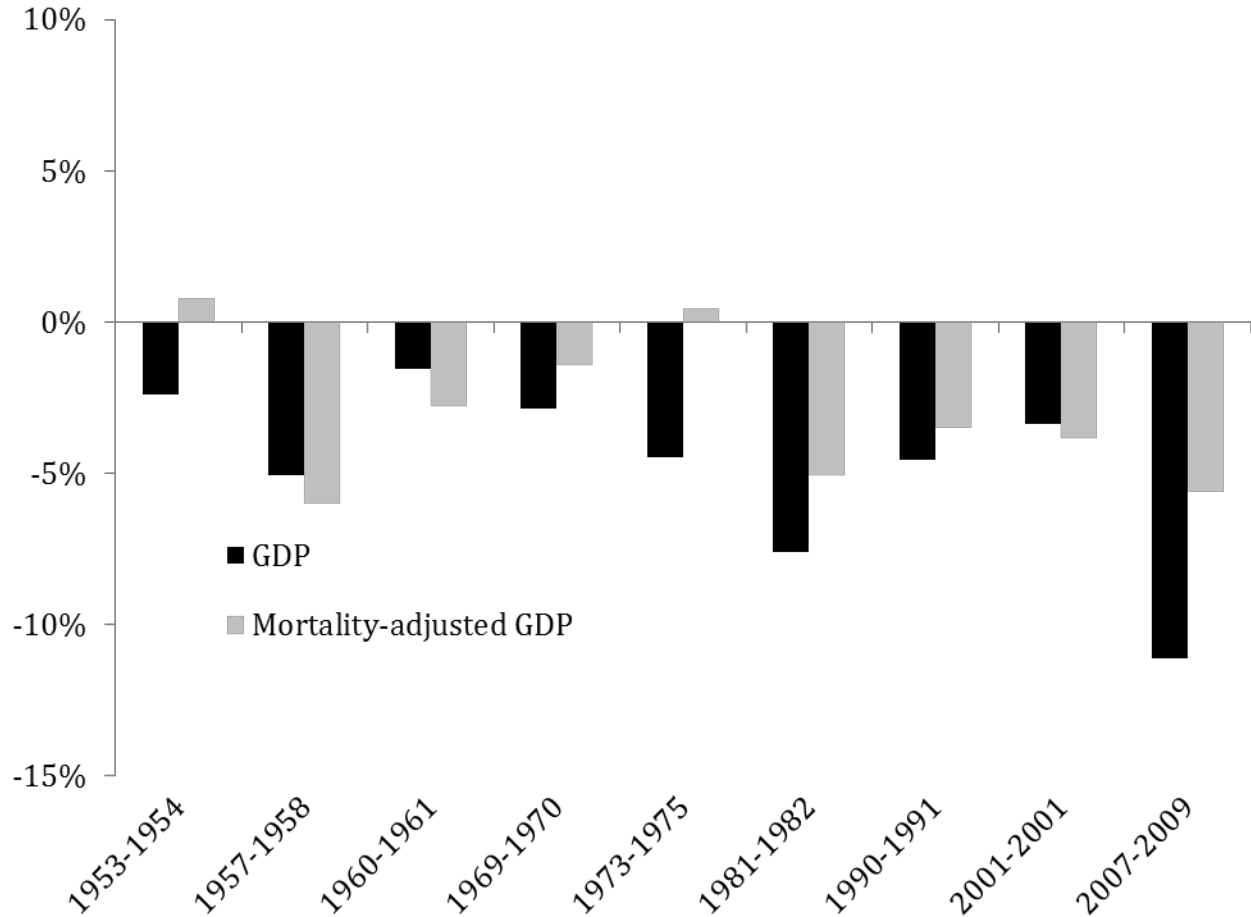
Economic Research (NBER 2013).³ Each bar represents the difference in actual output at the end of recession minus the implied trend output level between the years 1950 to 2010. In every recession other than in 1957, 1960 and 2001, adjusting for the value of mortality suggests that the total output fluctuations 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 the 1953 and 1973 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.

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 cyclicity of this unmeasured component 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 trends in gains in overall economic well-being in the United States. Becker et al. (2005) examined the impact of valuing health for world inequality and economic convergence. Jones and Klenow (2010) 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 deviations from trend are central to the business cycle and the value of counter-cyclical economic policy. Thus, we conclude by discussing how the counter-cyclical nature of health raises new concerns in evaluating counter-cyclical fiscal and monetary policy focused on GDP alone.

³ 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.

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



Notes: 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 using the average growth rates for the value of mortality and GDP over the period 1950-2010 as described in Section 4. Recessions are dated as per the NBER. Because our data is annual, we round NBER recession ending dates to the nearest year. 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 (VSL) estimates from Murphy and Topel (2006). The VSL in other years is scaled by trend per capita GDP as discussed in Section 3.

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 U.S. and abroad for human capital depreciation, looking at how peak-to-trough changes are affected. Section 5 provides estimates for how

the cyclical nature 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). 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 Theory and Practice

Part of traditional measures of economic activity over a specific time frame (hereafter, a calendar year) involves recognizing that 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 and water has been polluted or cleaned, etc. For many purposes it is desirable to have measures of economic activity that reflect the net change in the capital stock.

2.1 National Accounting for Physical Capital Depreciation

Not all of the nation's production is available for consumption or for adding to wealth because assets depreciate (with time or as part of the production process) and need to be replaced and maintained just in order to keep wealth constant. For this reason, national accounts include estimates of depreciation, which is the value of a year's destruction, aging, or economic obsolescence of pre-existing physical assets.⁴ In the expenditure account, the value of net additions to the nation's capital stock is found by subtracting depreciation from spending on investment goods. In the income account, the same depreciation (as used in the expenditure account) is excluded from the incomes of the owners of the factors of production. Either way, the resulting estimate of the total amount of production that is available for consumption or adding to wealth is Net (of depreciation) Domestic Product, or NDP (U.S. Bureau of Economic Analysis 2014a, p. 4).

⁴ The BEA defines depreciation as "the decline in value due to wear and tear, obsolescence, accidental damage, and aging." (Fraumeni, 1997).

Consider a couple of examples. Homes physically depreciate and their features become economically obsolete with time. Owners of these assets deal with this reality by periodically renovating their residential properties. Home improvement spending plus the construction of new homes is gross investment in homes, and thereby part of GDP (U.S. Bureau of Economic Analysis, 2014b, p. 6-2). The change in the stock of homes during the year is the difference between gross investment in homes and the depreciation of homes. Another example would be the capital stock of a rental-car business. The business' fleet of vehicles depreciates with time as customers use it. The rental-car business involves regularly updating the fleet by acquiring new vehicles and fixing or retiring old ones. The net addition to the fleet is the difference between purchases of new vehicles and the depreciation of the fleet.⁵ When it comes to physical assets, at least, these distinctions are enormous: in 2013, for example, net private domestic investment was only 20% of gross private domestic investment (U.S. Bureau of Economic Analysis, various issues, Table 5.2.5).

To formalize this, we begin by considering a cohort of assets: that is, all assets of the same type born at the same calendar time. All cohort members are the same, except in terms of the length of their lifetime. The probability an asset survives and remains functional until age a is given by the survival function $S(a)$. In continuous time, we let $m(a)$ denote the density of the cohort's survival function $S(a)$.

$$S(a) = \int_a^{\infty} m(x)dx$$

with $S(0) = 1$. Note that $m(a)$ does not have to be monotonic over time and could, for example, be correlated with the business cycle.

Each asset still in service at age a yields a service flow $b(a) \geq 0$. $b(a)$ tends to decline with age as assets become less efficient, more obsolete, or require more maintenance

⁵ Routine automobile maintenance expenditures such as cleaning and oil changes are a national accounting gray area (United Nations 2009, p. 609) because in practice "Gross" Domestic Product is itself net of some activities such as routine maintenance; subtracting routine maintenance from measured GDP would thereby duplicate a subtraction.

expenditure. We let $v(a)$ denote the present value, *conditional on survival* to age a , of an age- a asset's anticipated service flows. It is calculated from the service flow, discounted at rate $r > 0$:

$$v(a) = \frac{\int_a^\infty \left[\int_a^x e^{-r(z-a)} b(z) dz \right] m(x) dx}{S(a)} \quad (1)$$

where the square-bracket term is the age- a present value of the remaining service flow of an asset that lasts exactly x units of time. For the purposes of national accounting for physical capital depreciation, $v(a)$ is naturally interpreted as the market price of an age- a asset that is still in service, which implicitly invokes the additional assumption that market values are present values of service flows. However, as we explain below, this additional assumption is not required for our analysis.

It is important to recognize the distinction between age-value profiles v and age-efficiency profiles b , which Hulten and Wykoff (1981) describe as “the most misunderstood relationship in all of depreciation theory.” For example, the service $b(a)$ can decline monotonically with age but nonetheless the conditional value profile $v(a)$ need not decline monotonically.

The cohort's depreciation is defined to be the decline in the cohort's aggregate value, including retirements from service. Formally, depreciation is $-\frac{d}{da} [S(a)v(a)]$.⁶ By the product rule of calculus, this depreciation can be understood as the sum of two terms:

$$-\frac{d}{da} [S(a)v(a)] = m(a)v(a) - S(a)v'(a) \quad (2)$$

The nonnegative first term is a charge $v(a)$ for each cohort member that was retired from service at age a . The second term reflects movements along the conditional value profile by each of cohort member who survives beyond age a . The second term may partially offset

⁶ Hulten and Wykoff (1981).

the first term, but cannot fully offset it because the aggregate value cannot increase with age.

By definition, the cohort's total depreciation, summed (without discounting) over all members and ages, is the total initial value: $S(0)v(0) = v(0)$. Moreover, even though cohort members differ in terms of the age that they are retired from service, they all have the same lifetime total depreciation. Equation (2) shows how they differ in the timing of that depreciation, with early-retiring members taking depreciation charges earlier in time.

Equation (2) is an identity that is also useful for measurement purposes. Scaled up by the size of the cohort, $m(a)$ and $S(a)$ are numbers of assets, which means that (2) readily aggregates across cohorts to obtain national measures of depreciation. As long as we calculate each of the two terms cohort-by-cohort, there is no need to assume that the survival and service values are the same for each cohort.

The BEA's ideal method for measuring the depreciation of physical assets is to infer an age-aggregate-value profile $S(a)v(a)$ from purchase price and survival data in a well-functioning resale market for used assets (Fraumeni 1997). Depreciation over the year would then be inferred by moving 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, and all automobiles survive that year, then automobiles would be assumed to depreciate 10 percent during their second year.⁷

2.2. A proposal for human capital depreciation

Previous work has argued that there are valuable human and environmental assets and that, in principle, their accumulation and depreciation should be counted too (Hartwick 1990, Nordhaus and Kokkelenberg 1999, Jorgenson 2009). Human and environmental capital data has traditionally been lacking, but progress has been made by including, for example, environmental depreciation in measures of economic activity

⁷ In terms of our equation (2), this example has a zero mortality term; only the second term is contributing to depreciation during the year.

(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.

This paper develops methods and estimates for human assets using readily available data. GDP already includes spending on healthcare and education, which are ways of investing in or maintaining and adding to human assets. But in order to better estimate the part of GDP that is available for consumption and additions to wealth, we have to subtract human asset losses – “depreciation” – that occur during the year. The subtraction would be especially important for cyclical analysis to the extent that an economic expansion involves abnormal losses coincident with the extra economic activity.⁸

Now consider the loss in value $-\frac{d}{da}[S(a)v(a)] = m(a)v(a) - S(a)v'(a)$ when interpreted as a human capital stock. Recall that $v(a)$ accounts for a service flow $b(a)$ that may decline with age, which in the human-capital application refers to morbidity (the loss of life quality due to injury or disease). Note that the loss in value of retiring assets in the first term depends on the future of the service flow. For a health stock this means that the loss due mortality will depend on future morbidity, e.g., the value of a remaining old age life with Alzheimer’s may be lower than one without it. However, morbidity still enters into the total loss through the second term concerning the change in present value of flows of non-retired assets. A morbidity event contributes to the second term in equation (2) as a more negative (less positive) slope for $v(a)$.

We implement equation (2) for human capital by (i) taking $v(a)$ as the value-of-life profiles constructed in the literature, such as by Murphy and Topel (2006) and Aldy and Viscusi (2008), and (ii) using actual cohort-year-specific mortality rates. Thus, depreciation takes out the present value of all future living for those who die and the change in that present value for those who survive.

⁸ We do not attempt to form a time series of human capital, which would require an accurate distinction between consumption and investment, but rather to understand the timing of economic activity.

In practice, the Aldy-Viscusi measure captures an age-morbidity pattern, as experienced and anticipated by workers, because their measurement accounts for an age-specific willingness to take mortal risks.⁹ However, while we have cohort- and year-specific mortality data to measure $m(a)$, we do not have cohort- and year-specific value of life profiles $v(a)$. With year specific value of life profiles, one could examine how $v(a)$ varies with the business cycle due to changes in morbidity, medical innovation, or more generally knowledge human capital (Ehrlich 2007). Because we do not have year/cohort specific $v(a)$ profiles that would account for cyclical changes in morbidity, we use additional information to assess whether there are significant year-specific morbidity events (i.e., whether morbidity is correlated with the business cycle).

3. Constructing Mortality- and Morbidity-adjusted GDP Series

3.1 Mortality and aging adjustments by themselves

We define mortality-adjusted GDP (N_t) as a net output measure taking the value of GDP (Y_t) net of human capital depreciation. The depreciation is, as discussed, due to the value of lost life/mortality (M_t) and the value (A_t) lost to aging over the corresponding period.

$$N_t = Y_t - M_t - A_t$$

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: that is, the mv term in equation (2). A_t denotes the movement down the age-life-value profile for people who did not die during year t : that is, the Sv' term in equation (2).

⁹ Murphy and Topel also have an age-specific service flow to the extent that labor income varies by age. Note that, assuming that either Aldy-Viscusi or Murphy-Topel have correctly estimated the age-profile of service flows, we can treat the v equation (@) as a definition and therefore do not have to assume that v would be the value that would prevail in a resale market.

Our interest is in changes over the business cycle, as distinct from secular changes such as aging of a population that may coincide with the cycles. We use the usual statistical techniques – time trends and filters – to help make the distinction, but only after using any available and reliable measures of the secular changes themselves. In particular, we follow much of the literature on mortality and adjust for changes in the population-age distribution. M_t and A_t are therefore measured as:

$$M_t = \left(\sum_{age,g} \frac{death_{age,g,t}}{pop_{age,g,t}} VSL_{age,g,t} s_{age,g,2000} \right) \left(\sum_{age,g} pop_{age,g,t} \right)$$

$$A_t = \left(\sum_{age,g} (VSL_{age+1,g,t} - VSL_{age,g,t}) s_{age,g,2000} \right) \left(\sum_{age,g} pop_{age,g,t} \right)$$

where the subscripts are age, gender and year. We refer to these as “population-age-adjusted” because the each of year t ’s death and aging terms is weighted by the age distribution in the year 2000 rather than year t .

We use two methodologies to measure equation (1)’s $v(a)$, which the literature refers to as the “Value of a Statistical Life” (VSL). 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 18-62.¹⁰ We extrapolate their estimates for the non-working age populations. 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).¹¹ For individuals under the

¹⁰ See section IV of Aldy and Viscusi 2008 for further details.

¹¹ Viscusi and Hersch (2008) treat VSL as the discounted constant stream of future VSLY, which is $b(a)$ in our notation. Using the VSL estimates from Aldy and Viscusi (2008) we calculate the VSLY at age t as

$$VSLY(t) = \frac{0.03 VSL(t)}{1 - (1.03)^{-L(t)}}$$

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 0.03 is the discount rate assumed for the purposes of inferring VLSY from VSL. We construct the VSL for ages 63+ using the implied VSLY for 62 year olds.

age of 18, we assume a constant VSL of \$3.43mm (which corresponds to the estimated VSL for 18 year olds).¹² 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.

The 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. As a robustness check, we reconstruct Figure 1 using the VSL profile from Aldy and Viscusi scaled by one half. We find that adjusting for mortality still reduces the average measured severity of a recession by more than one percentage point. It should be further noted that these valuation 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 depreciation conditional on age.

¹² As a robustness check, we replicate the preceding analysis by assuming a VSL of zero for individuals 0-17 and find quantitatively similar results.

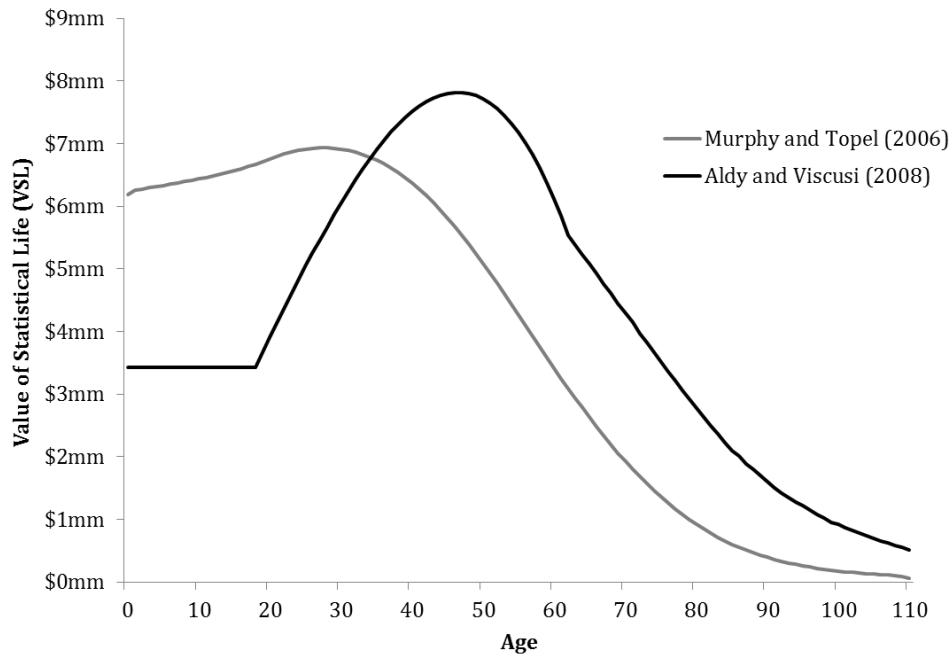
Both the Aldy and Viscusi and Murphy and Topel age-VSL profiles are calibrated to the year 2000. To calculate the value of life in other years we simply scale the VSL by the trend GDP per capita in the given year relative to the trend GDP per capita in 2000.¹³ This empirical implementation implicitly assumes the elasticity of VSL with respect to trend income is one and that VSL has no business cycle (more on this below).¹⁴ . A result of our empirical implementation is the terms $VSL_{age,g,t} \left(\sum_{age,g} \square pop_{age,g,t} \right)$ that appear in the definition M_t and A_t are acyclical by construction.¹⁵ This implies that (i) our measures of A_t are acyclical by construction and (ii) cyclical fluctuations in our measured M_t are driven by cyclical fluctuations in the death rate $\frac{death_{age,g,t}}{pop_{age,g,t}}$.

¹³ Trend GDP is calculated using the Hodrick Prescott Filter with a smoothing parameter of 6.5. We find qualitatively and quantitatively similar results if we calculate trend GDP using a log linear trend..

¹⁴ 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). See the U.S. Department of Transportation Memorandum (2013) for further discussion regarding the elasticity of the VSL with respect to income.

¹⁵ Notice that $VSL_{age,g,t} pop_t = VSL_{age,g,2000} \frac{Y_t^T}{Y_{2000}^T} pop_{2000}$, where Y_t^T is trend GDP. Thus, by construction the term $VSL_{age,g,t} pop_t$ will not vary with the business cycle.

FIGURE 2: VALUE OF A STATISTICAL LIFE BY AGE



Notes: 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).

3.2. Adjusting for both Mortality and Morbidity

In principle, the $v(a)$ and $v'(a)$ terms in equation (2) could vary over the business cycle, but our VSL measures cannot capture that variation because the profiles are taken from a single study. If, say, during an expansion more workers received serious (but not fatal) injuries then a healthy age- a worker's life may be worth less at the beginning of the expansion than at the end of it because of the increased risk of contracting a non-fatal disease. At the same time, the morbidity component of human depreciation $-v'(a)$ could be greater as more people contracted the disease, or less as people with the disease were less

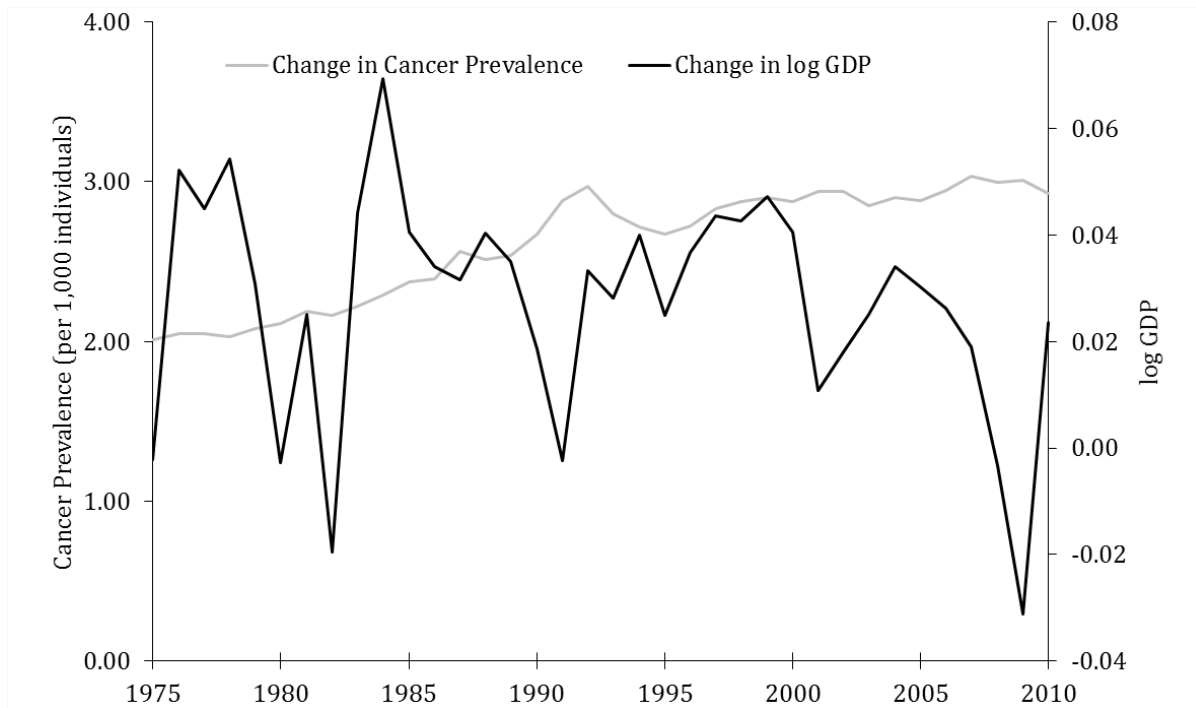
likely to survive. An important empirical question is therefore whether disease prevalence *changes* are cyclical.¹⁶

We do not have sufficiently long time series for the nationwide prevalence of the many diseases from which people suffer. But cancer is an important disease for which incidence and prevalence have been consistently measured by the National Cancer Institute from 1975 to the present, which includes four recessions. As shown in the graph below, cancer prevalence changes do not follow a business cycle. The correlation between the changes in cancer prevalence and changes in log GDP is -0.18 and is statistically insignificant ($p=0.28$).¹⁷

¹⁶ Note that the previous work on the cyclicity of mortality can be interpreted as measuring the cyclicity of *changes* in prevalence of a particular “disease” – namely being dead. The only conceptual difference between death and other diseases in our framework is that there is no exit from death, whereas people exit other diseases via cures or by entering death.

¹⁷ The most substantial high-frequency change occurs circa 1990, which is almost entirely prostate cancer, for which we believe diagnosis methods were changing rather than the true prevalence of the condition. The correlation between the changes in cancer prevalence excluding prostate cancer and changes in log GDP is -0.09 and is statistically insignificant ($p=0.59$).

FIGURE 3: CANCER PREVALENCE



Notes: Cancer prevalence data is from the National Cancer Institute’s Surveillance, Epidemiology, and End Results Program. For each year the change in cancer prevalence is computed as the age adjusted incidence of cancer minus cancer related deaths in the corresponding year.

The cancer data therefore support our assumption, required based on the available data, that A_t does not have a cyclical component. But further measurement of the business cycle of morbidity is a good topic for future research; this paper at least offers a conceptual framework for processing new morbidity data when it becomes available.

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 mortality-adjusted GDP at the end of a recession (N_t) minus its trend value for that year (N_t^T). In order to compare it with more familiar traditional-GDP gaps, our mortality-adjusted GDP gap is normalized by the trend level of traditional GDP for the same year. Specifically we calculate peak to trough for mortality-adjusted GDP as

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

Trend mortality-adjusted GDP is computed as

$$\begin{aligned} N_t^T &= Y_{t-\tau}(1 + \overline{\Delta\%Y})^\tau - M_{t-\tau}(1 + \overline{\Delta\%M})^\tau - A_{t-\tau}(1 + \overline{\Delta\%A})^\tau \\ &= Y_{t-\tau}(1 + \overline{\Delta\%Y})^\tau - M_{t-\tau}(1 + \overline{\Delta\%M})^\tau - A_t \end{aligned}$$

where $Y_{t-\tau}$, $M_{t-\tau}$, and $A_{t-\tau}$ are the pre-recession levels of GDP and the value of mortality, $\overline{\Delta\%Y}$, $\overline{\Delta\%M}$, and $\overline{\Delta\%A}$ are the average growth rates of traditional GDP, the value of mortality, and the annual lost value of those who remain alive, respectively, over the period 1950-2010. τ is the length of the recession.¹⁸ The second equality above confirms that our measure of A_t does not deviate from its trend and therefore contributes nothing to the peak-to-trough calculation.¹⁹

Figure 1 is calculated using the Murphy and Topel (2006) age-VSL profile while Figure 3 is calculated using the age and gender specific VSL estimates from Aldy and Viscusi (2008). Under both measures, mortality adjustment essentially negates the 1953 and 1973 U.S. “recessions”. Due to the comparability of the results and for convenience, the remaining analysis is conducted using the Murphy and Topel age-VSL profile.

¹⁸ The peak to trough calculations for unadjusted GDP are calculated in an analogous manner.

¹⁹ Recall that our measure of aggregate A changes over time only to the extent that the product of VSL and population does. But, by construction, that product only follows the trend for aggregate (traditional) GDP.

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

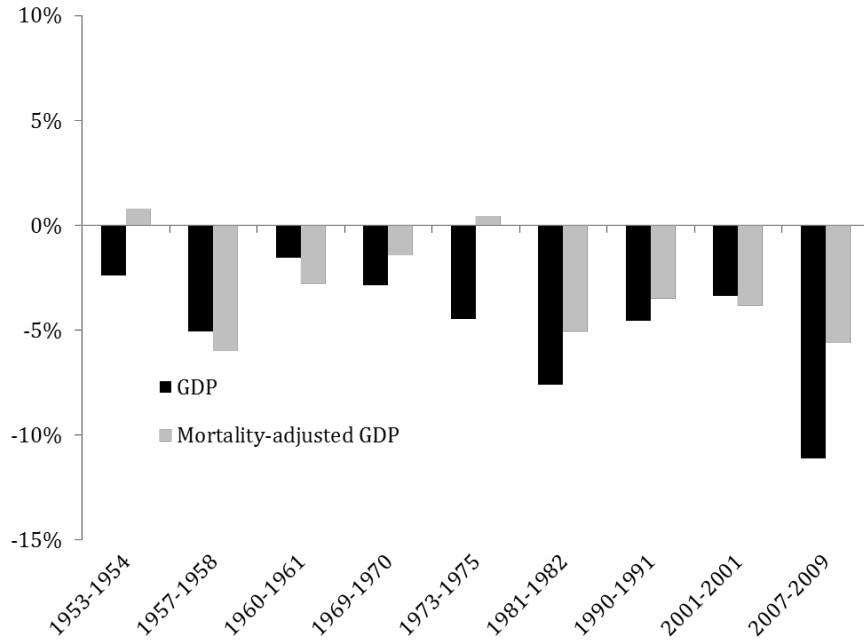
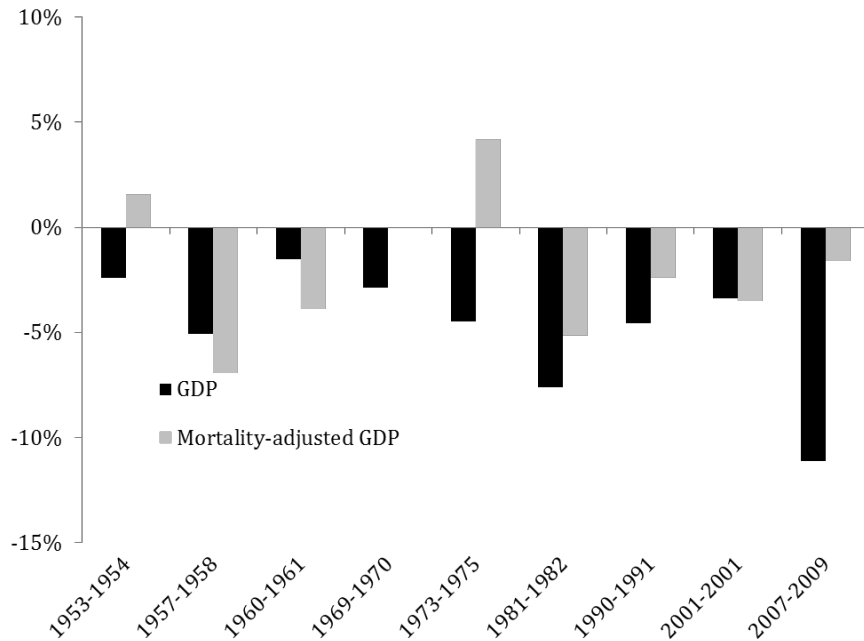


FIGURE 4: RECESSION – PEAK TO TROUGH (% OF GDP)



Notes: 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, using the average growth rates for the value of mortality and GDP over the period 1950-2010. We compute the value of aging and mortality using the VSL estimates from Murphy and Topel (2006) in Figure 1 and Aldy and Viscusi (2008) in Figure 3. Recessions are dated as per the NBER. Because our data is annual, we round NBER recession ending dates to the nearest year.

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)²⁰. The value of mortality is calculated across countries by scaling Aldy and Viscusi's (2008) VSL estimates by trend GDP per capita²¹

$$VSL_{a,i,t} = VSL_a^{AV} \frac{GDPPC_{i,t}}{GDPPC_{US,2000}}$$

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 Murphy and Topel (2006). 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 5 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 1.65% 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. Overall, we find that adjusting for mortality reduces the depth of the recession, on average, by over two absolute percentage points of GDP.

²⁰ Peaks are defined as the year preceding a year over year decline in real per capita GDP with the year(s) preceding 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.

²¹ Trend GDP is calculated using the Hodrick Prescott Filter with a smoothing parameter of 6.5

FIGURE 5: RECESSION – PEAK TO TROUGH (% OF GDP)

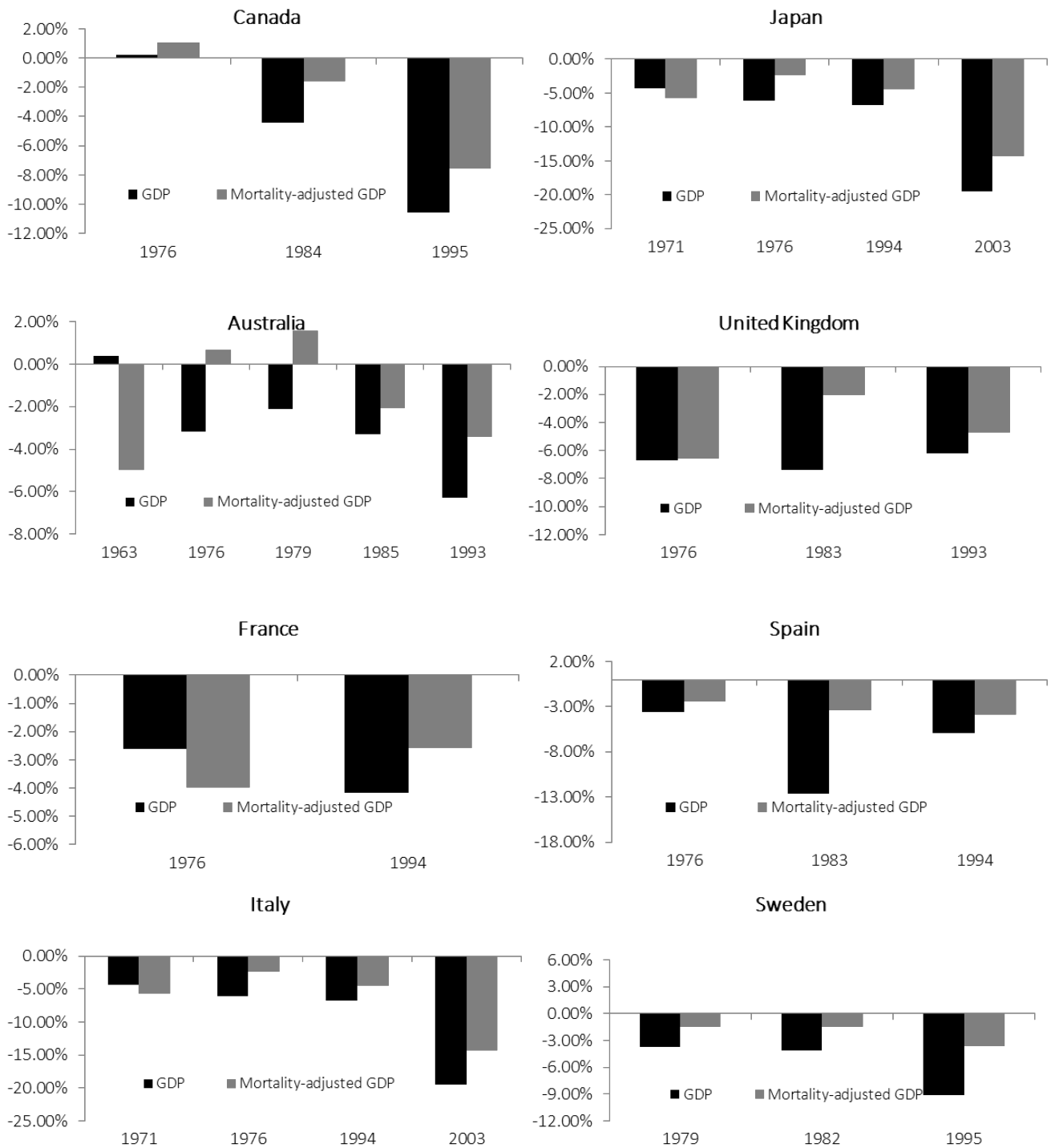


TABLE 1: AVERAGE RECESSION DEPTH (AVERAGE PEAK TO TROUGH, % OF GDP)

Country	GDP	Mortality-adjusted GDP (Age Specific VSL)
Australia	-2.90%	-1.65%
Austria	-2.34%	-2.11%
Belgium	-3.42%	-2.75%
Canada	-4.93%	-2.70%
Denmark	-1.40%	-2.75%
Finland	-8.35%	-1.51%
France	-3.40%	-3.30%
Hungary	-5.65%	-1.45%
Iceland	-6.21%	-4.45%
Ireland	-2.90%	-1.49%
Israel	-9.06%	-8.33%
Italy	-3.47%	-2.96%
Japan	-9.13%	-6.72%
Luxembourg	-9.99%	-6.46%
Netherlands	-3.82%	-3.56%
New Zealand	-1.09%	0.45%
Norway	-4.72%	-3.61%
Portugal	-8.52%	-3.75%
Spain	-7.38%	-3.23%
Sweden	-5.67%	-2.20%
U.K.	-6.74%	-4.43%
U.S.	-3.41%	-1.87%

Notes for Table 1 and Figure 5: 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, using the average growth rates for the value of mortality and the GDP over the period 1950-2010. 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 in the text. 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 Cyclicity 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 build on the existing literature showing that there is a positive relationship between mortality and the business cycle in the U.S. and internationally. We then incorporate these estimates into adjusting the cyclicity 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 build on 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 find similar evidence suggesting 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 (number of deaths) 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: Each age group coefficient is estimated in a separate regression with log age-group mortality (number of deaths) 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

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

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

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

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

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 $\ln Y_t$ and $\ln M_t$ on a time trend to recover the cyclical and trend components of both GDP as

well as value of mortality.²² We also estimate the cyclical and trend components of GDP and mortality using the Hodrick Prescott filter.

Figure 6 plots the estimated cyclical components of mortality-adjusted GDP and GDP as a fraction of trend GDP, denoted NY_t^C and YY_t^C respectively.

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

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

Overall, the two series exhibit a strong negative correlation over the past fifty years, especially prior to 1980. After 1980, the two cyclical series exhibit some positive correlation which is in line with the recent findings of Ruhm (2013) and McInerney and Mellor (2012) which suggests the pro-cyclical nature of mortality may be changing over time. As a robustness check, in Appendix Tables A1 and A2 we re-examine the relationship between mortality and GDP pre and post 1980. We find qualitative evidence suggesting that the relationship between total mortality and GDP is weaker after 1980, but it is not statistically different from the pre 1980 period. One of the key takeaways from Figure 6 is that the cyclical component of GDP appears more volatile than that of mortality-adjusted GDP. Statistically speaking, the measured volatility of GDP is almost 1.5 times that of mortality-adjusted GDP, 4.42% relative to 3.04%.

²² Formally, we assume that y_t^C and m_t^C are normally distributed such that

$$\ln Y_t = y_t^T + y_t^C = a_y + b_y t - \text{Var}(\varepsilon_y^C)/2 + \varepsilon_{y,t}^2$$

$$\ln M_t = m_t^T + m_t^C = a_m + b_m t - \text{Var}(\varepsilon_m^C)/2 + \varepsilon_{m,t}^2$$

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

$$\widehat{y}_t^C = \widehat{\varepsilon}_{y,t}^C - \text{Var}(\widehat{\varepsilon}_y^C)/2$$

$$\widehat{y}_t^T = \widehat{a}_y + \widehat{b}_y t$$

$$\widehat{m}_t^C = \widehat{\varepsilon}_{m,t}^C - \text{Var}(\widehat{\varepsilon}_m^C)/2$$

$$\widehat{m}_t^T = \widehat{a}_m + \widehat{b}_m t$$

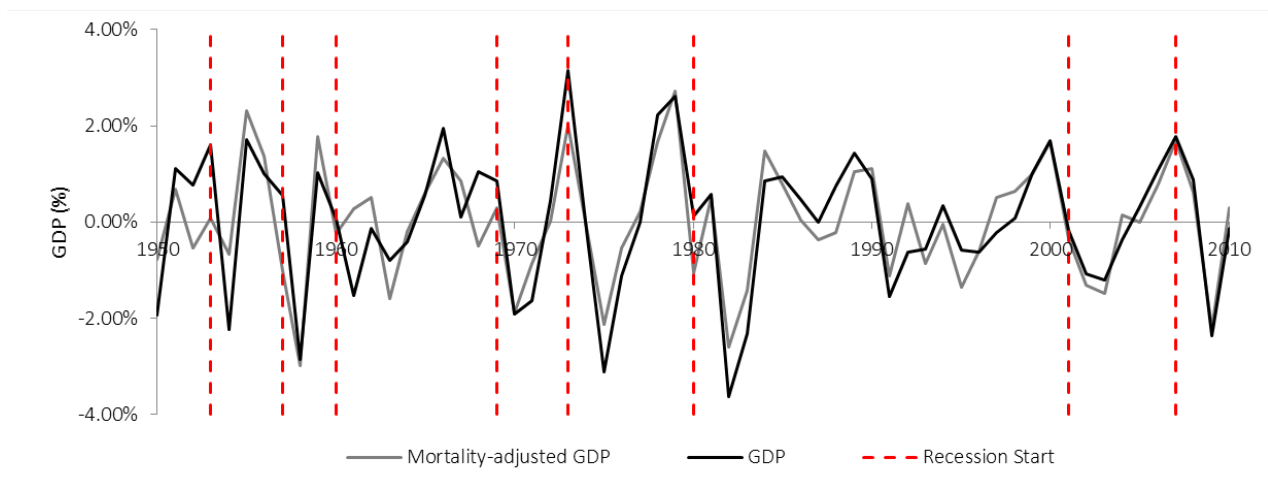
As a robustness check, we re-compute the cyclical components of mortality-adjusted GDP and GDP using the Hodrick Prescott Filter rather than a log linear trend. Figure 7 plots Hodrick Prescott Filter estimated cyclical components of mortality-adjusted GDP and GDP as a fraction of GDP. As in Figure 6, the cyclical component of mortality-adjusted GDP is less volatile than GDP (1.21% vs 1.41%). Two key differences between Figures 6 and Figures 7 are worth noting. First, both the cyclical component of mortality-adjusted GDP and GDP are smaller when computed the using the Hodrick Prescott Filter relative to using a log linear trend. Second, mortality adjustment has a smaller impact on the cyclical component of GDP when computed using the Hodrick Prescott Filter. These two differences result from how trend GDP and mortality-adjusted GDP are computed. As illustrated in Appendix Figures A-1 and A-2, the Hodrick Prescott Filter treats some of the lower frequency movements in GDP and the value of mortality as part of the trend while the log linear trend method treats these lower frequency movements as part of the cycle. This is particularly relevant when computing the trend/cyclical component of mortality. The Hodrick Prescott Filter treats the major fluctuations in the value of mortality occurring in the 1960s through the 1980s as part of the trend rather than the cycle. Neither approach is necessarily “better” than the other; rather it depends on how the researcher wishes to define the trend.

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.

FIGURE 6: CYCLICAL COMPONENTS OF GDP AND MORTALITY-ADJUSTED GDP (LOG LINEAR TREND)



FIGURE 7: CYCLICAL COMPONENTS OF GDP AND MORTALITY-ADJUSTED GDP (HP FILTER)



Notes: The cyclical and trend components of GDP and mortality in Figure 6 are estimated using a log linear trend. The cyclical and trend components of GDP and mortality in Figure 7 are estimated using the Hodrick Prescott Filter. Mortality-adjusted GDP is calculated using the age specific VSL estimates from Murphy and Topel (2006) as described in Section 3.

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%	1.41%	3.98%
Mortality-adjusted GDP	3.04%	1.21%	2.60%
Log Linear Trend	X		
Hodrick Prescott Filter		X	X

Notes on Table 3: The cyclical and trend components of GDP and mortality ($y_t^C, y_t^T, m_t^C, m_t^T$) 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 Murphy and Topel (2006) described in Section 3. The data set spans 1950-2010 with annual observations.

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, each cross-country estimate is 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.

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.²³ Figures 8-10 summarize the volatility of GDP as calculated using the two decomposition methods. 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 linear trend in Figure 10. Mortality adjustment reduces the magnitude of deviations from a log linear trend for each country in our 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 eight of the countries in the sample. Figures 9 and 10 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 pro-cyclical 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.

TABLE 4: REGRESSION OF LOG MORTALITY ON LOG GDP

	(1)	(2)	(3)	(4)
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²³ Mortality-adjusted GDP is calculated using the gender and age specific VSL estimates from Aldy and Viscusi (2008) described in Section 3.

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: 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.

FIGURE 8: VOLATILITY OF GDP VS MORTALITY-ADJUSTED GDP (LOG LINEAR TREND)

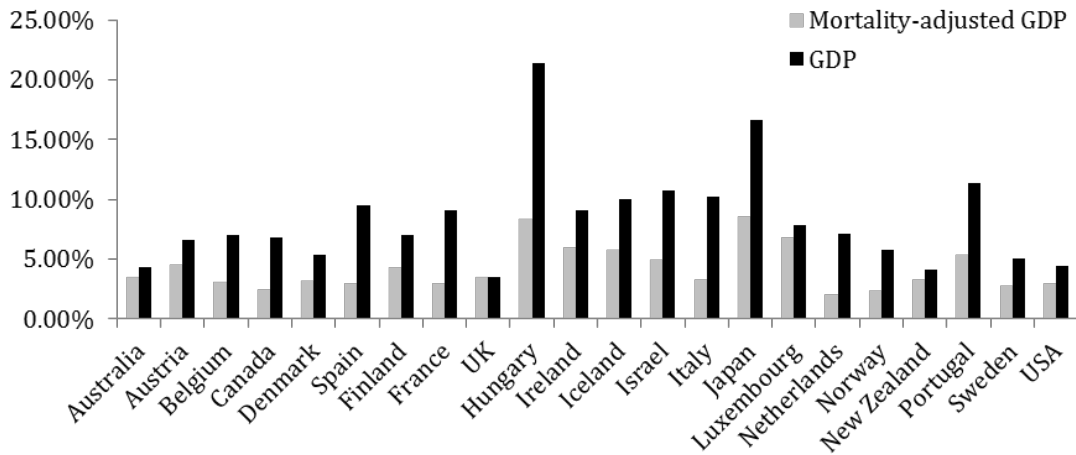


FIGURE 9: VOLATILITY OF GDP VS MORTALITY-ADJUSTED GDP (CYCLICAL COMPONENT –HP FILTER)

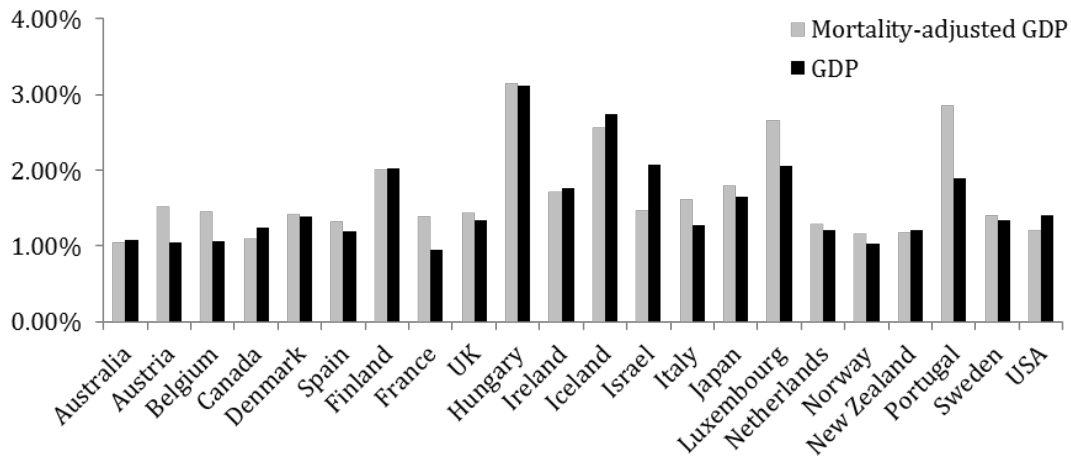
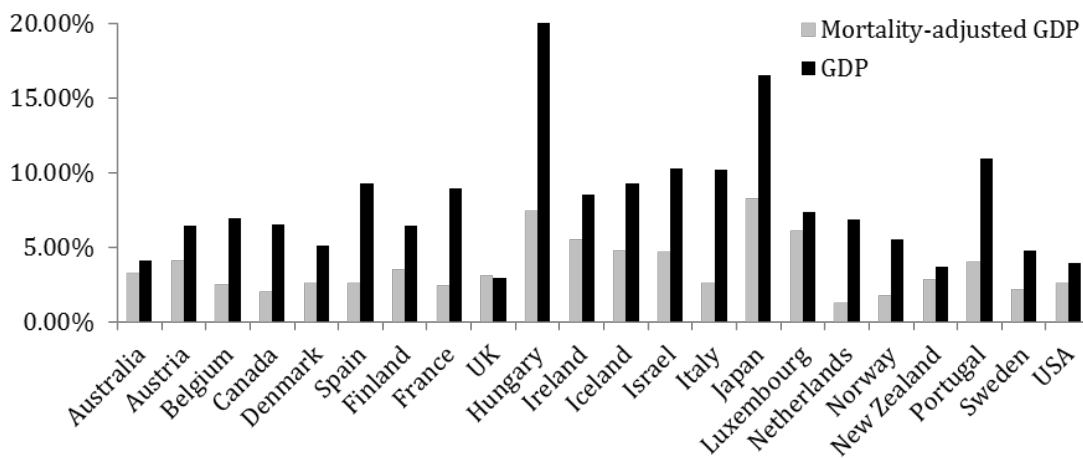


FIGURE 10: VOLATILITY OF GDP VS MORTALITY-ADJUSTED GDP (TREND COMPONENT –HP FILTER)



6. Concluding Remarks

This paper examines the macroeconomic fluctuations in the United States and globally during the past 50 years taking into account the depreciation of health in GDP measures, treating it analogously to depreciation in physical capital. 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 costly because of lower mortality. Consequently, when the depreciation in health is monetized and incorporated into the business cycle, 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 roughly 2 percentage points 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 in many different ways. We constructed a measure that accounts for changes in mortality and morbidity and showed that accounting for health changed the volatility of overall economic output. Although our measures emphasize mortality more than morbidity, previous research suggests that accounting for morbidity and other non-fatal aspects of health could also produce quantitatively meaningful effects on economic output levels and fluctuations. Ruhm (2005) finds that evidence suggesting that individuals live healthier lifestyles, smoke less, and gain less excess weight, during economic downturns.²⁴ Previous research indicates that other dimensions of well-being such as mental health (Ruhm 2000, Charles and Decicca 2008) and binge drinking (Dee 2001, Xu 2013) worsen during economic downturns. We examine the cyclicity of one major source of morbidity, cancer, and find evidence suggesting that it is acyclical. More research regarding the cyclicity of morbidity and, perhaps more importantly, its quantitative importance for business cycle analysis is warranted.

²⁴ However, other research suggests that weight gain may be pro-cyclical (Böckerman et al. 2007, Charles and Decicca 2008, Latif 2014).

In addition, our measure of mortality-adjusted GDP excludes some of the factors that may be augmenting the stock such as fertility and immigration. It should also consider changes in skill/knowledge human capital (Ehrlich 2007) such as appreciation in human capital through investments such as education and on the job training or depreciation in human capital due to unemployment and displacement. Previous empirical work remains inconclusive regarding the cyclicity 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). Dellas and Sakellaris (2003) have documented the counter-cyclical nature of formal human capital investments. Conversely, less formal types of human capital depreciation may be pro-cyclical. Previous work has shown that unemployed workers lose valuable human capital which results in lower future wages (Ruhm 1987, Jacobson et al. 1993, Dechter 2014). The monetized part of schooling is already part of GDP, but students' (and parents') time and effort is not and would likely prove to further offset traditional measures of the business cycle. 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.

Our main argument is that there are clear ways using standard data sources of extending traditional measures of fluctuations to incorporate human capital and such extensions are quantitatively important. Examining the *cyclicity* of previously unmeasured components differs from previous research that has focused on missing components in the *levels* 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 cyclicity. If the unmeasured components of GDP do not vary with the measured components, then either the inclusion or exclusion of these unmeasured components will have a negligible impact on business cycle analysis.

We show that accounting for mortality has an economically meaningful and first order impact on conclusions about the cyclicity of U.S. output fluctuations. Accounting for unmeasured components of output could even “reverse” observed recessions. These

results have potentially important policy implications for counter-cyclical fiscal and monetary policy. Automatic stabilizers such as taxes, safety net programs and government deficits that react to imperfect measures of economic activity may be exacerbating the true fluctuations rather than dampening them, especially when the policies are triggered by imperfect measures of welfare.²⁵ For example, the Congressional Budget Office's analysis of the long run economic impact of the American Recovery and Reinvestment Act of 2009 focused almost exclusively on projected GDP growth (Congressional Budget Office 2009), with no adjustments for the depreciation of human assets.²⁶ We show that GDP offers an incomplete measure of total output. Accounting for changes in health and human capital are first order and are correlated with the business cycle. Hence, any macroeconomic policies focused on GDP could potentially be misguided if one wishes to target policies related to total output.

Naturally, better measures of output fluctuations will add to our understanding of their causes. One theory, found in New Keynesian models and in part in real business cycle models, is that a recession is a time when the economy operates on the interior of its production set or that the production set has shifted toward the origin. Another view is that a recession is a time when people substitute nonmarket and unmeasured activity for the business activities that are already counted in GDP. Settling this debate is far beyond the scope of our paper, but our evidence adds further credibility to the second substitution interpretation.

To the extent that business cycles primarily reflect substitutions between market and nonmarket activity, countercyclical monetary and fiscal policy are counterproductive. Creating, say, inflation, or manipulating interest rates, in order to get the economy "back to work again" would merely accelerate another burst of mortality while leaving us with the problems that come with inflation. At the same time, recessions are different from each other. Those recessions that are not accompanied by significant human capital gains should

²⁵ This point is related to Friedman's (1953) error-variance analysis how counter-cyclical public policies may exacerbate the business cycle, even when those policies offset GDP changes on average.

²⁶ We thank Jay Bhattacharya for pointing out this example from the 2009 stimulus package.

be viewed as a problem that is more serious than the typical recession of the postwar period.

More research is needed to document the exact mechanism driving the pro-cyclical of mortality and other unmeasured dimensions of output. Understanding the exact mechanism behind the cyclical of mortality may have additional policy implications. One explanation for pro-cyclical mortality is that health-care quality is counter-cyclical (Stevens et al. 2011), which raises the policy question of whether quality fluctuations are indicative of market failures or the opportunity costs of business activity. In any case, business-cycle analysis can benefit from better human capital measurement.

References

- Ahn, Namkee, and Pedro Mira. 2002. "A Note on the Changing Relationship between Fertility and Female Employment Rates in Developed Countries." *Journal of Population Economics* 15(4): 667-682.
- Aldy, Joseph E., and W. Kip Viscusi. 2008. "Adjusting the Value of a Statistical Life for Age and Cohort Effects." *The Review of Economics and Statistics* 90(3): 573-581.
- Arthi, Vellore, Brian Beach, and W. Walker Hanlon. 2017. "Estimating the Recession-Mortality Relationship when Migration Matters." *NBER Working Paper* no. 23507.
- Becker, Gary S., Tomas J. Philipson, and Rodrigo R. Soares. 2005. "The Quantity and Quality of Life and the Evolution of World Inequality." *The American Economic Review* 95(1): 277-291.
- Böckerman, Petri, Edvard Johansson, Satu Helakorpi, Ritva Prättälä, Erkki Vartiainen, and Antti Uutela. 2007. "Does a Slump Really Make You Thinner? Finnish Micro-Level Evidence 1978–2002." *Health Economics*, 16(1): 103-107
- Bry, Gerhard, and Charlotte Boschan. 1971 . "Programmed Selection Of Cyclical Turning Points." *Cyclical Analysis of Time Series: Selected Procedures and Computer Programs*: 7-63.
- Butz, William P., and Michael P. Ward. 1979. "The Emergence of Countercyclical U.S. Fertility." *The American Economic Review* 69(3): 318-328.
- Carson, Carol S., and J. Steven Landefeld. 1994. "Integrated Economic and Environmental Satellite Accounts." *Survey of Current Business* 74(4): 33-49.
- Charles, Kerwin K., and Philip DeCicca. 2008. "Local Labor Market Fluctuations and Health: Is there a Connection and for Whom?" *Journal of Health Economics*, 27(6), 1532-1550.
- Claessens, Stijn, M. Ayhan Kose, and Marco E. Terrones. 2011. "Financial Cycles: What? How? When?. " *International Seminar on Macroeconomics* 7(1): 303-344.

- Congressional Budget Office, letter to the Honorable Judd Gregg providing the estimated macroeconomic impacts of H.R.1 as passed by the House and Senate, (2/11/2009), http://www.cbo.gov/sites/default/files/gregg_year-by-year_stimulus.pdf
- Costa, Dora L., and Matthew E. Kahn. 2004. "Changes in the Value of Life, 1940–1980." *Journal of Risk and Uncertainty* 29(2): 159-180.
- Cutler, David M., Elizabeth Richardson, Theodore E. Keeler, and Douglas Staiger. 1997. "Measuring the Health of the U.S. Population." *Brookings Papers on Economic Activity. Microeconomics*: 217-282.
- Dee, Thomas S. 2001. "Alcohol Abuse and Economic Conditions: Evidence from Repeated Cross-Sections of Individual-Level Data." *Health Economics*, 10(3): 257-270.
- Dechter, Evgenia Kogan. 2014. "Maternity leave, effort allocation, and postmotherhood earnings." *Journal of Human Capital*, 8(2): 97-125.
- Dellas, Harris, and Plutarchos Sakellaris. 2003. On the Cyclicity of Schooling: Theory and Evidence. *Oxford Economic Papers* 55(1): 148-172.
- Doucouliaqos, Hristos, T.D. Stanley and W. Kip Viscus. 2014. "Publication Selection and the Income Elasticity of the Value of a Statistical Life." *Journal of Health Economics* 33: 67-75.
- Ehrlich, Isaac. 2007. "The mystery of human capital as engine of growth, or why the US became the economic superpower in the 20th century", *NBER Working Paper* no. 12868
- Fraumeni, Barbara. 1997. "The Measurement of Depreciation in the U.S. National Income and Product Accounts." *Survey of Current Business – United States Department of Commerce* 77: 7-23.
- Friedman, Milton. 1953. The Effects of Full Employment Policy on Economic Stability: A Formal Analysis. In M. e. Friedman, *Essays in Positive Economics* (pp. 117-32). Chicago: University of Chicago Press.

- Gerdtham, Ulf-G., and Christopher J. Ruhm. 2006. "Deaths Rise in Good Economic Times: Evidence from the OECD." *Economics & Human Biology* 4(3): 298-316.
- Hartwick, John M. 1990. "Natural Resources, National Accounting and Economic Depreciation." *Journal of Public Economics* 43(3): 291-304.
- Hulten, Charles R., and Frank C. Wykoff. "The Measurement of Economic Depreciation." In Charles R. Hulten, ed. *Depreciation, Inflation, and the Taxation of Income from Capital*. Washington, DC: The Urban Institute Press, 1981: 81-125.
- Human Mortality Database*. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). [www.mortality.org] (accessed on 4/24/2013)
- Jacobson, Louis, Robert LaLonde and Daniel Sullivan. 1993. "Earnings Losses of Displaced Workers" *American Economic Review* 83(4): 685-709.
- Jones, Charles I., and Peter J. Klenow. 2010. "Beyond GDP? Welfare Across Countries and Time." National Bureau of Economic Research Working Paper w16352.
- Jordà, Òscar, Moritz Schularick, and Alan M. Taylor. 2011. "Financial Crises, Credit Booms, and External Imbalances: 140 Years of Lessons." *IMF Economic Review* 59(2): 340-378.
- Jorgenson, Dale W. 2009. "Human Capital and the National Accounts." Paper presented to the China Center for Human Capital and Labor Market Research, Central University of Finance and Economics.
- Kniesner, Thomas J., W. Kip Viscusi, and James P. Ziliak. 2010. "Policy Relevant Heterogeneity in the Value of Statistical Life: New Evidence from Panel Data Quantile Regressions." *Journal of Risk and Uncertainty* 40(1): 15-31.
- Latif, Ehsan. 2014. "The Impact of Macroeconomic Conditions on Obesity in Canada." *Health Economics*, 23(6): 751-759.

- McInerney, Melissa, and Jennifer M. Mellor. 2012. "Recessions and Seniors' Health, Health Behaviors, and Healthcare Use: Analysis of the Medicare Current Beneficiary Survey." *Journal of Health Economics*, 31(5), 744-751.
- Miller, Ted R. 2000 "Variations Between Countries in Values of Statistical Life." *Journal of Transport Economics and Policy* 34(2): 169-188.
- Mocan, Naci H. 1990. "Business Cycles and Fertility Dynamics in the United States." *Journal of Population Economics* 3(2): 125-146.
- Murphy, Kevin M., and Robert H. Topel. 2006. "The Value of Health and Longevity." *Journal of Political Economy* 114(5): 871-904.
- National Bureau of Economic Research, "U.S. Business Cycle Expansions and Contractions," [www.nber.org/cycles.html] (accessed May 5, 2013)
- Nordhaus, William D., and Edward C. Kokkelenberg. 1999. *Nature's Numbers: Expanding the National Economic Accounts to Include the Environment*. National Academies Press.
- Nordhaus, William D. 2002. "The Health of Nations: the Contribution of Improved Health to Living Standards." National Bureau of Economic Research Working Paper w8818.
- Ravn, Morten O., and Harald Uhlig. 2002. "On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations." *Review of Economics and Statistics* 84(2): 371-376.
- Ruhm, Christopher J. 1987. "The Economic Consequences of Labor Mobility." *Industrial and Labor Relations Review*, 41(1): 30-49.
- Ruhm, Christopher J. 2000. "Are Recessions Good for Your Health?" *The Quarterly Journal of Economics* 115(2): 617-650.
- Ruhm, Christopher J. 2005. "Healthy Living in Hard Times." *Journal of Health Economics*, 24(2), 341-363.
- Ruhm, Christopher J. 2013. "Recessions, Healthy No More?" National Bureau of Economic Research Working Paper w19287.

- Stevens, Ann Huff, Douglas L. Miller, Marianne E. Page, and Mateusz Filipski. 2011. "The Best of Times, the Worst of Times: Understanding Pro-cyclical Mortality." National Bureau of Economic Research Working Paper w17657.
- United Nations. 2009. "System of National Accounts, 2008." New York.
- U.S. Department of Transportation. 2013. "Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses." Memorandum to Secretarial Officers Modal Administrators from Polly Trottenberg, under Secretary for Policy, and Robert S. Rivkin, General Counsel, [<http://www.dot.gov/office-policy/transportation-policy/guidance-treatment-economic-value-statistical-life>] (accessed January 16, 2014).
- U.S. Bureau of Economic Analysis. 2014a. "Measuring the Economy: A Primer on GDP and the National Income and Product Accounts." October.
- U.S. Bureau of Economic Analysis. 2014b. "NIPA Handbook: Concepts and Methods of the U.S. National Income and Product Accounts." November.
- U.S. Bureau of Economic Analysis, various issues. "National Economic Accounts," [www.bea.gov/national/index.htm#gdp] (accessed May 6, 2013 and June 10, 2015).
- Viscusi, W. Kip. 2014 "The Value of Individual and Societal Risks to Life and Health." In: Mark J. Machina and W. Kip Viscusi (eds), *Handbook of the Economics of Risk and Uncertainty*, vol. 1. North-Holland, Amsterdam.
- Viscusi, W. Kip, and Joseph E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World." *Journal of Risk and Uncertainty* 27(1): 5-76.
- Viscusi, W. Kip, and Joni Hersch. 2008. "The Mortality Cost to Smokers." *Journal of Health Economics* 27(4): 943-958.
- The World Bank, "World DataBank." [<http://databank.worldbank.org/data/>] (accessed May 6, 2013)

Xu, Xin. 2013. "The Business Cycle and Health Behaviors." *Social Science & Medicine*,
77:126-136.

Appendix A: Additional Figures and Tables

FIGURE A1: VALUE OF MORTALITY AND TREND

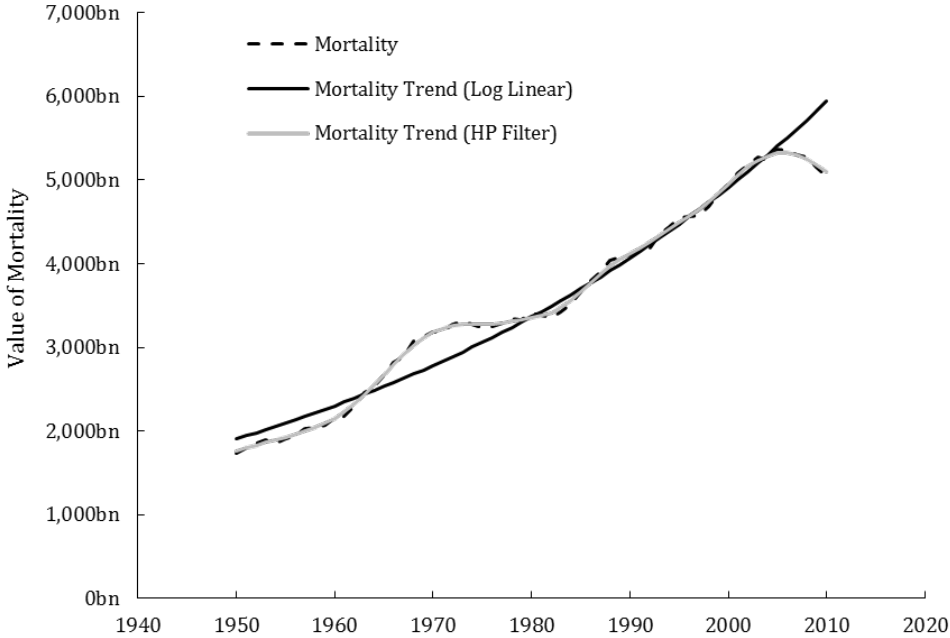


FIGURE A2: GDP AND TREND

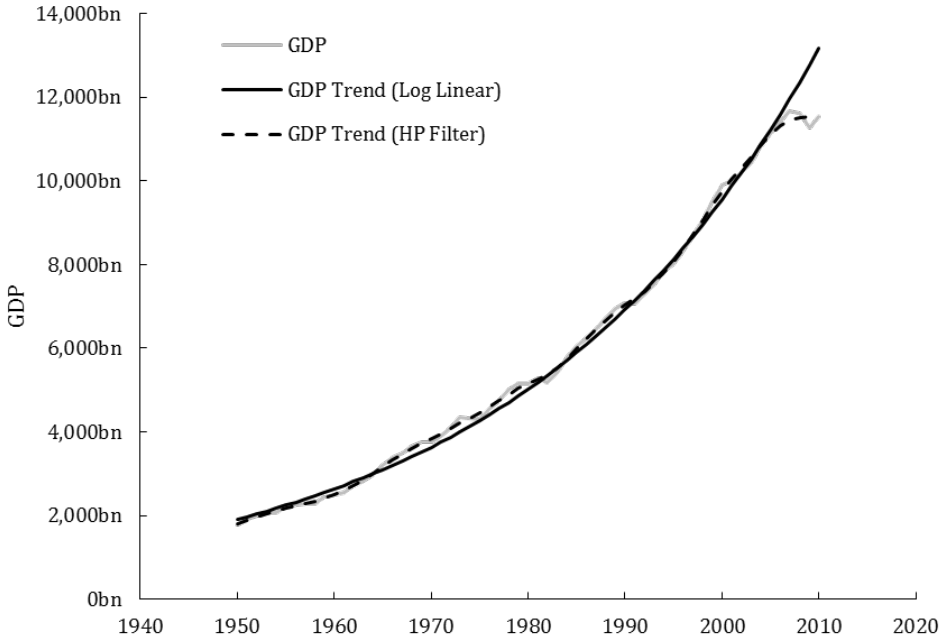


TABLE A1: REGRESSION OF LOG MORTALITY ON LOG GDP (PRE-1980)

Age Group	(1)	(2)	(3)	(4)
All	0.4003* (0.2141)	0.2785** (0.1339)	0.2689** (0.1311)	0.2494* (0.1322)
65+	0.2481 (0.2599)	0.2943* (0.1553)	0.2879* (0.1519)	0.2611* (0.1520)
25-64	0.8420*** (0.2086)	0.3143** (0.1338)	0.3036** (0.1318)	0.2887** (0.1341)
0-24	0.1062 (0.3830)	0.1041 (0.1737)	0.2004 (0.1315)	0.0460 (0.1607)
Time Trend	X	X		X
AR(1) Correction		X		
First Differences			X	X

Notes:

- Each age group coefficient is estimated in a separate regression with log age-group mortality (number of deaths) 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 1950-1980 with annual observations.

TABLE A2: REGRESSION OF LOG MORTALITY ON LOG GDP (POST-1980)

Age Group	(1)	(2)	(3)	(4)
All	0.3679*** (0.0771)	0.2661** (0.0971)	0.1656 (0.1165)	0.1469 (0.1233)
65+	0.6942*** (0.1499)	0.2649* (0.1490)	0.2252 (0.1468)	0.1556 (0.1492)
25-64	-0.4917*** (0.1560)	-0.0579 (0.1358)	-0.0352 (0.1345)	0.0565 (0.1295)
0-24	-0.1709 (0.2438)	0.2700 (0.2061)	0.2004 (0.1315)	0.3957* (0.2214)
Time Trend	X	X		X
AR(1) Correction		X		
First Differences			X	X

Notes:

- Each age group coefficient is estimated in a separate regression with log age-group mortality (number of deaths) 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 1981-2010 with annual observations.

Appendix B: Data Sources

GDP:

U.S. Bureau of Economic Analysis, "National Economic Accounts,"
[www.bea.gov/national/index.htm#gdp] (accessed May 6, 2013)

The World Bank, "World DataBank." [<http://databank.worldbank.org/data/>] (accessed
May 6, 2013)

MORTALITY:

Human Mortality Database. University of California, Berkeley (USA), and Max Planck
Institute for Demographic Research (Germany). [www.mortality.org] (accessed on
4/24/2013)

U.S. RECESSION DATES:

National Bureau of Economic Research, "U.S. Business Cycle Expansions and Contractions,"
[www.nber.org/cycles.html] (accessed May 5, 2013)

VSL ESTIMATES:

Murphy, Kevin M., and Robert H. Topel. 2006. "The Value of Health and Longevity." *Journal
of Political Economy* 114(5): 871-904.

Viscusi, W. Kip, and Joseph E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review
of Market Estimates Throughout the World." *Journal of Risk and Uncertainty* 27(1):
5-76.