Adjusting National Accounting for Health
Is the Business Cycle Countercyclical?

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October 2017
Motivation

National accounts offer an incomplete picture of total output
- Home production
- Value of leisure
- Health/mortality

Propose a new methodology: Health/Mortality Adjusted GDP
- Incorporate monetized changes in health
- Implications for cycle and recessions
To illustrate the quantitative magnitudes, consider that in 2016

- 2.5 million deaths in the United States
- Suppose we value a life at $9 million (EPA, USDOT)
- Implies a mortality cost of $22.5 trillion
- To put this in perspective, GDP was $19 trillion
Motivation
GDP and Mortality

![Graph showing the relationship between log(GDP) and log(Mortality) over time from 1950 to 2010.](image)
Motivation
Deviations from Trend

It is well known that mortality is cyclical (Ruhm, 2000)
This paper

- Propose a methodology to measure of health adjusted GDP
  - Incorporates monetized changes in health
  - Mortality Adjusted GDP

- Construct mortality adjusted GDP
  - Use existing Value of Statistical Life estimates
  - US and 21 other countries

- Reexamine recessions and the business cycle after adjusting for mortality
Relative to GDP, mortality is
- Quantitatively meaningful
- Cyclical

Consequently
- Booms are not as valuable due to increased mortality
- Busts are not as costly due to decreased mortality
Preview of Results

We find that adjusting for mortality...

- Reduces the volatility of measured output by 15-30%
- Reduces the measured severity of recessions by 2pp
- Accounting for mortality essentially reverses one in four recessions
Roadmap

- Economic Framework for Depreciation
- Constructing Health/Mortality Adjusted GDP
- Implications
  - Adjusting recessions for health
  - Reexamining the business cycle
  - International results
Economic Framework

Measuring economic activity involves recognizing the value of capital is different at the end of the time frame

- Investment
- Depreciation

The “Ideal" method for measuring depreciation is to infer an age-value profile from purchase price data from a frictionless resale marked for used assets.

- We don’t have a resale market for humans.
- We use existing value of statistical life (VSL) estimates
Begin with a cohort of assets of age $a$
Let $v(a)$ denote the present value, conditional on survival to age $a$, of an asset's service flows.

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

where
- $S(\cdot)$ is the survival function with corresponding density $m(\cdot)$
- $b(a)$: service flow of age $a$ asset
- $r$: discount rate
- $\left[ \int_a^x e^{-r(z-a)} b(a) \, dz \right]$ : present value of asset that lasts exactly $x$ years
Depreciation reflects the decline in a cohort’s value

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

where

- \( m(a)v(a) \): cohort members retired from service
- \( S(a)v'(a) \): change in value among surviving cohort members
Consider depreciation in the context of human capital

\[
Depreciation = m(a)v(a) - S(a)v'(a)
\]

where

- \(v(a)\) : value of a statistical life
- \(m(a)v(a)\) : depreciation due to mortality
- \(S(a)v'(a)\) : depreciation due to aging/morbidity
Define mortality adjusted GDP ($N_t$) as

$$N_t = Y_t - M_t - A_t$$

where

- $Y_t$: GDP
- $M_t$: Value of mortality ($m(a)v(a)$)
- $A_t$: Value of aging/morbidity ($S(a)v'(a)$)
Calculate mortality as

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

Use two methodologies for calculating the Value of a Statistical Life (VSL)

- Aldy and Viscusi (2008): hedonic wage regressions
- Murphy and Topel (2006): calibrated life-cycle model
Constructing Mortality Adjusted GDP
Value of Statistical Life

Value of Statistical Life (VSL)

Age

$0mm

$1mm

$2mm

$3mm

$4mm

$5mm

$6mm

$7mm

$8mm

$9mm

Murphy and Topel (2006)
Aldy and Viscusi (2008)
Calculate aging as

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

where

$$\Delta VSL_{age,g,t} = VSL_{age,g,t+1} - VSL_{age,g,t}$$
Only observe VSL for one year (2000), not over time
- Scale VSL across time by trend GDP per capita

\[
VSL_{age,g,t} = VSL_{age,g,2000} \times \left( \frac{\frac{Y_t}{pop_t}}{\frac{Y_{2000}}{pop_{2000}}} \right)
\]

- Assume elasticity of VSL to trend income is one (Miller, 2000)
Our analysis focuses on the cyclicality of output

\[ M_t = \left( \sum_{age,g} \frac{death_{age,g,t}}{pop_{age,g,t}} VSL_{age,g,t} s_{age,g,2000} \right) \left( \sum_{age,g} \operatorname{pop}_{age,g,t} \right) \]

\[ A_t = \left( \sum_{age,g} \frac{death_{age,g,t}}{pop_{age,g,t}} (\Delta VSL_{age,g,t}) s_{age,g,2000} \right) \left( \sum_{age,g} \operatorname{pop}_{age,g,t} \right) \]

Our empirical implementation implies
\( (VSL_{age,g,t}) \left( \sum_{age,g} \operatorname{pop}_{age,g,t} \right) \) is acyclical

- Also implies \( A_t \) is acyclic
- Cyclicality of \( M_t \) is driven by the cyclicality of the death rate
Constructing Mortality Adjusted GDP
Cyclicality of Morbidity

Change in Cancer Prevalence
Change in log GDP

Cancer Prevalence (per 1,000 individuals)

log GDP
Reexamine the severity of past US recessions

Calculate peak to trough Mortality Adjusted GDP as

- Difference in actual output $N_t$ minus trend value $N_t^T$
- Normalized by GDP

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

Calculate trend mortality and GDP based on average growth rates

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

where $\tau$ is the length of the recession
Mortality Adjusted GDP

Adjusting National Accounting for Health
It's well established that mortality co-varies positively with unemployment

- Ruhm (2000), Gerdtham and Ruhm (2006), etc

Reconfirm and build on these results looking at mortality and GDP

- Mechanism drives the cyclicality of mortality adjusted GDP
\[ \Delta \ln \text{Mortality}_t = \beta_0 + \beta_1 \Delta \ln \text{GDP}_t + \beta_2 t + \epsilon_t \]

<table>
<thead>
<tr>
<th>Age Group</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0.41***</td>
<td>0.27***</td>
<td>0.24***</td>
<td>0.21**</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>65+</td>
<td>0.76***</td>
<td>0.32***</td>
<td>0.29***</td>
<td>0.23**</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.10)</td>
<td>(0.10)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>25-64</td>
<td>0.10</td>
<td>0.14</td>
<td>0.15</td>
<td>0.19*</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.09)</td>
<td>(0.09)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>0-24</td>
<td>0.19</td>
<td>0.21</td>
<td>0.20</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>(0.19)</td>
<td>(0.13)</td>
<td>(0.13)</td>
<td>(0.14)</td>
</tr>
</tbody>
</table>

Time Trend  \( \times \) \( \times \) \( \times \)
AR(1) Correction \( \times \)
First Differences \( \times \) \( \times \)
Decompose GDP, Mortality, and Mortality Adjusted GDP into trend and cycle components

\[ Y_t = \exp(y_t^T + y_t^C), \quad M_t = \exp(m_t^T + m_t^C) \]

where

\[ E\left[ Y_t | y_t^T \right] = \exp\left( y_t^T \right), \quad E\left[ M_t | m_t^T \right] = \exp\left( m_t^T \right) \]
Cyclicality of Mortality Adjusted GDP
Trend/Cycle Decomposition

Mortality Adjusted GDP is defined as

\[ N_t = Y_t - M_t - A_t \]

Cyclical component of mortality adjusted GDP and GDP

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

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

Recover trend using the HP Filter and a log-linear trend
Cyclicality of Mortality Adjusted GDP

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Adjusting National Accounting for Health
### Cyclicality of Mortality Adjusted GDP

#### Volatility of Measured Output

<table>
<thead>
<tr>
<th>Measure</th>
<th>Std.Dev. $\sigma$ – Cycle</th>
<th>$\sigma$ – Cycle</th>
<th>$\sigma$ – Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>4.42%</td>
<td>1.41%</td>
<td>3.98%</td>
</tr>
<tr>
<td>Mortality-adjusted GDP</td>
<td>3.04%</td>
<td>1.21%</td>
<td>2.60%</td>
</tr>
<tr>
<td>Log Linear Trend</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP Filter</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Methodology can be extended to account for morbidity

- Need time varying VSL estimates or
- Prevalence data for diseases

Results hold for other developed countries:  

- Examine 21 OECD countries
- Mortality adjustment...
  - Reduces severity of recessions by 2pp
  - Reduces volatility of output by 40%
Conclusions

- Construct a new measure of output that incorporates changes in health
- Examined macroeconomic fluctuations in the US over the past 60 years
- Because mortality tend to be pro-cyclical, fluctuations in standard GDP are in part offset by human depreciation
  - Booms are not as valuable because of increased mortality
  - Recessions are not as bad because of lower mortality
- Fluctuations in economic output are milder than commonly measured
  - Adjusting for mortality reduces the severity of recessions by 2pp
  - Adjusting for mortality reduces the volatility of GDP by 15-30%
• **Human capital investments**
  ▶ Stock replenishment: fertility and immigration/emigration
    ■ Cyclicality of fertility: Butz and Ward 1979; Mocan 1990; Ahn and Mira 2002
  ▶ Skill/Knowledge human capital: Ehrlich 2007
    ■ Countercyclical investments: Dellas and Sakellaris 2003

• **Gradual changes in human depreciation**
  ▶ Morbidity
  ▶ Demographic changes

• **Quantitative welfare effects of counter-cyclical fiscal policies**
We replicate the preceding peak to trough analysis

- Unbalanced sample of twenty-one other developed countries
- 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).
- Assume that the elasticity of VSL with respect to income is one.
Adjusting International Recessions for Health
Peak to Trough

Mortality-adjusted GDP  GDP
## Adjusting International Recessions for Health

<table>
<thead>
<tr>
<th>Country</th>
<th>GDP</th>
<th>Mortality Adjusted GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>-2.90%</td>
<td>-1.65%</td>
</tr>
<tr>
<td>Austria</td>
<td>-2.34%</td>
<td>-2.11%</td>
</tr>
<tr>
<td>Belgium</td>
<td>-3.42%</td>
<td>-2.75%</td>
</tr>
<tr>
<td>Canada</td>
<td>-4.93%</td>
<td>-2.70%</td>
</tr>
<tr>
<td>Denmark</td>
<td>-1.40%</td>
<td>-2.75%</td>
</tr>
<tr>
<td>Finland</td>
<td>-8.35%</td>
<td>-1.51%</td>
</tr>
<tr>
<td>France</td>
<td>-3.40%</td>
<td>-3.30%</td>
</tr>
<tr>
<td>Hungary</td>
<td>-5.65%</td>
<td>-1.45%</td>
</tr>
<tr>
<td>Iceland</td>
<td>-6.21%</td>
<td>-4.45%</td>
</tr>
<tr>
<td>Ireland</td>
<td>-2.90%</td>
<td>-1.49%</td>
</tr>
<tr>
<td>Israel</td>
<td>-9.72%</td>
<td>-8.33%</td>
</tr>
<tr>
<td>Italy</td>
<td>-3.47%</td>
<td>-2.96%</td>
</tr>
<tr>
<td>Japan</td>
<td>-9.13%</td>
<td>-6.72%</td>
</tr>
</tbody>
</table>
### Adjusting International Recessions for Health

<table>
<thead>
<tr>
<th>Country</th>
<th>GDP</th>
<th>Mortality Adjusted GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luxembourg</td>
<td>-9.99%</td>
<td>-6.46%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-3.82%</td>
<td>-3.56%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>-1.09%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Norway</td>
<td>-4.72%</td>
<td>-3.61%</td>
</tr>
<tr>
<td>Portugal</td>
<td>-8.52%</td>
<td>-3.75%</td>
</tr>
<tr>
<td>Spain</td>
<td>-7.38%</td>
<td>-3.23%</td>
</tr>
<tr>
<td>Sweden</td>
<td>-5.67%</td>
<td>-2.20%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-6.74%</td>
<td>-4.43%</td>
</tr>
<tr>
<td>United States</td>
<td>-4.43%</td>
<td>-2.06%</td>
</tr>
</tbody>
</table>
Adjusting International Output for Health
Volatility of Output

Mortality-adjusted GDP
GDP

Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, UK, Hungary, Ireland, Iceland, Israel, Italy, Japan, Luxembourg, Netherlands, Norway, New Zealand, Portugal, Sweden, USA