DOUBLE DIVIDEND: Confidence Intervals for Policy Evaluation

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August 20, 2014
Chicago, IL
DOUBLE DIVIDEND

In Environmental Economics the Standard Approach to Policy Evaluation Is to Rank Policies by Differences between Benefits and Costs.

This Has Led to a Search for Benefits, For Example, in the Widely Cited *Stern Review of the Economics of Climate*, for the British Government.

In the Contentious Debate that Has Followed, the Most Persuasive Argument for Climate Policy Has Been Overlooked: The Reduction of Cost to Zero.

Careful Design of Climate Policies Makes It Possible to Attain Environmental Goals, Slowing Climate Change, while Improving Economic Performance, the *Double Dividend* of the Title.
AN ECONOMETRIC APPROACH TO GENERAL EQUILIBRIUM MODELING


Econometric Modeling of Producer Behavior:
   Jorgenson and Fraumeni, 2000;
   Jin and Jorgenson, 2010.

Econometric Modeling of Consumer Behavior:
   Jorgenson, Lau, and Stoker, 1997;
   Jorgenson and Slesnick, 2008.
IGEM:
An Intertemporal Model of the U.S. Economy for Modeling Energy and Environmental Policy

Household Model Incorporates Demography
Demand for Leisure and the Supply of Labor
Production Model Incorporates Technology
Endogenous Technical Change
Resources and Energy Supply
Growth

Energy, the Environment, and Economic Growth

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The Carbon Tax Scenarios

Carbon Tax Paths

- $10 in 2020
- $20 in 2020
- $30 in 2020
- $40 in 2020
- $50 in 2020

$0.00
$250.00
$200.00
$150.00
$100.00
$50.00

$2005 per mtCO2-e
The Model $F$, Where $Y$ Is Endogenous, $X$ Is Exogenous, and $\beta$ Is a Parameter:

$$Y = F(X, \beta)$$

The Predicted Value $\hat{Y}$, Where $\hat{\beta}$ Is an Estimator:

$$\hat{Y} = F(X, \hat{\beta}, 0)$$

Prediction Error $e$, Where $\delta$ Is a Disturbance:

$$e = Y - \hat{Y} = F(X, \beta, \epsilon) - F(X, \hat{\beta}, 0)$$

Taylor Series Expansion (Tuladhar and Wilcoxon (1999)):

$$F(X, \hat{\beta}, 0) \approx F(X, \beta, \epsilon) + J_\beta (\hat{\beta} - \beta) - J_\epsilon \epsilon$$

Where $J_\beta$ and $J_\epsilon$ Are Jacobians of $F$ with Respect to $\beta$ and $\delta$.

Asymptotic Covariance Matrix:

$$\Sigma_Y \approx J_\beta \Sigma_\beta J_\beta^\prime + J_\epsilon \Sigma_\epsilon J_\epsilon^\prime$$
Figure 9.7
Results of delta versus Monte Carlo methods: Key macroeconomic variables.

Parameter covariance matrix: household
Figure 9.8
Results of delta versus Monte Carlo methods: Industry output.
Figure 9.9
Results of delta versus Monte Carlo methods: Industry prices.
POLICY EVALUATION

Policy Outcome $\Delta Y$, Exogenous Variables under the Base and Policy Cases, $X_b$ and $X_p$:

$$\Delta Y = Y_p - Y_b = F(X_p, \beta) - F(X_b, \beta)$$

Prediction Error $e\Delta Y$:

$$e\Delta Y = (Y_p - Y_b) - (\hat{Y}_p - \hat{Y}_b) = (Y_p - \hat{Y}_p) - (Y_b - \hat{Y}_b) = e_p - e_b$$

Define $\Delta J_\beta$:

$$\Delta J_\beta = J_\beta \mid_{X_p} - J_\beta \mid_{X_b}$$

Asymptotic Covariance Matrix:

$$\Sigma_{\Delta Y} \approx \Delta J_\beta \Sigma_\beta \Delta J_\beta'$$
Figure 9.30
Confidence intervals: Key macroeconomic variables.
Figure 9.31
Confidence intervals: Industry output.
Figure 9.32
Confidence intervals: Industry prices.
DEMAND ANALYSIS

Notation:

\[ w_{nk} = \frac{p_n x_{nk}}{M_k} \] – expenditure share of the \( n \)th commodity in the budget of the \( k \)th consuming unit \((n = 1,2, ..., N; k = 1,2, ..., K)\).

\[ w_k = (w_{1k}, w_{2k}, ..., w_{Nk}) \] – vector of expenditure shares for the \( k \)th consuming unit \((k = 1,2, ..., K)\).

\[ \ln \frac{p}{M_k} = (\ln \frac{p_1}{M_k}, \ln \frac{p_2}{M_k}, ..., \ln \frac{p_N}{M_k}) \] – vector of logarithms of ratios of prices to expenditure by the \( k \)th consuming unit \((k = 1,2, ..., K)\).

\[ \ln p = (\ln p_1, \ln p_2, ..., \ln p_N) \] – vector of logarithms of prices.

Individual Expenditure Shares:

\[ w_k = \frac{1}{D(p)} \left( \alpha_p + B_{pp} \ln p - B_{pp} i \cdot \ln M_k + B_{pA} A_k \right), (k = 1,2, ..., K). \]

Aggregate Expenditure Shares:

\[ w = \frac{1}{D(p)} \left( \alpha_p + B_{pp} \ln p - B_{pp} i \cdot \frac{\sum M_k \ln M_k}{M} + B_{pA} \frac{\sum M_k A_k}{M} \right). \]
DATA ISSUES

The Consumer Expenditure Survey (CEX), U.S. Bureau of Labor Statistics:

Data on expenditures on goods and services and labor supply.

CEX data for 1980-2006, 4000-8000 observations per year, 154,180 observations.

Consumer Price Index (CPI), U.S. Bureau of Labor Statistics:

Price data for four Census regions in all years.
WAGE EQUATION

Wage equation for worker $i$:

$$\ln P_{Li} = \sum_j \beta_j^z z_{ji} + \sum_j \beta_j^s (S_i^* z_{ji}) + \sum_j \beta_j^{nw} (NW_i^* z_{ji}) + \sum_l \beta_l^g g_{li} + \epsilon_{it}$$

(8)

where:

$P_{Li}$ -- wage of worker $i$.

$z_i$ -- vector including age, age squared, education, education squared.

$S_i$ -- dummy variable female.

$NW_i$ -- dummy variable nonwhite.

$g_i$ -- vector of region-year interaction dummy variables.

Quality-adjusted wage for a worker in region $s$:

$$p_L^s = \exp(\beta_s)$$
QUALITY-ADJUSTED LEISURE

Quality index for worker \( m \):

\[
q_{kt}^m = \frac{E_{kt}^m}{p_{Lt}H_{kt}^m}
\]

Time endowment in efficiency units \( T_{kt}^m = q_{kt}^m \times (14) \); leisure consumption:

\[
R_{kt}^m = q_{kt}^m (14 - H_{kt}^m)
\]

Full expenditure for household \( k \):

\[
F_{kt} = p_{Lt}R_{kt} + \sum_i p_{ik}x_{ik}
\]

where \( R_{kt} = \sum_m R_{kt}^m \) leisure summed over adult members.
<table>
<thead>
<tr>
<th>Good</th>
<th>Uncompensated price elasticity</th>
<th>Compensated price elasticity</th>
<th>Full expenditure elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rank 2</td>
<td>Rank 3</td>
<td>Rank 2</td>
</tr>
<tr>
<td>Nondurables</td>
<td>−0.918</td>
<td>−0.903</td>
<td>−0.822</td>
</tr>
<tr>
<td>Capital services</td>
<td>−1.428</td>
<td>−1.432</td>
<td>−1.314</td>
</tr>
<tr>
<td>Consumer services</td>
<td>−0.613</td>
<td>−0.614</td>
<td>−0.548</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.012</td>
<td>0.014</td>
<td>−0.323</td>
</tr>
<tr>
<td>Labor supply</td>
<td>−0.026</td>
<td>−0.030</td>
<td>0.698</td>
</tr>
</tbody>
</table>
INDIVIDUAL WELFARE

Indirect Utility Function:
\[
\ln V_k = \ln p' \alpha_p + \frac{1}{2} \ln p' B_{pp} \ln p - D(p) \ln \left[ \frac{M_k}{m_0(p, A_k)} \right], \quad (k = 1, 2, ..., K)
\]

General Household Equivalence Scale:
\[
\ln m_0(p, A_k) = \frac{1}{D(p)} \left[ \ln m(A_k)' \alpha_p + \frac{1}{2} \ln m(A_k)' B_{pp} \ln m(A_k) + \ln m(A_k)' B_{pp} \ln p \right], \quad (k = 1, 2, ..., K)
\]

Where:
\[
\ln m(A_k) = B_{pp}^{-1} B_{pa} A_k, \quad (k = 1, 2, ..., K)
\]

Individual Expenditure Function:
\[
\ln M_k = \frac{1}{D(p)} \left[ \ln p' \left( \alpha_p + \frac{1}{2} B_{pp} \ln p \right) - \ln V_k \right] + \ln m_0(p, A_k), \quad (k = 1, 2, ..., K)
\]
Household Welfare Effects, Family Size

Household Welfare Changes, $20 Tax Path
Weighted averages as %'s of mean full wealth

Children, Adults per Household

Capital Tax Rates  All Tax Rates  Labor Tax Rates  Lump Sum
Household Welfare Effects, Race & Gender of Head

Household Welfare Changes, $20 Tax Path
Weighted averages as %'s of mean full wealth

- Non-white female
- White female
- Non-white male
- White male

- Capital Tax Rates
- All Tax Rates
- Labor Tax Rates
- Lump Sum
Household Welfare Effects, Region & Location

Household Welfare Changes, $20 Tax Path
Weighted averages as %'s of mean full wealth

- Capital Tax Rates
- All Tax Rates
- Labor Tax Rates
- Lump Sum

Legend:
- Northeast
- Midwest
- South
- West
- Urban
- Rural
SOCIAL WELFARE

Social Welfare Function:
\[
W(u, x) = \ln \bar{V} - \gamma(x) \left[ \frac{\sum_{k=1}^{K} m_0(p, A_k) \ln V_k - \ln \bar{V}}{\sum_{k=1}^{K} m_0(p, A_k)} \right]^{-1/\rho}
\]

Utilitarian Case:
\[
\ln \bar{V} = \frac{\sum_{k=1}^{K} m_0(p, A_k) \ln V_k}{\sum_{k=1}^{K} m_0(p, A_k)} = \ln p' \left( \alpha_p + \frac{1}{2} B_{pp} \ln p \right) - D(p) \frac{\sum_{k=1}^{K} m_0(p, A_k) \ln \frac{M_k}{m_0(p, A_k)}}{\sum_{k=1}^{K} m_0(p, A_k)}
\]

Egalitarian Case:
\[
\gamma(x) = \left\{ \frac{\sum_{k=1}^{K} m_0(p, A_k)}{\sum_{k=1}^{K} m_0(p, A_k)} \left[ 1 + \left( \frac{\sum_{k=1}^{K} m_0(p, A_k)}{m_0(p, A_k)} \right)^{-(\rho+1)} \right] \right\}^{1/\rho}
\]

where:
\[
m_0(p, A_j) = \min_k m_0(p, A_k), \ (k = 1, 2, \ldots, K).
\]

Social Expenditure Function:
\[
\ln M(p, W) = \frac{1}{D(p)} \left[ \ln p' \left( \alpha_p + \frac{1}{2} B_{pp} \ln p \right) - W \right] + \ln \left[ \sum_{k=1}^{K} m_0(p, A_k) \right].
\]
CONFIDENCE INTERVALS FOR SOCIAL WELFARE

Social Equivalent Variation:
\[ EV = G(F(X_b, \phi, \theta), F(X_p, \phi, \theta), \theta) \]

Taylor’s Series Expansion:
\[ \Delta EV = \Gamma_\phi \Delta \phi + \Gamma_\theta \Delta \theta \]

Asymptotic Covariance Matrix:
\[ \Sigma_{EV} = \Gamma_\phi^T \Sigma_\phi \Gamma_\phi + \Gamma_\theta^T \Sigma_\theta \Gamma_\theta \]
Figure 9.34
Confidence ellipse for the egalitarian measure of social welfare.
Figure 9.35
Confidence ellipse for the utilitarian measure of social welfare.
DOUBLE DIVIDEND: SUMMARY

We Have Identified a Double Dividend Based on Substitution of a Carbon Tax for a Capital Income Tax

This Substitution is Based on Econometric Models of Producer and Consumer Behavior

These Models Are Combined into an Intertemporal General Equilibrium Model of the U.S. Economy

Policy Evaluation Compares a Base Case with No Change in Policy with Alternative Cases

The Economic Impact of a Change in Policy Is a Money Metric Measure of the Change in Social Welfare
USING DEMAND ANALYSIS TO CONSTRUCT
CONFIDENCE INTERVALS FOR SOCIAL WELFARE:
SUMMARY.

Preferences Depend on Demographic Characteristics of Households, As Well As Prices and Total Expenditure.


Economic Impacts Are Equivalent Variations in Full Wealth for Households.

Social Welfare Depends on Individual Welfare for All Households.

Social Welfare Also Depends on Value Judgments on Horizontal and Vertical Equity.

Economic Impact Is the Equivalent Variation in Full Wealth and Can Be Decomposed into Efficiency and Equity.