DOUBLE DIVIDEND:

Confidence Intervals for Policy Evaluation

by

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BECKER FRIEDMAN INSTITUTE
FOR RESEARCH IN ECONOMICS
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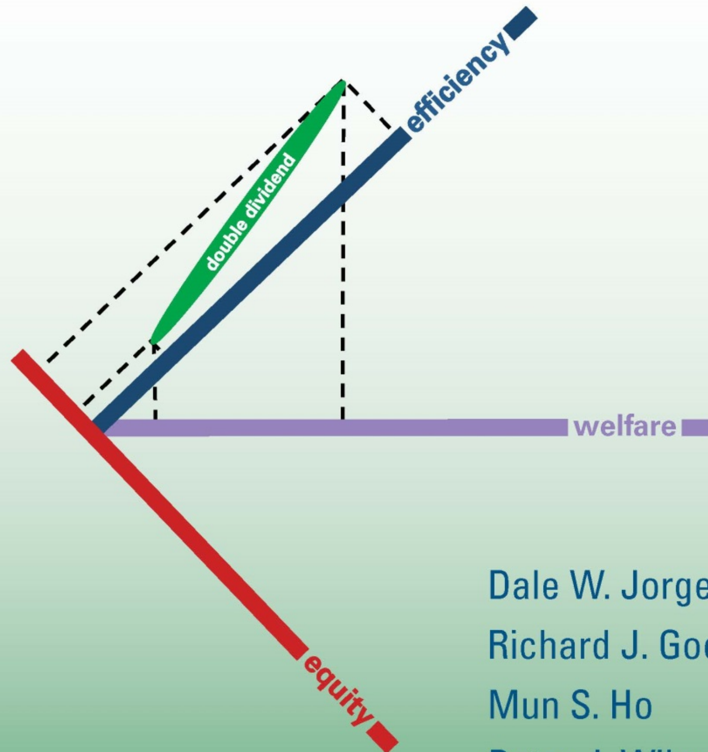
DOUBLE DIVIDEND

Environmental Taxes and Fiscal Reform in the United States



Dale W. Jorgenson
Richard J. Goettle
Mun S. Ho
Peter J. Wilcoxen

DOUBLE DIVIDEND

Jorgenson, Goettle, Ho, and Wilcoxen

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

Climate Economic Modeling, U.S. Environmental Protection Agency, http://www.epa.gov/climatechange/EPAactivities/economics/modeling.html

Intertemporal General Equilibrium Model, Version Eighteen, 2013

Version One: Jorgenson and Wilcoxen, 1990.

Version Sixteen: Jorgenson, Goettle, Ho, and Wilcoxen, 2012.

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

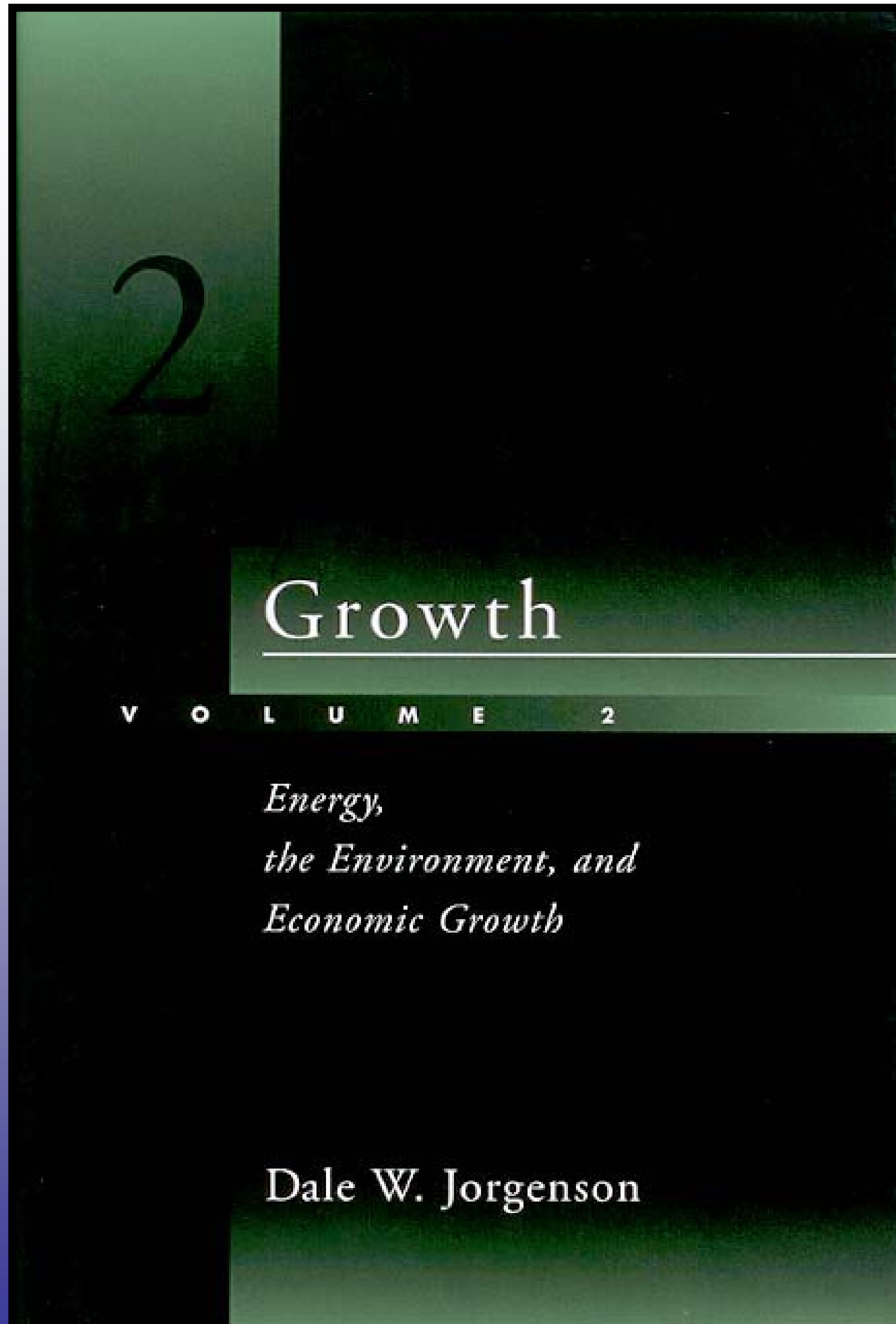
Household Model Incorporates Demography

Demand for Leisure and the Supply of Labor

Production Model Incorporates Technology

Endogenous Technical Change

Resources and Energy Supply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Growth
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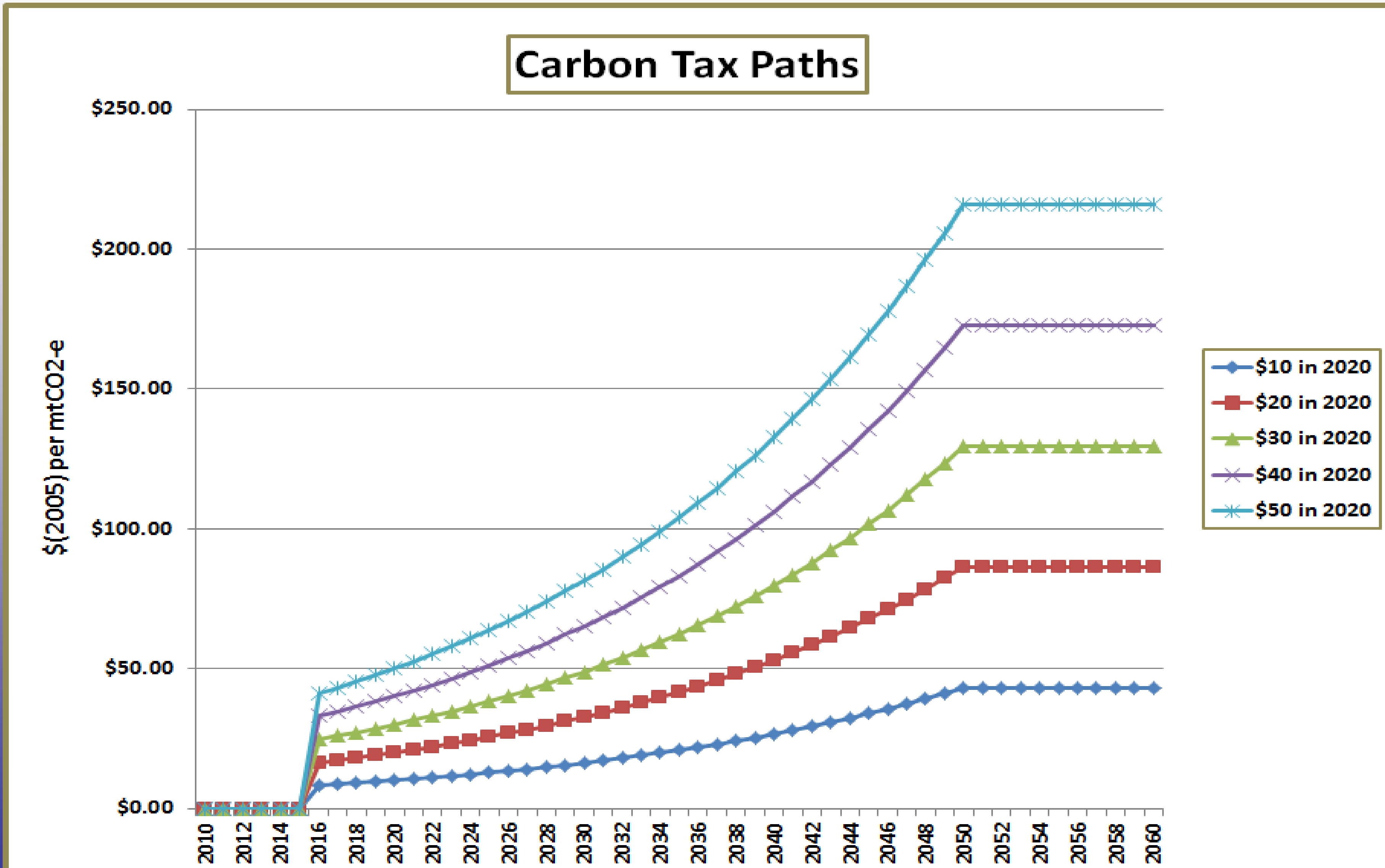
Energy, the Environment, and Economic Growth
Dale W. Jorgenson

The Carbon Tax Scenarios



BASE CASE

The Model F, Where Y Is Endogenous, X Is Exogenous, and β 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 ϵ Is a Disturbance:

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

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

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

Where J_{β} and J_{ϵ} Are Jacobians of *F* with Respect to β and ϵ.

Asymptotic Covariance Matrix:

$$\Sigma_Y \approx J_{\beta}\Sigma_{\beta}J_{\beta}' + J_{\epsilon}\Sigma_{\epsilon}J_{\epsilon}'$$

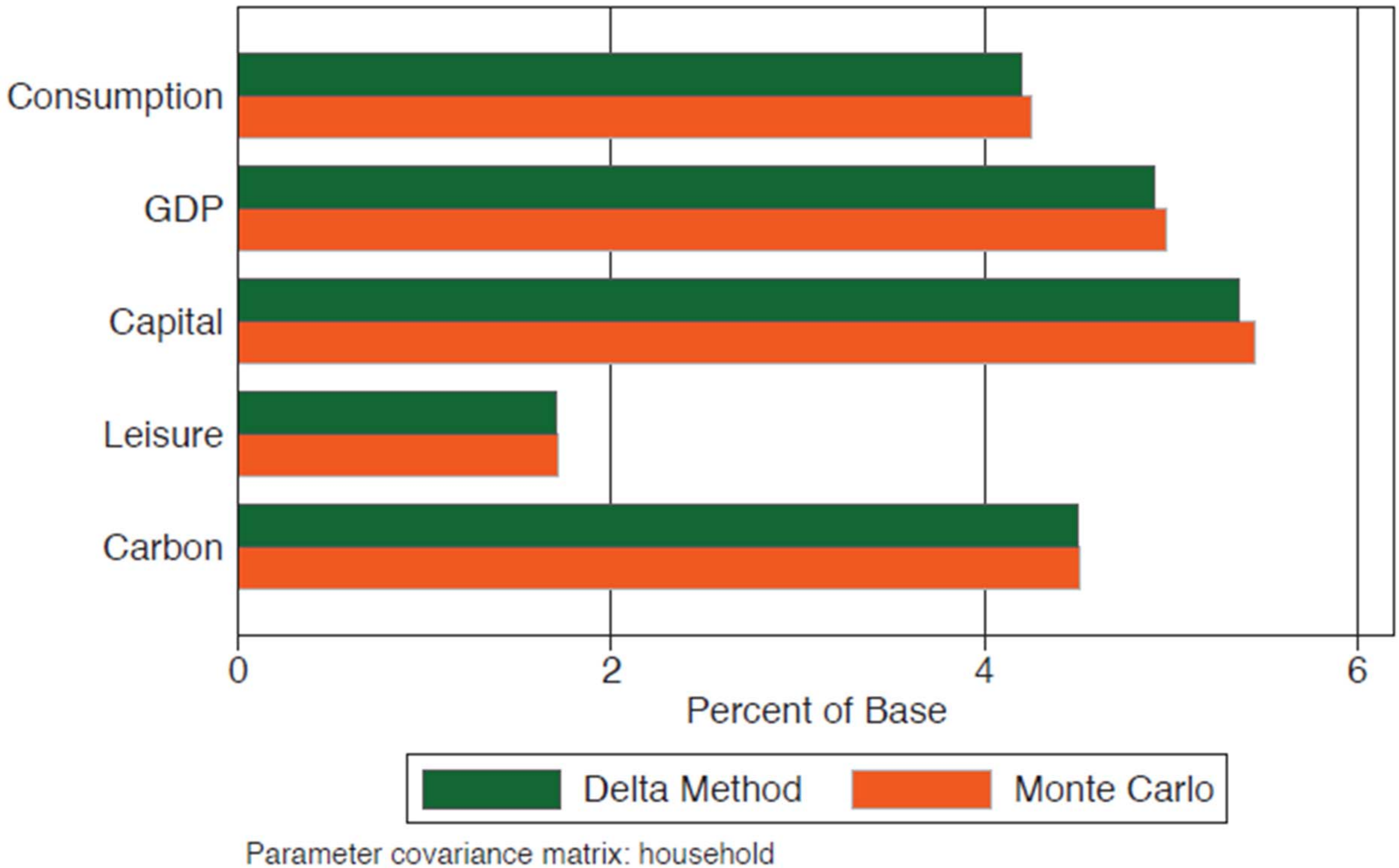


Figure 9.7
Results of delta versus Monte Carlo methods: Key macroeconomic variables.

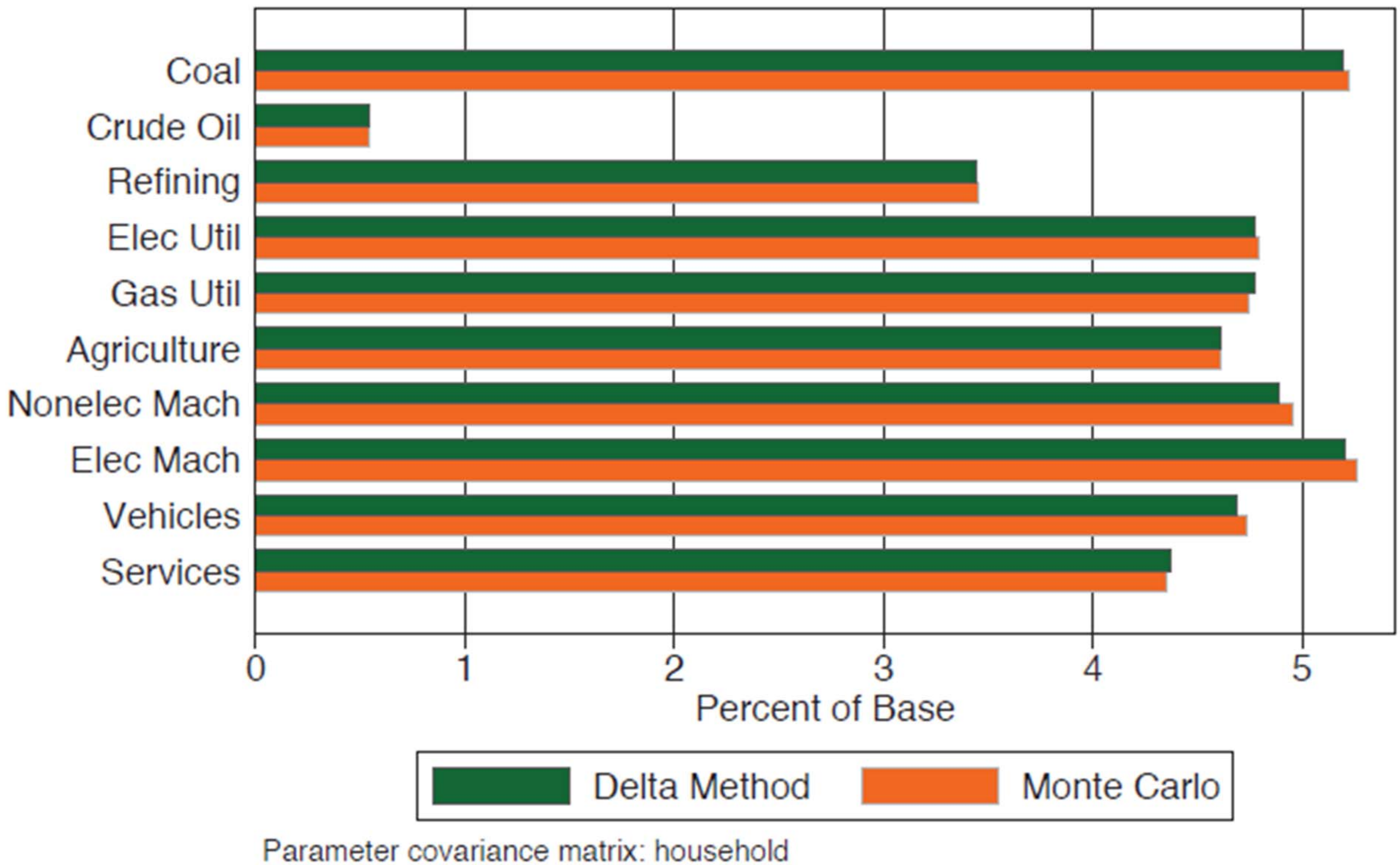


Figure 9.8
Results of delta versus Monte Carlo methods: Industry output.

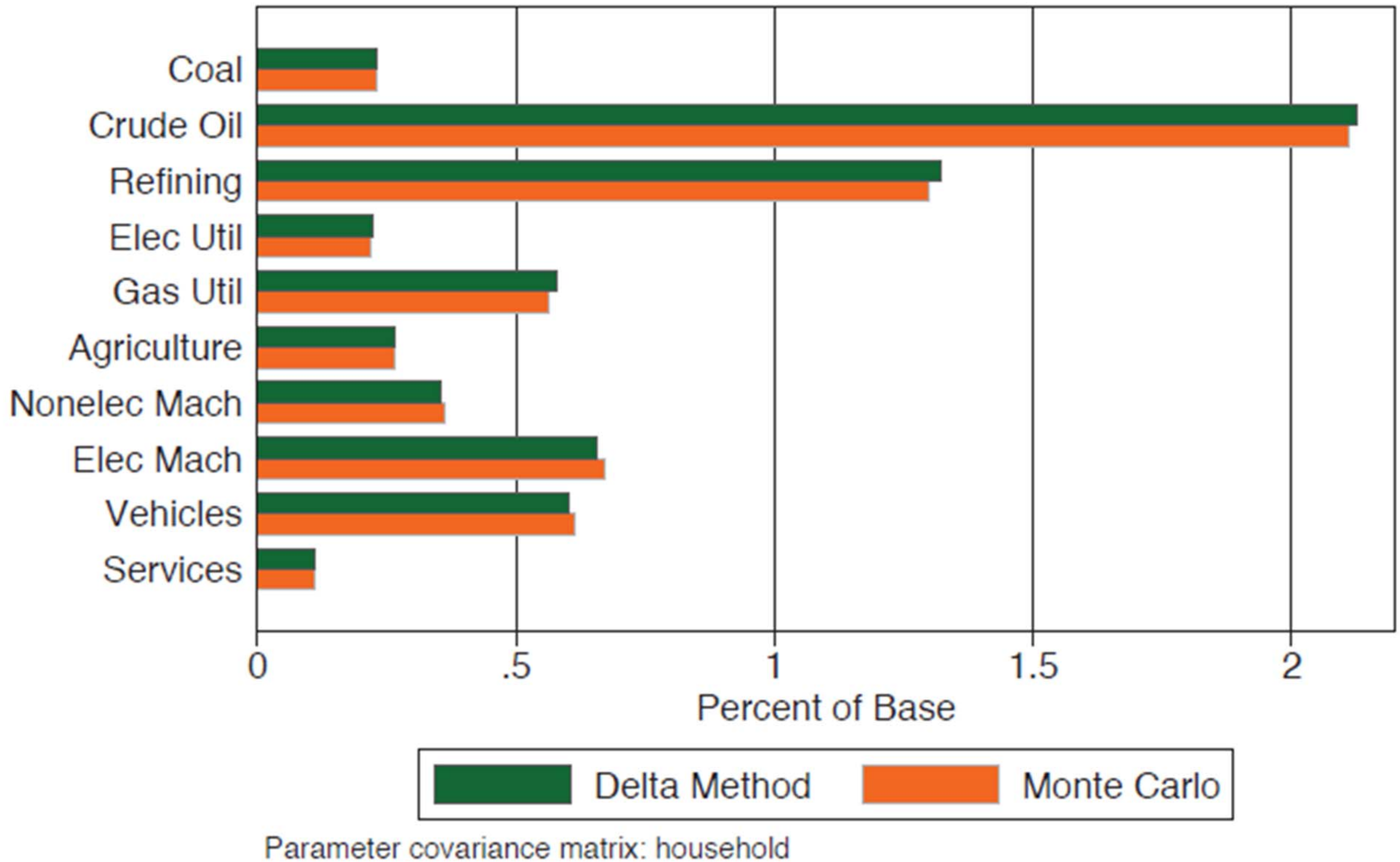


Figure 9.9
Results of delta versus Monte Carlo methods: Industry prices.

POLICY EVALUATION

Policy Outcome ΔY , 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 $e\Delta Y$:

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

Define ΔJ_β :

$$\Delta J_\beta = J_\beta |_{Xp} - J_\beta |_{Xb}$$

Asymptotic Covariance Matrix:

$$\Sigma_{\Delta Y} \approx \Delta J_\beta \Sigma_\beta \Delta J_\beta '$$

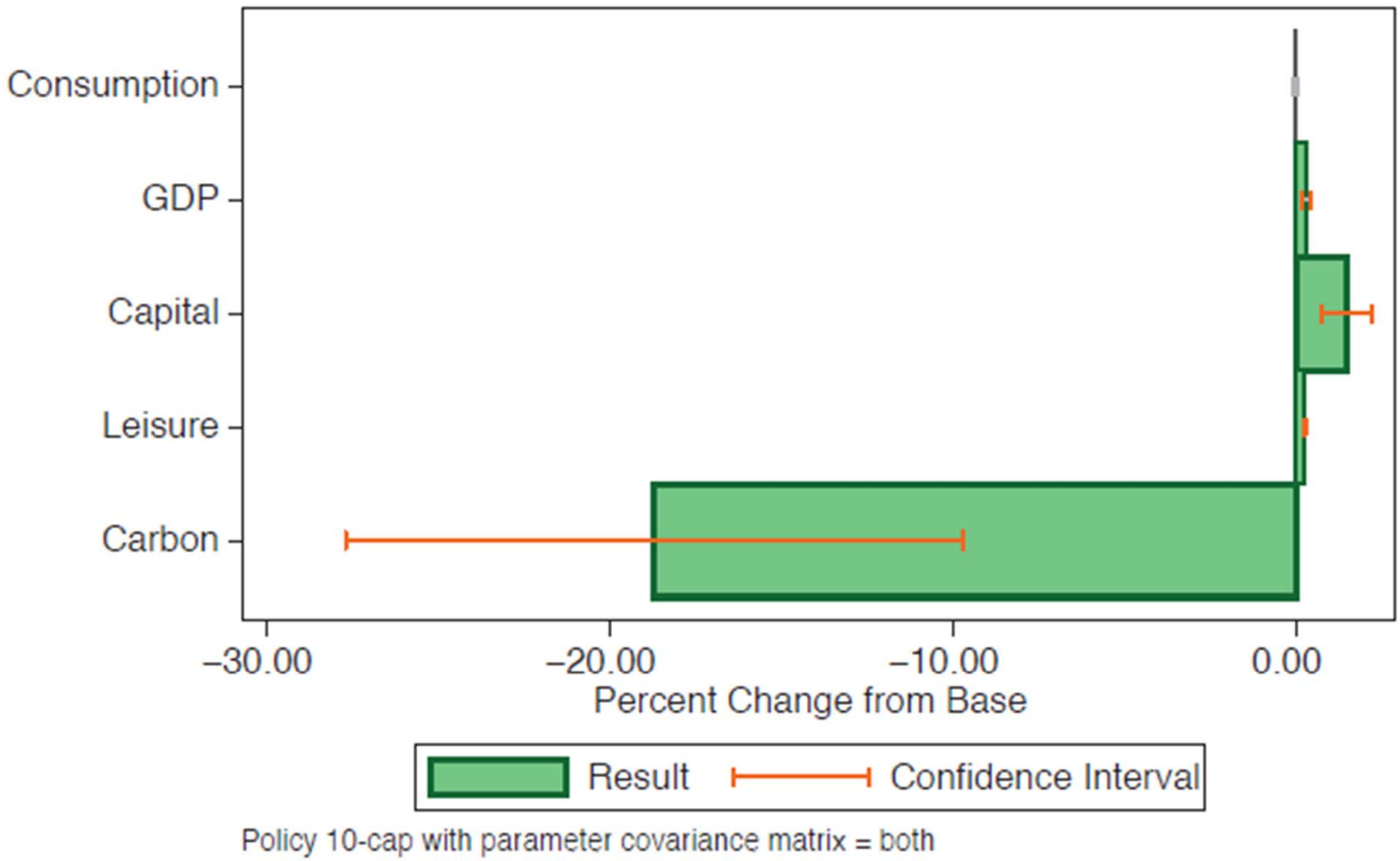


Figure 9.30
Confidence intervals: Key macroeconomic variables.

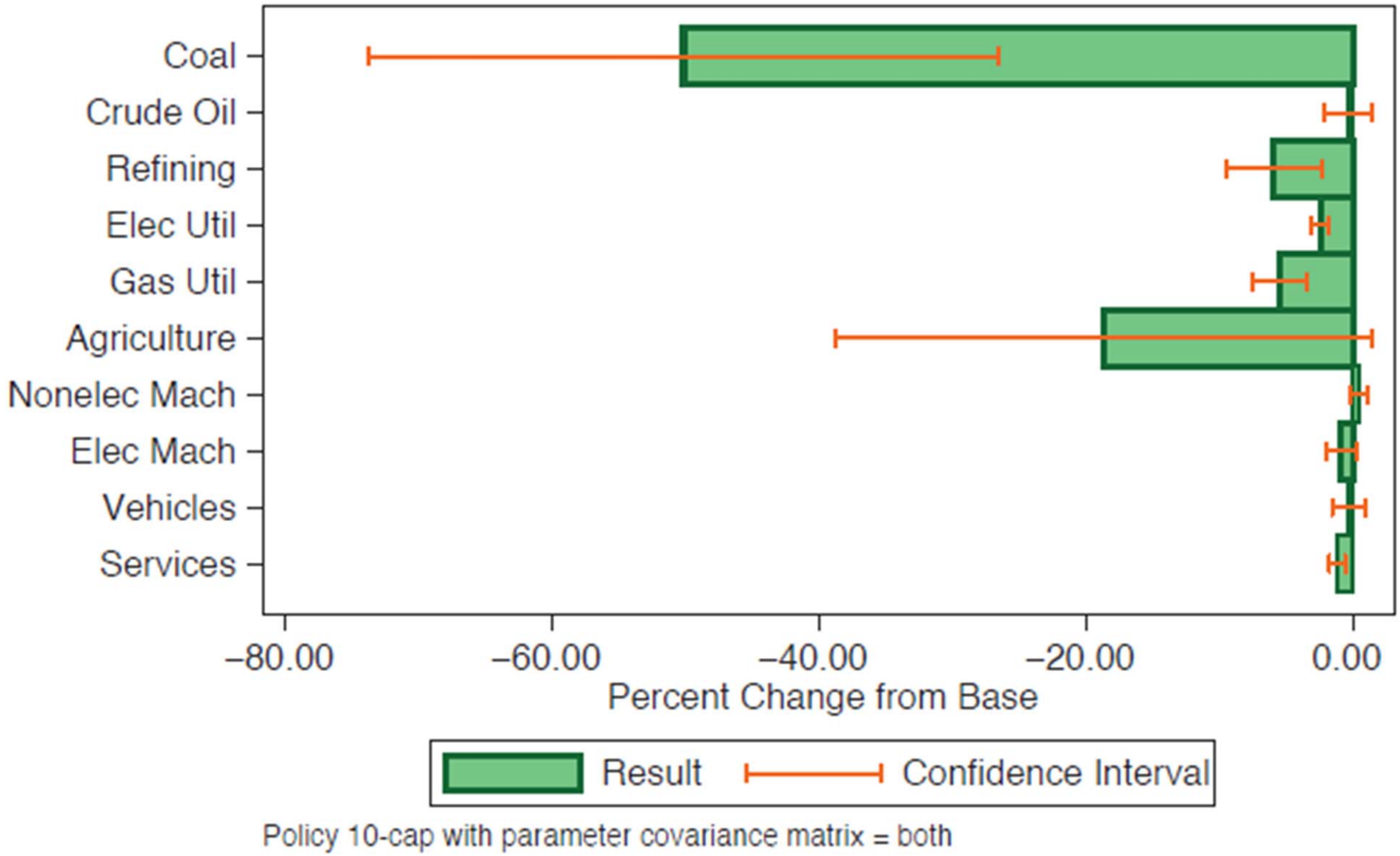


Figure 9.31
Confidence intervals: Industry output.

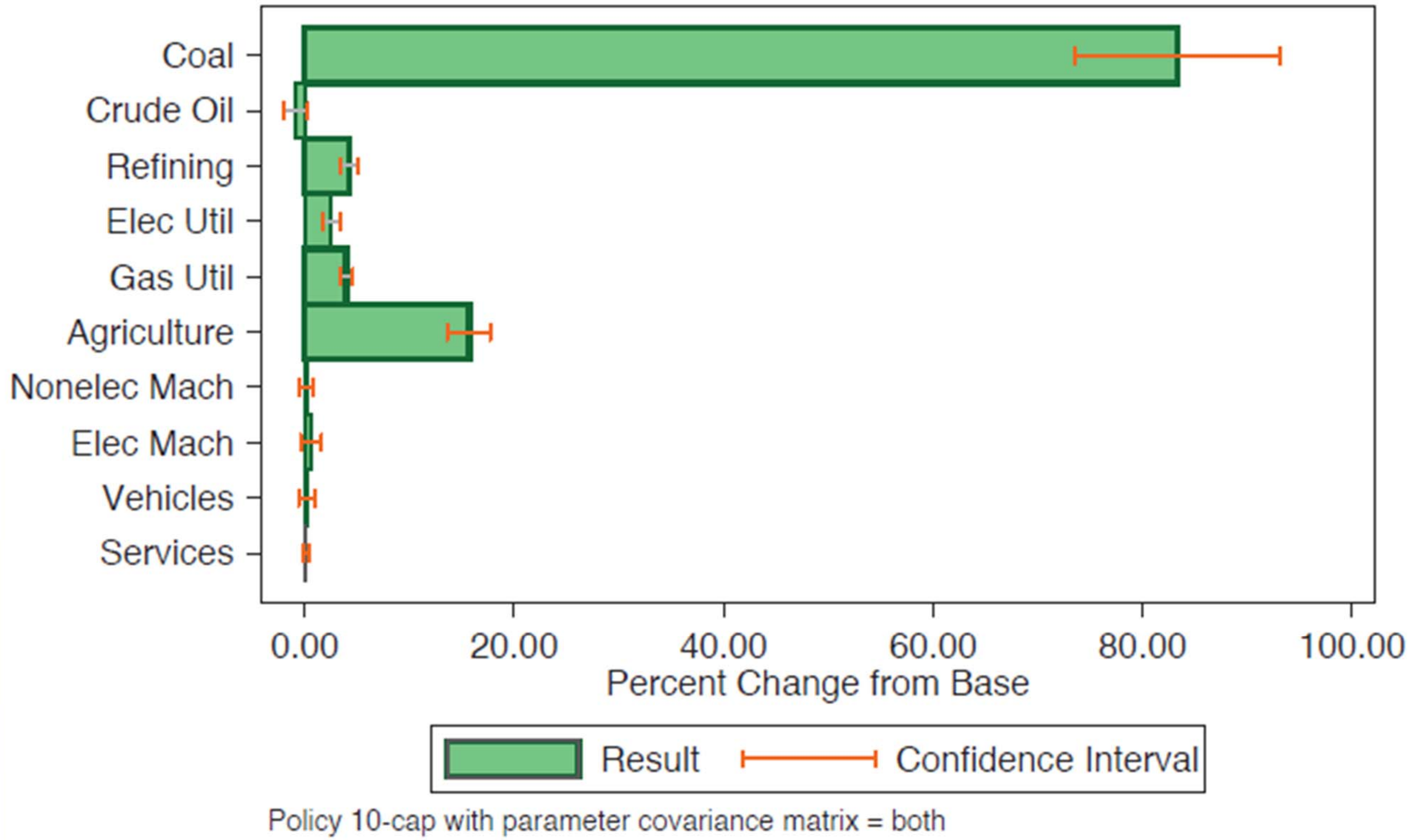


Figure 9.32
Confidence intervals: Industry prices.

DEMAND ANALYSIS

Notation:

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

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

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

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

Individual Expenditure Shares:

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

Aggregate Expenditure Shares:

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

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*:

$$\ln P_{Li} = \sum_j \beta_j^z z_{ji} + \sum_j \beta_j^s (S_i^* z_{ji}) + \sum_j \beta_j^{nw} (NW_i^* z_{ji}) + \sum_l \beta_l^g g_{li} + \varepsilon_{it} \qquad (8)$$

where:

P_{Li} -- wage of worker i.

$\mathbf{z_i}$ -- vector including age, age squared, education, education squared.

S_i -- dummy variable female.

NW_i -- dummy variable nonwhite.

$\mathbf{g_i}$ -- 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 $T_{kt}^{m} = q_{kt}^{m} * (14)$; 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.

Price and income elasticities (Reference household: Two adults, Two children, NE Urban, Male, White, Full expenditure = 100 K).

Good	Uncompensated price elasticity		Compensated price elasticity		Full expenditure elasticity	
	Rank 2	Rank 3	Rank 2	Rank 3	Rank 2	Rank 3
Nondurables	−0.918	−0.903	−0.822	−0.809	0.722	0.724
Capital services	−1.428	−1.432	−1.314	−1.319	0.926	0.930
Consumer services	−0.613	−0.614	−0.548	−0.548	1.088	1.096
Leisure	0.012	0.014	−0.323	−0.314	1.059	1.056
Labor supply	−0.026	−0.030	0.698	0.698	−2.289	−2.342

INDIVIDUAL WELFARE

Indirect Utility Function:

$$\ln V_k = \ln p'\alpha_p + \frac{1}{2}\ln p' B_{pp} \ln p - D(p)\ln\left[\frac{M_k}{m_0(p, A_k)}\right], \qquad (k = 1,2,\dots,K)$$

General Household Equivalence Scale:

$$\ln m_0(p, A_k) = \frac{1}{D(p)}\left[\ln m(A_k)'\alpha_p + \frac{1}{2}\ln m(A_k)' B_{pp} \ln m(A_k) + \ln m(A_k)' B_{pp} \ln p\right], (k = 1,2,\dots,K)$$

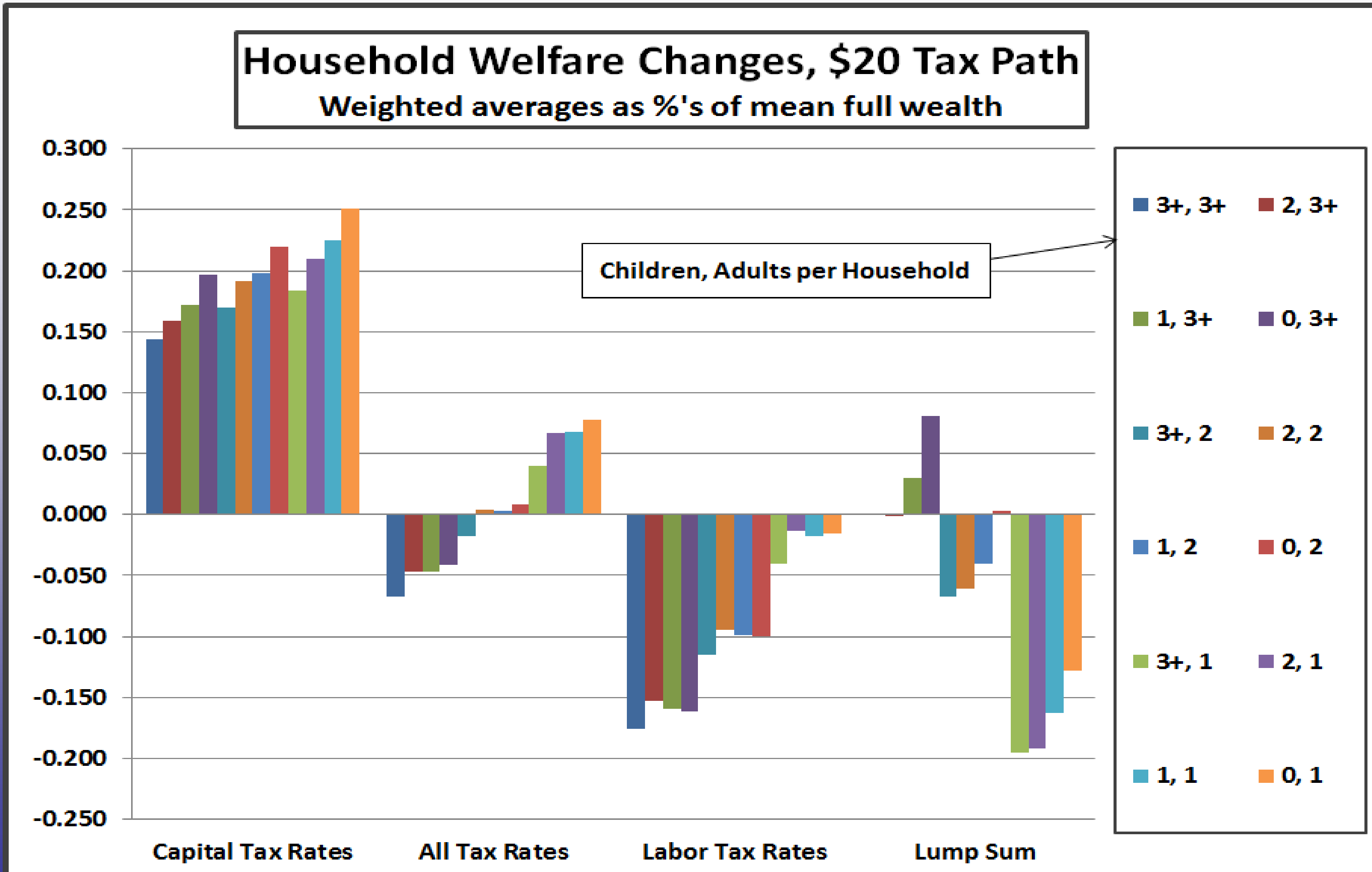
Where:

$$\ln m(A_k) = B_{pp}^{-1} B_{pA} A_k, \qquad (k = 1,2,\dots,K)$$

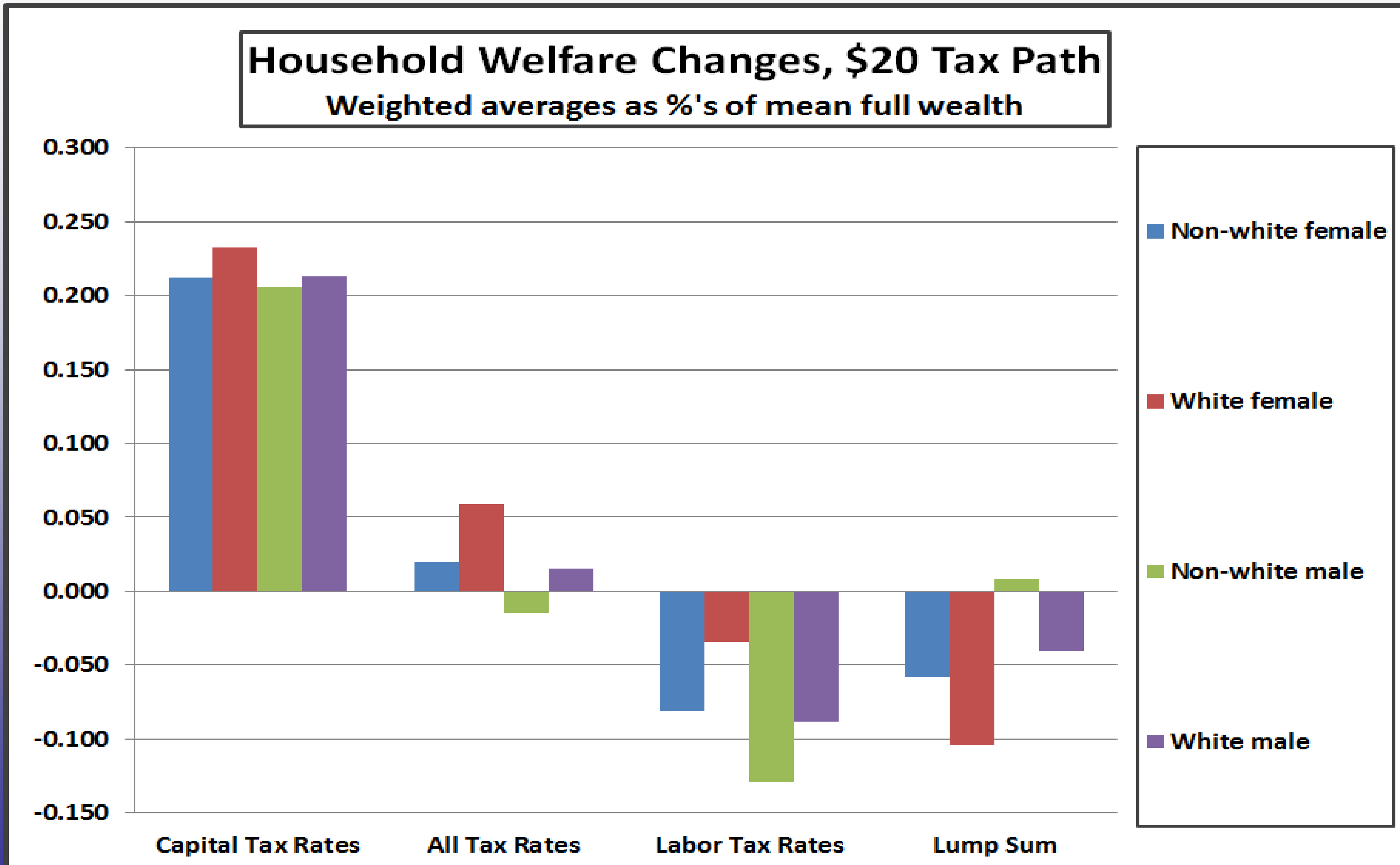
Individual Expenditure Function:

$$\ln M_k = \frac{1}{D(p)}\left[\ln p'\left(\alpha_p + \frac{1}{2}B_{pp}\ln p\right) - \ln V_k\right] + \ln m_0(p, A_k), \qquad (k = 1,2,\dots,K)$$

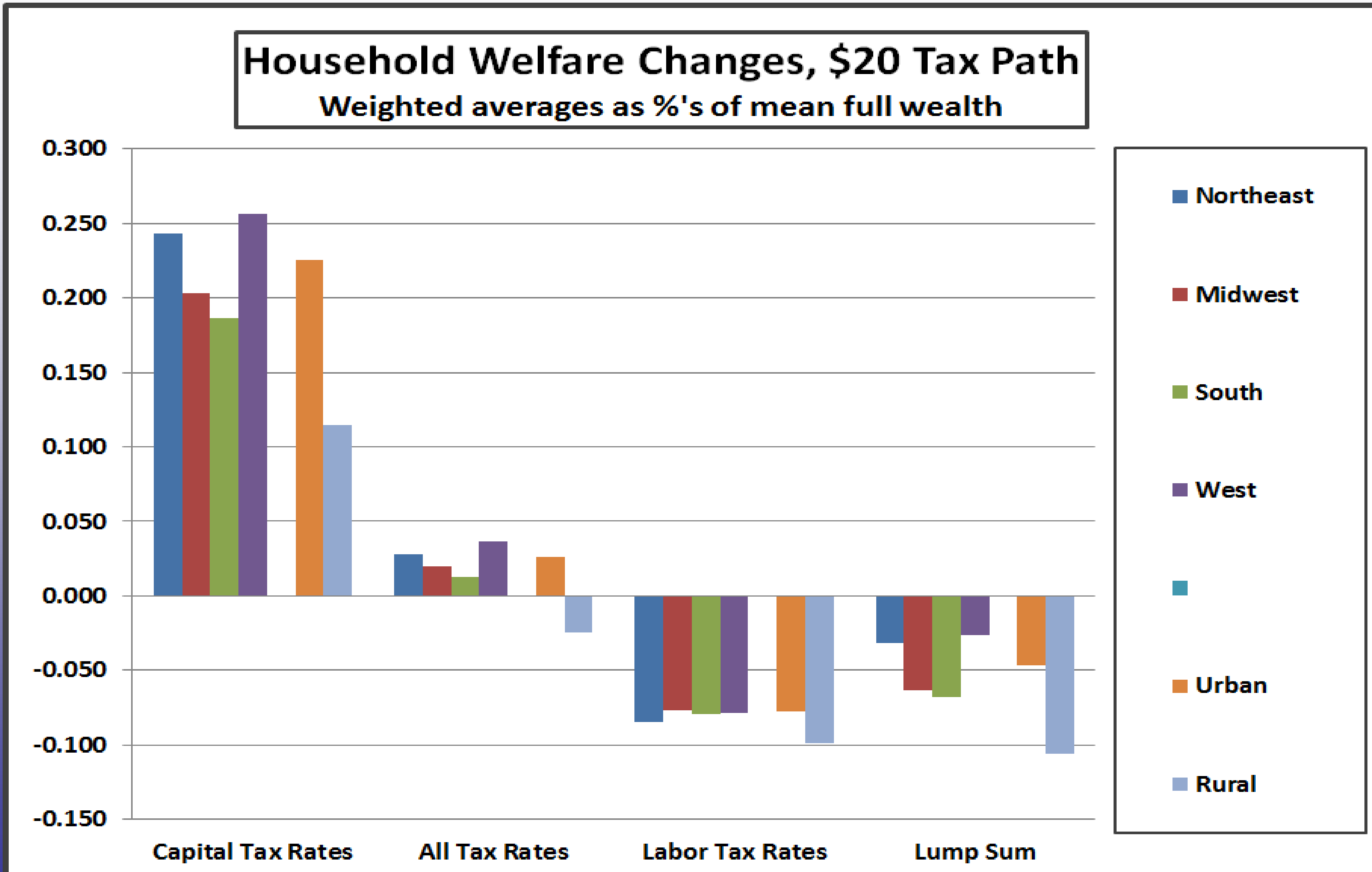
Household Welfare Effects, Family Size



Household Welfare Effects, Race & Gender of Head



Household Welfare Effects, Region & Location



SOCIAL WELFARE

Social Welfare Function:

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

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:

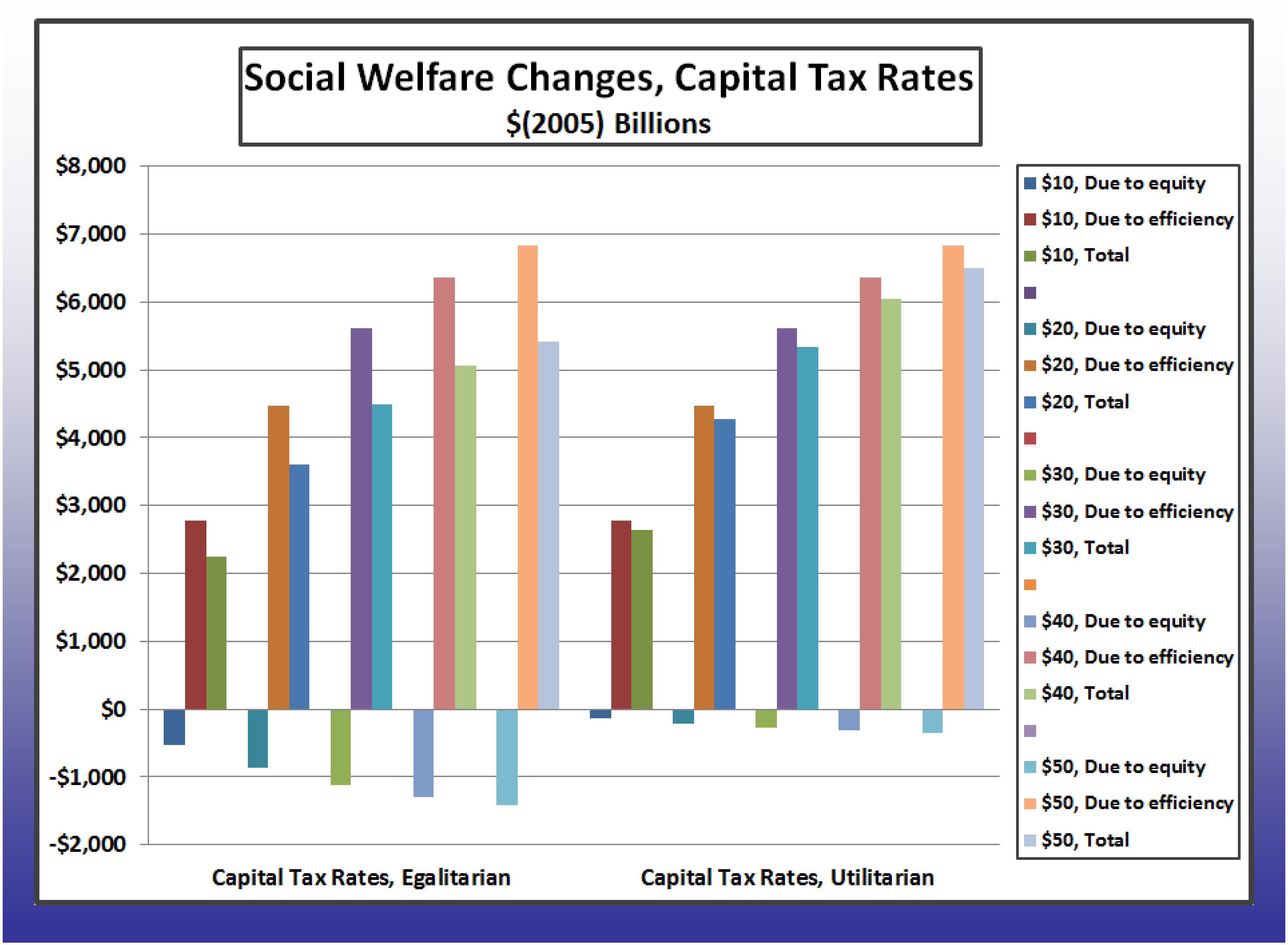
$$\gamma(x) = \left\{\frac{\sum_{k=!j}^{K} m_0(p,A_k)}{\sum_{k=1}^{K} m_0(p,A_k)}\left[1 + \left[\frac{\sum_{k=!j}^{K} m_0(p,A_k)}{m_0(p,A_k)}\right]^{-(\rho+1)}\right]\right\}^{1/\rho}$$

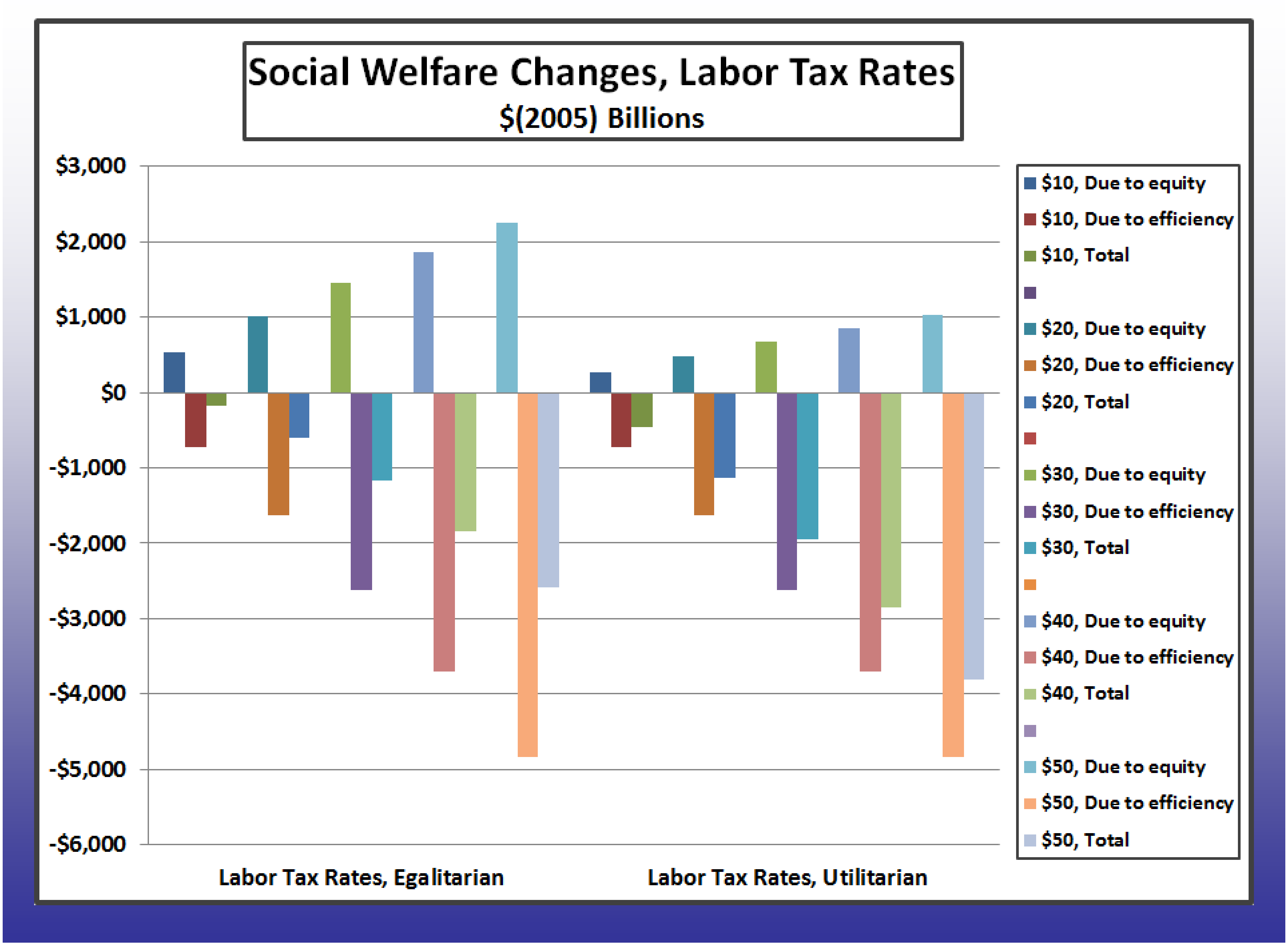
where:

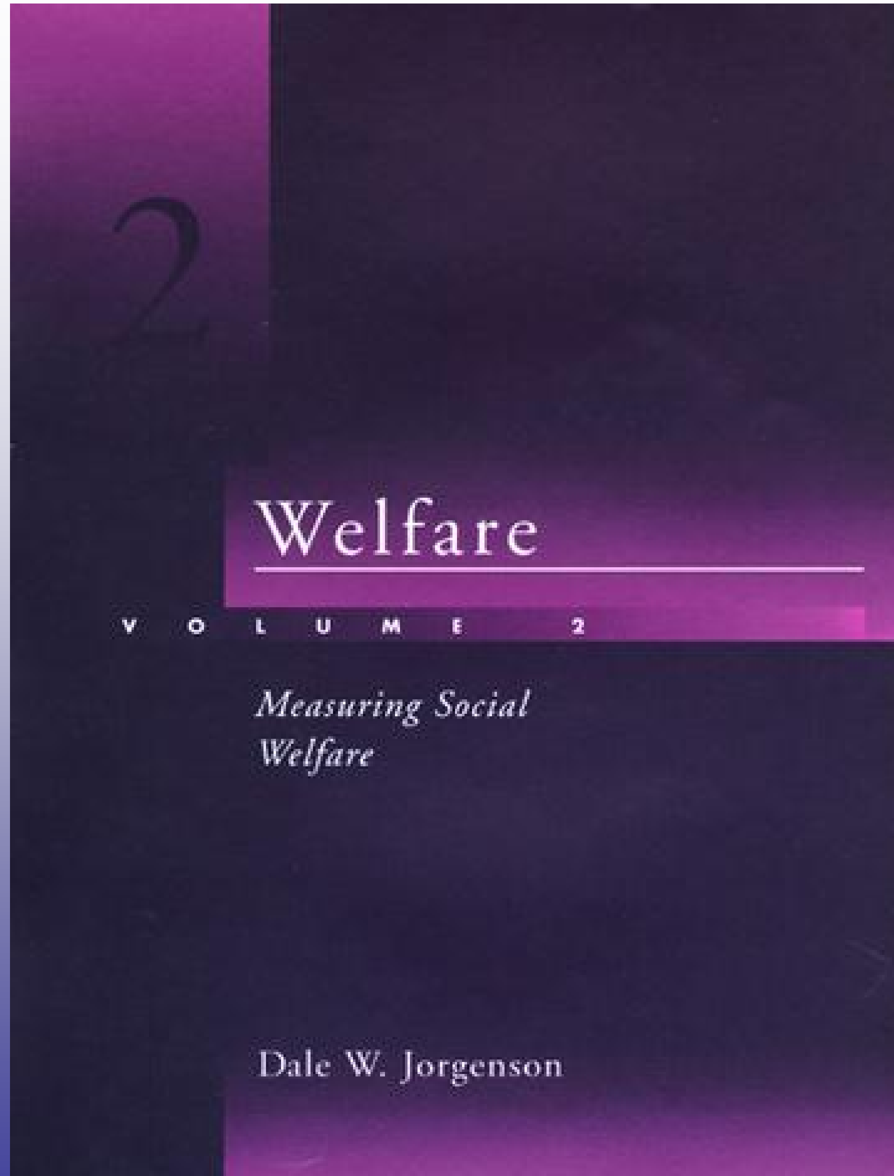
$$m_0(p,A_j) = \min_k\ m_0\,(p,A_k),\ \ (k = 1,2,\ldots,K)\ .$$

Social Expenditure Function:

$$\ln M(p,W) = \frac{1}{D(p)}\left[\ln p'\left(\alpha_p + \frac{1}{2}B_{pp}\ln p\right) - \ W\right] + \ln\left[\sum_{k=1}^{K} m_0(p,A_k)\right].$$


Social Welfare Changes, Capital Tax Rates
$(2005) Billions
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
-$1,000
-$2,000
Capital Tax Rates, Egalitarian
Capital Tax Rates, Utilitarian
$10, Due to equity
$10, Due to efficiency
$10, Total
$20, Due to equity
$20, Due to efficiency
$20, Total
$30, Due to equity
$30, Due to efficiency
$30, Total
$40, Due to equity
$40, Due to efficiency
$40, Total
$50, Due to equity
$50, Due to efficiency
$50, Total


Social Welfare Changes, Labor Tax Rates
$(2005) Billions
$3,000
$2,000
$1,000
$0
-$1,000
-$2,000
-$3,000
-$4,000
-$5,000
-$6,000
Labor Tax Rates, Egalitarian
Labor Tax Rates, Utilitarian
$10, Due to equity
$10, Due to efficiency
$10, Total
$20, Due to equity
$20, Due to efficiency
$20, Total
$30, Due to equity
$30, Due to efficiency
$30, Total
$40, Due to equity
$40, Due to efficiency
$40, Total
$50, Due to equity
$50, Due to efficiency
$50, Total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Welfare
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Measuring Social Welfare
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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:

$$\Sigma_{EV} = \Gamma_{\phi}' \Sigma_{\phi} \Gamma_{\phi} + \Gamma_{\theta}' \Sigma_{\theta} \Gamma_{\theta}$$

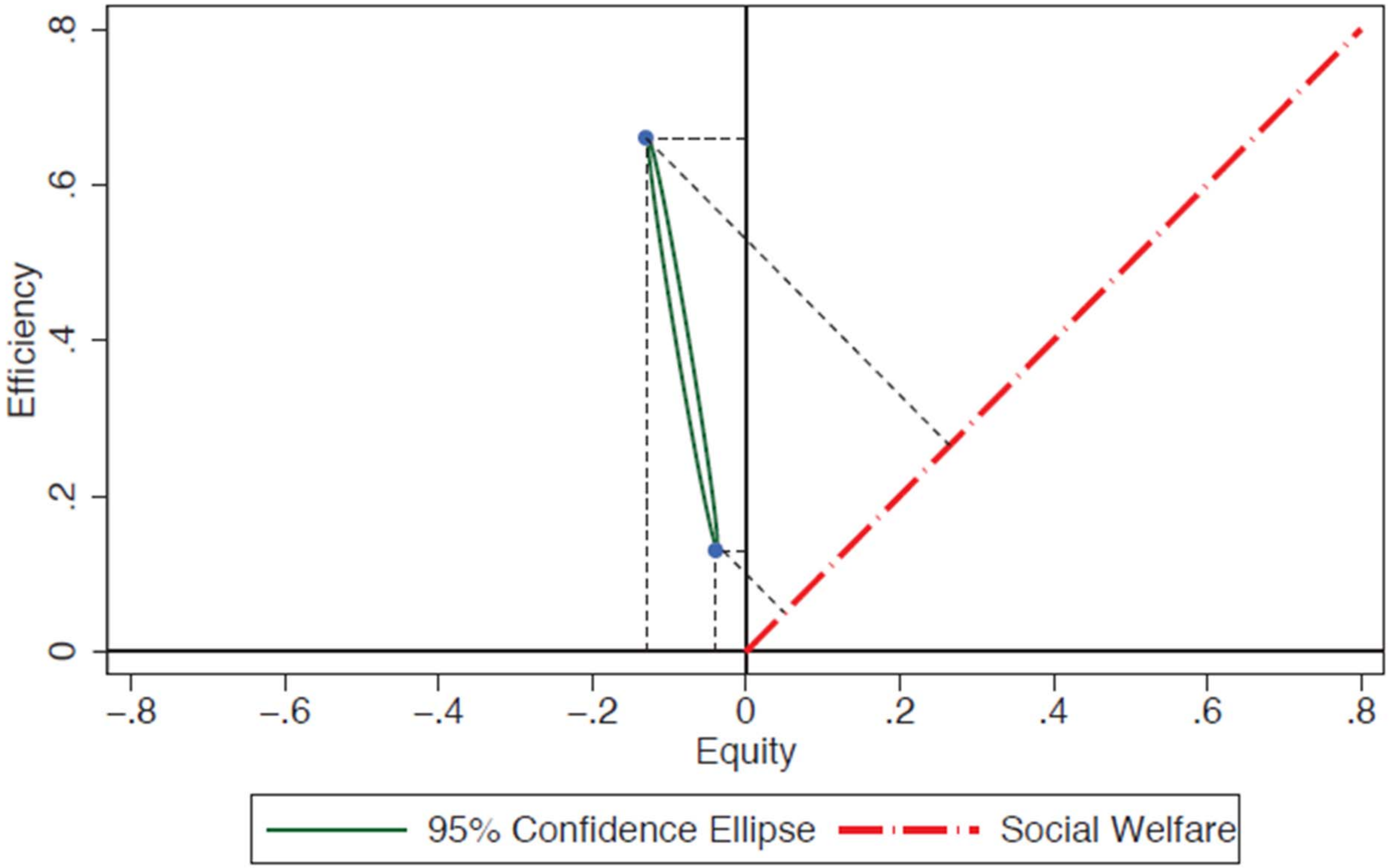

Figure 9.34
Confidence ellipse for the egalitarian measure of social welfare.

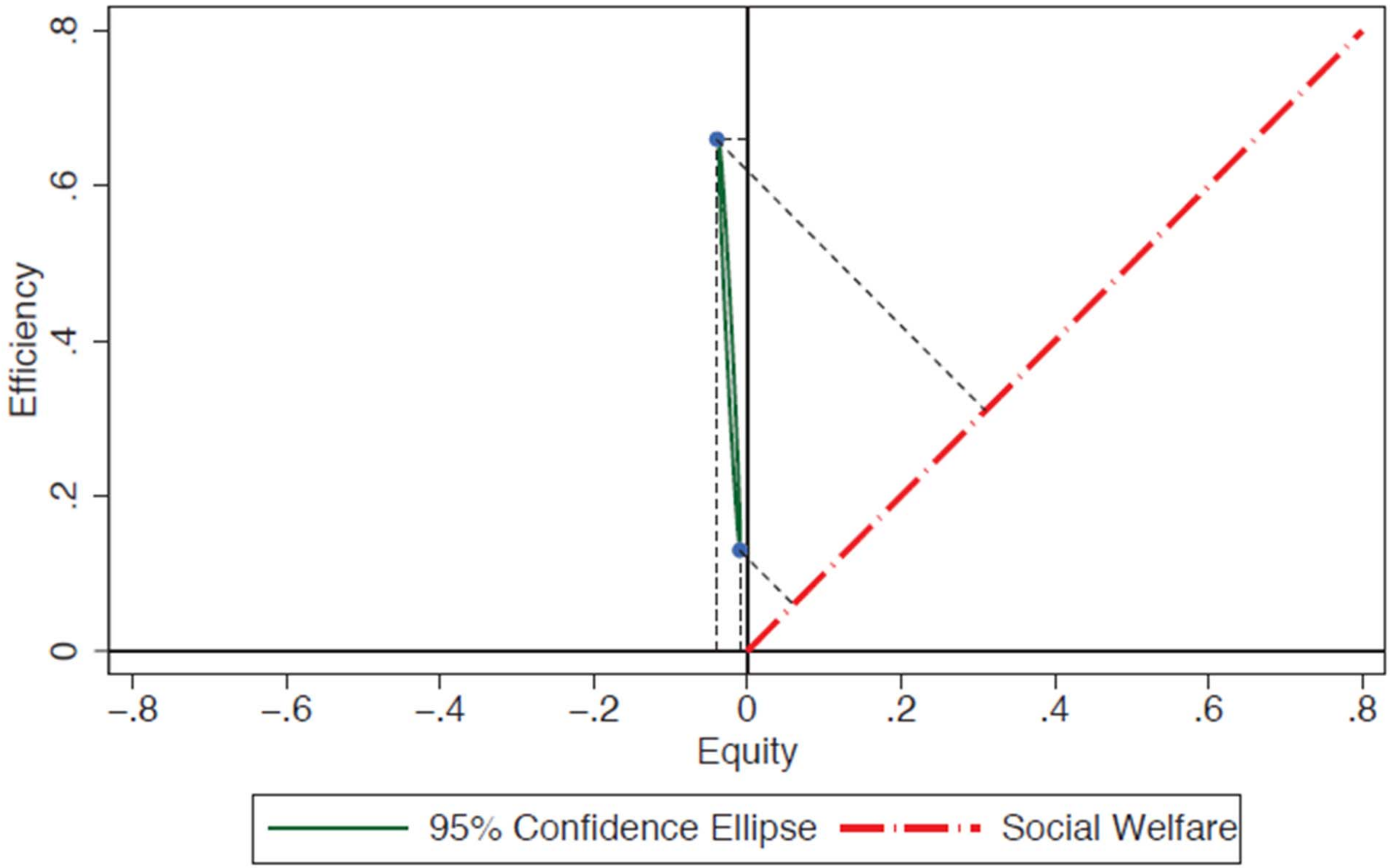

Figure 9.35
Confidence ellipse for the utilitarian measure of social welfare.

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.

Individual Welfare Is Given by the Indirect Utility Function.

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.