2/01/12 PRESENTATION: STATE TAX POLICY AND OIL PRODUCTION BY SHELBY GERKING

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Senate Resources Committee
February 1, 2012

Today, the Senate Resources Committee welcomes Dr. Shelby Gerking to present research that appears in Chapter 9 of this book, *U.S. Energy Tax Policy*. The chapter, co-authored by Dr. Gerking, is titled "State Tax Policy and Oil Production: The Role of the Severance Tax and Credits for Drilling Expenses."

The book was just published in 2011.

I have read two other research papers authored or co-authored by Dr. Gerking:

- "Effective Tax Rates on Oil and Gas Production: A Ten State Comparison (dated 2005)"

- "State Taxation, Exploration, and Production in the U.S. Oil Industry (dated 2001)"

As Dr. Gerking notes in his research, "Alaska has increased the severance tax on the value of its oil production and attempted to stimulate future production by allowing a credit against this tax for expenditures on capital items, including drilling rigs, infrastructure, exploration, and facility expansion."

While Alaska has not been the sole focus of Dr. Gerking's research, he has tracked the changes in our tax policy over the past decade. His research on state tax policy and oil production is, obviously, relevant to important issues before this committee and, indeed, the State of Alaska.

I am pleased that he is joining us, via teleconference, from The Sunshine State. Welcome, Dr. Gerking. Thank you for participating in this important legislative hearing.

[Gerking response]

For starters, please identify yourself for the record and tell the Committee about your educational background, professional work experience and, especially, your research and experience regarding state tax policy and oil production.

[Gerking response]

I understand that you have testified extensively before State legislatures. Can you please tell the Committee more about those experiences and the sort of information that you have provided other State Legislatures.

[Gerking response]

Thank you. Please proceed with your presentation.

V I T A
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Education:

B.A.	Economics, Indiana University, 1968
M.B.A.	University of Washington, 1970
M.A.	Economics, Indiana University, 1972
Ph.D.	Economics, Indiana University, 1975

Teaching and Research Fields:

Environmental and Natural Resource Economics
Regional Economics
Econometrics and Statistics

Academic Positions:

University of Central Florida, Galloway Professor, Department of Economics, 2001- present

Tilburg University, Professor, Department of Economics/Tilburg Sustainability Center, 2011-present

University of Alberta, Adjunct Professor, Department of Rural Economy, 2009-present

Free University of Amsterdam, Visiting Professor, Department of Spatial Economics, Fall 2007.

Tilburg University, Extramural Fellow of CentER, 2006 - 2011

University of Wyoming, Professor, Department of Economics and Finance, 1982 - 2001

Tilburg University, Visiting Fellow, Center for Economic Research (CentER), 1999-2000

University of Wyoming, Chair, Department of Economics and Finance, 1996 - 1999

University of Wyoming, Assistant to the President for Economic Development Coordination and Planning, 1988 - 1992.

University of Economics, Vienna, Austria, Visiting Scholar, Spring, 1985

University of Wyoming, Director, Institute for Policy Research, 1980 - 1984

University of Wyoming, Associate Professor, Department of Economics, 1978 - 1982

Indiana University, Visiting Assistant Professor, Department of Economics, 1977 - 1978

Arizona State University, Assistant Professor, Department of Economics, 1974 – 1978

Publications:

Books:

Estimation of Stochastic Input-Output Models: Some Statistical Problems. Leiden, The Netherlands: Martinus Nijhoff Social Sciences Division, 1976.

Frontiers in Environmental Economics, eds. Henk Folmer, Landis Gabel, Shelby Gerking, and Adam Rose. London: Elgar Publishing, 2001.

Articles:

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"Reconciling 'Rows Only' and 'Columns Only' Regional Coefficients in an Input-Output Model," International Regional Science Review, I, No. 2 (Fall 1976), 30-46.

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"The Wyoming Economy: Historical Trends and Projections," Southwestern Review of Management and Economics, II, No. 4 (Fall 1982), 37-55. (With J. Merrifield).

"Factor Rewards and the International Migration of Unskilled Labor: A Model with Capital Mobility," Journal of International Economics, XIV, No. 2 (May 1983), 367-80. (With J. H. Mutti).

"Compensating Differences and Interregional Wage Differentials," The Review of Economics and Statistics, LXV, No. 3 (August 1983), 483-87. (With W. Weirick).

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"An Economic Analysis of Air Pollution and Health: The Case of St. Louis," The Review of Economics and Statistics, LXVIII, No. 1, (February 1986), 115-121. (With L. Stanley). (Reprinted in Environmental Economics: A Reader, eds. Anil Markandya and Julie Richardson. London: St. Martin's Press, 1992).

"A Note on Measuring the Elasticity of Substitution of Wages for Municipal Infrastructure: A Comparison of the Survey and Wage Hedonic Approaches," Journal of Environmental Economics and Management, XIII, No. 3, (September 1986), 269-276. (With R. Cummings, W. Schulze and D. Brookshire).

"Regional Labor Market Analysis," in Handbook of Regional and Urban Economics, (eds.) Peter Nijkamp and Edwin Mills, Amsterdam: North-Holland, 1986, 543-580. (With A. M. Isserman, C. A. Taylor, and U. Schubert).

"The Economic Evaluation of Job Safety: A Methodological Survey and Some Estimates for Austria," Empirica, 1986, 53-67. (With P. Weiss and G. Maier).

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"Interregional Wage Differentials: An Equilibrium Perspective," Journal of Regional Science, XXVII, No. 4 (November 1987), 571-86. (With M. Dickie).

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"Measuring Productivity Growth in U.S. Regions: A Survey," International Regional Science Review, XVI, No. 1 and 2 (1994), 155-185 (reprinted in Modern Classics in Regional Science: Volume 4, eds. Kenneth J. Button and Peter Nijkamp, Cheltenham, UK, Edward Elgar Publishing, 1996).

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"Anti-Suppressants and the Creation and Use of Non-Survey Regional Input-Output Models," in Perspectives in Regional Science, (eds.) Ronald E. Miller and Michael Lahr, Amsterdam: Elsevier, 2001 (with A. Isserman and T. Pickton).

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"Environmental Policy and the Timing of Drilling and Production in the Oil and Gas Industry," in Recent Advances in Environmental Economics, (eds.) John A. List and Aart de Zeeuw, London: Elgar Publishing, 2002 (with M. Kunce and W. Morgan).

"Effects of Environmental and Land Use Regulation in the Oil and Gas Industry Using the Wyoming Checkerboard as an Experimental Design," American Economic Review, XCV, No. 5 (December 2002), 1588-1593 (with M. Kunce and W. Morgan).

"Foreign Direct Investment: Agglomeration Economies and Returns to Promotion Expenditures," Review of Regional Studies, XXXIII, No.1 (July 2003), 63-74. (with S-H Kim and T. Pickton).

"Parents' Valuation of Latent Health Risks to Their Children," in Risk and Uncertainty in Environmental Economics, (eds.) Justus Wesseler, Hans-Peter Weikard, and Robert Weaver, Cheltenham, UK: Elgar Publishing, 2003. (with M. Dickie).

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"Environmental and Land Use Regulation in Nonrenewable Resource Industries: Implications from the Wyoming Checkerboard," Land Economics LXXX, No.1 (February 2004), 75-93. (with M. Kunce and W. Morgan).

"What Determines the Success of States in Attracting SBIR Awards?" Economic Development Quarterly, XVIII, No. 1 (February 2004), 81-90. (with A. van der Vlist and H. Folmer).

"Knowledge Transfer and the Location of New ICT Firms," International Journal of Entrepreneurship and Innovation Management, IV, No.1 (2004), 11-19. (with D. van Soest and F. van Oort).

"Do Causes of Environmental Problems Affect Hicksian Equivalent Surplus? Evidence from the Field," Economics Letters, LXXXV, No. 2, (November 2004), 157-62. (with E. Bulte, J. List, and A. de Zeeuw).

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"The Effect of Varying the Causes of Environmental Problems on Stated WTP Values: Evidence from a Field Study," Journal of Environmental Economics and Management, XXXXVIIII, No. 2 (March 2005), 330-342. (with E. Bulte, J. List, and A. de Zeeuw). (Among most cited articles published in Elsevier's economics and finance journals, 2005-2009.)

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"Altruism and Environmental Risks to Health of Parents and their Children," Journal of Environmental Economics and Management, LIII, No. 3 (May 2007), 323-41. (with M. Dickie).

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"Effects of Environmental and Land Use Regulation in the Oil and Gas Industry Using the Wyoming Checkerboard as an Experimental Design: Retraction," American Economic Review, IIIC, No. 3 (June 2007), 1032. (with W. Morgan).

"Decentralization and Environmental Decision-Making," in Decentralization and Land Policies (eds.) Gregory K. Ingram and Yu-Hung Hong, Boston, MA, Lincoln Institute of Land Policy (2008).

"What Explains the Increased Utilization of Powder River Basin Coal in Electric Power Generation?" American Journal of Agricultural Economics, XC, No. 4 (November 2008), 933-950. (with Stephen F. Hamilton).

"Family Behavior: Implications for Health Benefits Transfer from Adults to Children," Environmental and Resource Economics, LXIII, No. 1 (May 2009), 31-43 (with Mark Dickie) (Special issue on household behavior and environmental policy).

"SO_2 Policy and Input Substitution under Spatial Monopoly," Resource and Energy Economics, XXXII, No. 3, (August 2010), 327-340. (with Stephen F. Hamilton).

"State Tax Policy and Oil Production: The Role of the Severance Tax and Credits for Drilling Expenses," in U. S. Energy Tax Policy (ed.) Gilbert Metcalf, Cambridge: Cambridge University Press, 2011 (with Ujjayant Chakravorty and Andrew Leach).

"Perceptions of Health Risk and the Smoking Decisions of Young People," Health Economics, forthcoming (with Raman Khaddaria).

"Andy Isserman and the Early Years of the *International Regional Science Review*," International Regional Science Review, forthcoming.

Grants:

"Development of Procedures for Predicting Water Quality Responses to Land Use Measures in the Salt River Basin," Granting Agency: Eisenhower Consortium. Contract Period: September 1, 1976 to August 31, 1978 (Co-Principal Investigator).

"Demand for Second Homes in the Salt River Basin," Granting Agency: Eisenhower Consortium. Contract Period: December 1, 1976 to November 30, 1978 (Principal Investigator).

"Methods Development for Estimation of Benefits of Environmental Improvements," Granting Agency: Environmental Protection Agency. Contract Period: October 29, 1976 to October 28, 1979 (Investigator).

"Methods Development for Estimating Benefits of Environmental Improvements," Granting Agency: Environmental Protection Agency. Contract Period: May 9, 1980 to October 28, 1980 (Investigator).

"Assessing Revenue Adequacy and Capital Facility Needs of Wyoming Local Governments," Granting Agency: Wyoming Department of Economic Planning and

Development. Contract Period: September 30, 1980 to January 15, 1981 (Principal Investigator).

"An Emergency Energy Conservation Plan for Wyoming," Granting Agency: Wyoming Department of Economic Planning and Development. Contract Period: January 16, 1981 to February 28, 1982 (Principal Investigator).

"The Economic Impact of Grand Teton National Park on Teton County, Wyoming," Granting Agency: National Park Service Research Center, University of Wyoming. Contract Period: May 1, 1981 to April 30, 1982 (Principal Investigator).

"Methods Development in Measuring Benefits of Environmental Improvements," Granting Agency: Environmental Protection Agency. Contract Period: June 9, 1981 to June 8, 1983 (Project Director).

"Development of Research Plan for Consortium on Energy Impacts," Granting Agency: Exxon, USA, Mobile Corporation, Gas Research Institute, Amoco Minerals, Inc., Getty Oil Corporation, Gulf Oil Corporation. Contract Period: February, 1982 to December, 1982 (Vice-Chairman, Research Program Committee).

"Recomputing County Specific Assessment Ratios for Certain Types of Property in Wyoming," Granting Agency: Wyoming State Legislature. Contract Period: May 1, 1983 to October 31, 1983 (Principal Investigator).

"Experimental Methods for Assessing Environmental Benefits," Granting Agency: U.S. Environmental Protection Agency. Contract Period: September 1, 1983 to September 30, 1984 (Project Director).

"Improving Accuracy and Reducing Costs of Environmental Benefit Assessments," Granting Agency: U.S. Environmental Protection Agency (via subcontract from University of Colorado). Contract Period: October 1, 1984 to August 30, 1987 (Principal Investigator).

"Potential Intrastate Air Travel for Wyoming State Employees," Granting Agency: Office of the Governor of Wyoming. Contract Period: September 15, 1985 to January 31, 1986 (Principal Investigator).

"Cooperative Industry/University of Wyoming Research Program," Granting Agency: National Science Foundation (University/Industry Cooperative Research Centers Program). Contract Period: October 1, 1986 - September 30, 1991 (R. E. Ewing, Project Director, S. Gerking, Evaluator).

"Economic Development and Diversification Strategies for Wyoming," Granting Agency: Wyoming Legislature and the University of Wyoming. Contract Period: July 2, 1986 to June 30, 1987 (Principal Investigator).

"Improving Environmental Benefit Assessments: Application Studies and Methods Development," Granting Agency: U.S. Environmental Protection Agency. Contract Period: October 1, 1987 to September 30, 1988 (Principal Investigator).

"Enhancement and Coordination of Energy Research: A Plan for Wyoming," Granting Agency: U.S. Department of Energy. Contract Period: October 1, 1991 - September 30, 1992 (Investigator).

"Environmental Research and Development Plan for Wyoming," Granting Agency: U.S. Environmental Protection Agency. Contract Period: October 1, 1991 - May 31, 1992 (Investigator).

"Knowledge Transfer to Stimulate Production of Wyoming Natural Gas," Granting Agency: National Science Foundation. Contract Period: July 15, 1994 - June 30, 1996 (Co-Principal Investigator).

"Public Costs and Benefits of Economic Development," Granting Agency: Wyoming Department of Commerce. Contract Period: April 1996 - August 1996 (Principal Investigator).

"Economic Impacts of the Wyoming Travel Industry," Granting Agency: Wyoming Travel Commission. Contract Period: July 1, 1995 – June 30, 2001 (Principal Investigator).

"Analysis of External Cost Adjustment Factors for Wyoming K-12 Education Finance," Granting Agency: Wyoming Legislative Service Office. Contract Period: June 1, 1999 – July 31, 1999 (Principal Investigator).

"Mineral Tax Incentives and Mineral Production: An Interstate Analysis," Granting Agency: Wyoming Legislative Service Office. Contract Period: July 1, 1999 – June 30, 2004 (Principal Investigator).

"Environmental Risks to Children's Health: Parents' Risk Beliefs, Protective Behavior and Willingness to Pay," Granting Agency: USEPA. Contract Period: April 1, 2001—December 31, 2005 (Co-principal Investigator).

"Willingness to Pay to Reduce Asthma Episodes for Adults and Children," Granting Agency: USEPA. Contract Period: October 1, 2002-September 30, 2007 (Co-Principal Investigator).

"A Consistent Framework for Valuing Latent Morbidity and Mortality Risks to Adults and Children," Granting Agency: USEPA. Contract period: November 1, 2004-October 31, 2008 (Co-Principal Investigator).

"Morbidity Valuation, Benefit Transfer and Family Behavior," Granting Agency: USEPA. Contract period: April 1, 2007-March 31, 2011 (Co-Principal Investigator).

"Fischer-Tropsch Synthesis, Combustion/Emission Characteristics and Economic Impact of Synthetic Jet Fuels," Granting Agency: NASA. Contract Period: January 1, 2007-June 30, 2008 (Co-Principal Investigator).

Other Papers and Documents:

Some Statistical Problems in Estimating Stochastic Input-Output Models, unpublished Ph.D. dissertation, Indiana University, 1975.

"Linear Programming and the Value of Resources," Arizona Business, XXII (July, 1975), pp. 17-24. (With others).

Environmental Baseline Studies for Crow-Indian Coal Leases Socio-Economic Report. Prepared for Westmoreland Resources under the direction of Mountain West Research, Inc., 1975. (With others)

Arizona's Economy Yesterday, Today and Tomorrow. Tempe, Arizona: Bureau of Business and Economic Research, 1976. (With others).

"Development of Procedures for Predicting Water Quality Responses to Land Use Measures in the Salt River Basin," Eisenhower Consortium Report, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado, 1976. (With others).

"The Demand for Second Homes in Northeastern Arizona," Eisenhower Consortium Report, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado, 1977. (With others).

"Some Economics of Air Pollution-Induced Chronic Illness," Experiments in Air Pollution Epidemiology, Washington, D.C., USEPA, 1980.

"Effects of Air Pollution and Environmental Variables on Offered Wages," Experiments in Air Pollution Epidemiology, Washington, D.C., USEPA, 1981.

"Assessing Revenue and Capital Facility Needs in Wyoming Local Governments," University of Wyoming: Institute for Policy Research, 1981. (With A. Bryson, S. Nyhus, and J. Merrifield).

"Emergency Energy Conservation Act Management Plan for Wyoming," University of Wyoming, Laramie: Institute for Policy Research, 1981. (With A. Bryson, S. Nyhus, and J. Merrifield).

"Incidence of a Mineral Severance Tax: The Case of Kansas," University of Wyoming, Laramie: Institute for Policy Research, February, 1981. (With J. Mutti and W. Morgan).

"Exportation of State Taxes: A Comparative Analysis." University of Wyoming, Laramie: Institute for Policy Research, February, 1982. (With J. Mutti and W. Morgan).

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"Production and Taxation in Wyoming's Energy Industry: The Case of Crude Oil, Natural Gas, and Carbon Dioxide," Enhanced Oil Recovery Institute, University of Wyoming, Laramie, Wyoming, January, 1986. (With R. E. Ewing).

"Potential for Commercial Air Travel by Wyoming State Employees," Institute for Policy Research, University of Wyoming, Laramie, January, 1986. (With A. Weber).

"Value of Symptoms of Ozone Exposure: An Application of the Averting Behavior Method," in Improving Accuracy and Reducing Costs of Environmental Benefit Assessments, U.S. Environmental Protection Agency, Final Report, Cooperative Agreement #CR812054-01-2, September, 1986. (With others).

"Reconciling Averting Behavior and Contingent Valuation Benefit Estimates of Reducing Symptoms of Ozone Exposure," in Improving Accuracy and Reducing Costs of Environmental Benefit Assessments, U.S. Environmental Protection Agency, Cooperative Agreement #CR812054-01-2, February, 1987. (With others).

"Economic Development and Diversification Strategies for Wyoming," Institute for Policy Research, University of Wyoming, Laramie, Wyoming, July, 1987. (With S. K. Yost).

"Valuing Morbidity: An Overview and State of the Art Assessment," in Improving Accuracy and Reducing Costs of Environmental Benefit Assessments, U.S. Environmental Protection Agency, Cooperative Agreement #CR812054-01-2, December, 1987. (With others).

"Historical Profile of the University of Wyoming Enhanced Oil Recovery Institute," National Science Foundation, University/Industry Cooperative Research Program, January, 1988.

"Stratospheric Ozone Depletion, Skin Damage Risks, and Protective Action," in Improving Environmental Benefit Assessments, U.S. Environmental Protection

Agency, Cooperative Agreement #CR-814647-01-0, October, 1989. (With M. Dickie and M. Agee).

"Report on State-Federal Technology Partnership Colloquium," in Science and Technology Linkage (Proceedings of the Ninth Annual EPSCoR Conference), Rapid City, South Dakota, University of South Dakota, 1994.

"Wyoming's Economy: An Historical Perspective and Forecast," Department of Economics, University of Wyoming, February 1994.

"The Future of Minerals in Wyoming: Revenue Analysis," Institute for Energy Research, University of Wyoming, November 1995.

"Income, Revenue from Personal Taxes, and Public Service Costs," Department of Economics and Finance, University of Wyoming, May 1996.

"Wyoming's Economy, Tax Structure, and Prospects for Economic Growth," Department of Economics and Finance, University of Wyoming, June 1996.

"Economic Impact of the Yellowstone National Park Closure on Teton and Park Counties," Department of Economics and Finance, University of Wyoming, June 1996.

"The Economic Contribution of the Travel Industry in Wyoming," Morey and Associates, Jackson, Wyoming, April 1997. (With Michael Morey).

"Productivity," World Book Encyclopedia, 1998.

"Review of Industrial Incentives: Competition Among American States and Cities, by Peter S. Fisher and Alan H. Peters. 1998. Kalamazoo, Michigan: Upjohn," Journal of Regional Science, XXXIX, No. 2 (May 1999), 411-413.

"Analysis of External Cost Adjustment Factors in Wyoming K-12 Education Finance," University of Wyoming, July 1999.

"Mineral Tax Incentives, Mineral Production and the Wyoming Economy," Department of Economics and Finance, University of Wyoming, December 1, 2000.

'Income, Revenue from Personal Taxes, and Public Service Costs in Orange County, Florida," Institute for Economic Competitiveness, University of Central Florida, September 30, 2004.

"Taxation of Oil and Gas: A Ten State Comparison," University of Central Florida, April 11, 2005.

"A Consistent Framwework for Valuing Latent Morbidity and Mortality Risks to Adults and Children," United States Environmental Protection Agency, RD-83159201-0, July 9, 2009 (with Mark Dickie).

"Morbidity Valuation, Benefit Transfer and Family Behavior," United States Environmental Protection Agency, RD-83326301-0, July 31, 2011.

Professional Service:

Editorships:

Associate Editor, Journal of Regional Science, 1996 - present.

Guest Editor (with Stephen C. Sheppard and Andrew M. Isserman) symposium issue in honor of Roger Bolton, International Regional Science Review, July, 2009.

Editorial Board member, International Review of Environmental and Resource Economics, 2006-present.

Editorial Board member, Letters in Spatial and Resource Economics, 2006-2010.

Guest Editor (with G.W. Harrison and J.A. List) for symposium issue on risk perception, valuation, and policy, Environmental and Resource Economics XXXIII, No.3, March 2006.

Editorial Board member, International Yearbook in Environmental Economics, 1995-2005.

Editorial Board member, International Regional Science Review, 1986 - present.

Editorial Council member, Journal of Environmental Economics and Management, 1989 - 1991.

Editorial Board member, Growth and Change, 1988 - 1993.

Co-Editor, International Regional Science Review, 1979 - 1986.

Guest Editor for a symposium issue in honor of William H. Miernyk, Socioeconomic Planning Sciences, XVIII, No. 5, (1984).

Advisory Editor, Wyoming Quarterly Update, 1981 - 1984.

Government Service (federal/international):

Greek Ministry of Education, External reviewer for the Archimedes III research program (2010-present)

European Commission, European Research Council, Advanced Grants Panel, 2008-2013.

U.S. Environmental Protection Agency, Science Advisory Board Council on Clean Air Compliance Analysis, 2006-2012.

U.S. Environmental Protection Agency, STAR and GRO Fellowships "Economics" Review Panel, 2005-2007.

Special Reviewer, Social Sciences and Population Study Committee, National Institute of Child Health and Human Development, June, 1983.

Visiting Staff Member, Los Alamos Scientific Laboratory, 1981 - 82.

Member, Special Study Committee on International Migration, National Institute of Child Health and Human Development, March, 1980.

Judge, Ph.D. Dissertation Competition, sponsored jointly by Regional Science Association and Economic Development Administration, Fall, 1979.

Government Appointments (Wyoming):

Tax Reform 2000 Committee, 1997-1999.

Experimental Program to Stimulate Competitive Research (EPSCoR) Steering Committee, 1985-1995.

Economic Development and Stabilization Board, 1988-1993.

Science, Technology and Energy Authority, 1989-1993 (Executive Director).

Science Advisor, Governor's Office, 1993-1994.

Member, Peacekeeper Modeling Task Force, University of Wyoming representative, April, 1983 - September, 1984.

Other Service:

Co-Chair, Local Arrangements Committee for Miami meeting, North American Regional Science Council, November 2011

Member, Program Committee, Annual Meetings of the European Association of Environmental and Resource Economists, 2007, 2009, 2011, 2012

Member, Program Committee, Annual Meetings of the Association of Environmental and Resource Economists, 2011, 2012

Member Program Committee, World Congress of Environmental Economists, 2010

Councillor, Regional Science Association, International, 1986 – 1988

Proposal Reviewer for:

Rockefeller Foundation (Research Program on U.S. Immigration Policy)
National Science Foundation (Economics and Geography and Regional Science)
Environmental Protection Agency (Health Effects of Air Pollution)
Public Policy Institute of California (policy issues facing California)
Economic and Social Research Council, United Kingdom

Referee for:

Economic Journal
International Economic Review
Review of Economics and Statistics
Southern Economic Journal
Journal of Environmental Economics and Management
American Journal of Agricultural Economics
Ricerche Economiche
Journal of Regional Science
Regional Science and Urban Economics
Papers, Regional Science Association
Environmental and Planning, A
Growth and Change
International Regional Science Review
Social Science Journal
Social Science Quarterly
Defense Economics
Journal of Risk and Uncertainty
Review of International Economics
Environment and Development Economics
Journal of Geographical Systems
Urban Studies
Resource and Energy Economics

Ecological Economics
Environmental and Resource Economics
Journal of Political Economy
Rand Journal of Economics
Experimental Economics
Contemporary Economic Policy
Land Economics

Doctoral Students:

Raman Khaddaria, Department of Economics, University of Central Florida (Ph.D. granted August 2011)

Anne Alexander, Department of Economics, University of Wyoming (Ph.D. granted May 2001)

John A. List, Department of Economics, University of Chicago (Ph.D. granted August 1996)

Mark T. Dickie, Department of Economics, University of Central Florida (Ph.D. granted May 1987)

John Merrifield, Department of Economics, University of Texas, San Antonio (Ph.D. granted December 1984)

William N. Weirick, Department of Economics, Louisiana State University, Monroe, Louisiana (Ph.D. granted December 1984)

Dennis O. Olson, Department of Finance, University of Northern British Columbia, Prince George, British Columbia (Ph.D. granted July 1982)

Fellowships, Honors, and Awards:

Visiting Grant, Netherlands Organization for Scientific Research (NWO), 1999-2000.

Flittie Sabbatical Award, University of Wyoming, 1999-2000.

Top Professor, awarded by UW Chapter of Mortar Board, 1994.

Certificate of Appreciation, awarded by Wyoming Governor Sullivan, September 1993.

UW President's Speakers Series Lecture, 1991.

Medal of Achievement in Regional Economics, awarded by Council on Regional Economy, USSR Academy of Sciences, Moscow, 1990.

Grant-in-Aid of Research, Department of Economics, University of Wyoming, Summer 1978.

Grant-in-Aid of Research, Office of Grants and Contracts, Arizona State University, Summer 1976 and Summer 1977.

Henry M. Oliver Prize for Distinguished Achievement in Economics, awarded by the Department of Economics, Indiana University, 1975.

Finalist, Ph.D. Dissertation Competition, sponsored jointly by the Regional Science Association and the Economic Development Administration, Fall 1975.

Dissertation Fellowship in Applied Urban Economics, Indiana University, 1973 - 1974.

Grant-in-Aid of Research, Division of Research, Indiana University, 1973 - 1974.

Fellowship for Graduate Study in Business, University of Washington, 1968 - 1969.

Selected Presentations:

University of Illinois, Andrew Isserman Memorial Conference, November 2011

Tinbergen Institute, Labor and Environmental Economics Seminar, April 2011

Tilburg University, Tilburg Sustainability Center, October 2010

ETH Zurich, Seminar in Energy, Environmental and Resource Economics, May 2010

American Tax Policy Institute, October 2009

Canadian Resource and Environmental Economics Study Group, October 2009.

Tilburg University, CentER, September 2008

University of Alberta, Department of Economics, September 2008

Georgia State University, Department of Economics, April 2008

Netherlands Environmental Assessment Agency, November 2007

Erasmus University Rotterdam, Tinbergen Institute, November 2006

University of Illinois, Department of Agricultural and Consumer Economics, September 2006

NBER Summer Institute, Environmental Economics Workshop, July 2006.

Conference on Valuing Environmental Health Risk Reduction to Children, USEPA National Centers for Environmental Research and Environmental Economics, April 2006.

University of Wyoming, Casper College Center, November 2004.

University of Maryland, Agricultural and Resource Economics Department, October 2004.

NBER Summer Institute, Environmental Economics Workshop, August 2004

University of Wyoming, Stroock Forum on Wyoming Lands and People, April 2004.

Free University of Amsterdam, Department of Spatial Economics, February, 2004.

Conference on Valuing Environmental Health Risk Reduction to Children, USEPA National Centers for Environmental Research and Environmental Economics, October, 2003.

University of Durham, Department of Economics, September 2003.

International Conference on Environmental Risk Assessment, Wageningen Agricultural University, June 2002.

University of South Florida, Department of Economics, Tampa, Florida, December 2001.

UCF/CentER International Conference on Environmental Economics and Policy, Orlando, Florida, December 2000.

University of Illinois, Departments of Natural Resources and Environmental Sciences and Agricultural and Consumer Economics, November 2000.

Colorado State University, Department of Economics, October 2000.

European Science Foundation Conference on International Dimensions of Environmental Policy, Kerkrade, the Netherlands, October 2000.

University of York, Department of Environment, York, United Kingdom, May 2000.

University of Groningen, Economics Faculty, Groningen, the Netherlands, May 1985 and February 2000.

University of Nevada, Las Vegas, Department of Economics, December 1999.

Netherlands Organization for Scientific Research, Conference on Environmental Policy and Industrial Location, Maastricht, the Netherlands, October 1999.

Tinbergen Institute, Amsterdam, the Netherlands, October 1999.

Tilburg Unversity, Center for Economic Research (CentER), Tilburg, the Netherlands, September 1999.

Indiana University, School of Public and Environmental Affairs, January 1997.

University of Central Florida, College of Business, March 1997, March 1999.

Western Economic Roundtable, Center for the New West, Denver, Colorado, February 1994, June 1996, and September 1998.

University of Kentucky, Department of Economics, Lexington, Kentucky, November 1995.

West Virginia University, Regional Research Institute, Morgantown, West Virginia, November 1995.

Wageningen Agricultural University, Department of General Economics, Wageningen, the Netherlands, September 1994.

Montana State University, Bozeman, Montana, Department of Agricultural Economics and Economics, May, 1993

University of Maine, Orono, Maine, Department of Economics, March 1991.

West Virginia University, Morgantown, West Virginia, Conference marking the 25th Anniversary of the Regional Research Institute, 1990.

US-USSR Commission on the Humanities and Social Sciences of the American Council of Learned Societies and the Soviet Academy of Sciences, Fourth Soviet-American Seminar on Regional Economics and Planning, Yalta, USSR, 1990.

USSR Academy of Sciences, Central Economics and Mathematics Institute, Moscow, 1990.

University of Florida, Gainesville, Florida, Department of Economics, 1990.

National Science Foundation, Fifth Annual Conference on the Experimental Program to Stimulate Competitive Research, Humacao, Puerto Rico, 1989.

Free University of Amsterdam, European Science Foundation Conference on Economic Analysis for Environmental Toxicology: Applications on Persistent Micro-Pollutants, Noordwijkerhout, the Netherlands, 1989.

Wageningen Agricultural University, Wageningen, the Netherlands, Department of General Economics, 1989.

University of Louisville, Louisville, Kentucky, Conference on Regional Modelling, 1989.

Federal Reserve Bank of Kansas City, Denver Branch, Denver, Colorado, 1989.

US-USSR Commission on the Humanities and Social Sciences of the American Council of Learned Societies and the Soviet Academy of Sciences, Third Soviet-American Seminar on Regional Economics and Planning, Alpine Lakes, West Virginia, 1988.

Arizona State University, Tempe, Arizona, Department of Economics, 1988.

University of Tennessee, Knoxville, Tennessee, A Symposium on Industry Location and Public Policy, 1988.

University of Tennessee, Knoxville, Tennessee, International Conference on Migration and Labor Market Efficiency, 1987.

Wageningen Agricultural University, Wageningen, The Netherlands, Conference on Environmental Policy in a Market Economy, 1987.

Free University of Amsterdam, Amsterdam, the Netherlands, Department of Economics, 1987.

U.S. Environmental Protection Agency, Washington, D.C., Office of Policy Analysis, joint seminar with Environmental Law Institute, 1987.

University of Kentucky, Lexington, Kentucky, Department of Economics, 1987.

West Virginia University, Morgantown, West Virginia, Department of Economics and Regional Research Institute, 1986.

U.S. Environmental Protection Agency, Washington, D.C., Office of Policy Analysis, joint seminar with Environmental Law Institute, 1986.

Urban Institute, Washington, D.C., Conference on Traffic Safety Policy, 1986.

American Association for the Advancement of Science, Los Angeles, California, 1985.

University of Vienna, Vienna, Austria, Department of Geography, 1985.

University of Economics, Vienna, Austria, Economics Staff Seminar, 1985.

University of Chicago, Chicago, Illinois, Resources Workshop, 1984.

University of Iowa, Iowa City, Iowa, Department of Geography, 1982.

University of Colorado, Boulder, Colorado, Department of Economics, 1982.

Consultant:

Westmoreland Resources
Western Governors' Policy Office
Mathtech
Kansas State Senate
Pacific Power and Light
Louisiana Board of Regents
Morey and Associates
Consulate-General of Japan
Center for the New West
Union Pacific Resources
HDR Engineering, Inc.
Utah Tax Commission
Fishkind and Associates
Lincoln Institute of Land Policy
Shook, Hardy & Bacon L.L.P.

Organizations:

American Economic Association
Regional Science Association, International
European Association of Environmental and Resource Economists
Association of Environmental and Resource Economists

January 11, 2012

Senate Resources Committee
Wednesday, February 1
Dr. Shelby Gerking: State Tax Policy and Oil Production

DRAFT DRAFT DRAFT DRAFT

Introduction:

1. Please tell the Committee about your educational background, professional work experience, and, especially, your research and experience regarding state tax policy and oil production.

2. I understand that you have testified extensively before State legislatures. Can you please tell the Committee more about those experiences and the sort of information that you have been asked to provide.

State Tax Policy and Oil Production:

1. On the first page of the chapter titled, State Tax Policy and Oil Production, you present some interesting questions to the reader. Can you please elaborate briefly on a few of these:

    a. "To what extent do state energy tax increases result in lower collections of federal tax revenues?" For the folks following this issue, does a decrease in state taxes increase federal tax revenues? What is the net gain/loss for the taxpayer?
    b. "Do state taxes tilt the time path of energy production to the present or future?" Why is the answer to this question important to policy makers? What are the pros and cons for Alaska?
    c. "How do upstream subsidies for exploration and development work together with downstream taxes on production to influence the levels and time paths of production and tax collections?" This sounds important. Please elaborate.
    d. "What are the implications of these taxes for the long-run sustainable use of nonrenewable natural resources?" What should we be thinking about here?

2. Key result (page 306): "Oil production is closely related to the size of the reserve base and is relatively insensitive to changes in oil prices. This outcome, which is broadly consistent with experience in the U.S. oil industry over the past 50 years, leads to the conclusion that the severance tax has little effect on production levels and serves mainly to redirect rents earned in the oil industry to the public sector. Thus, increases in severance tax rates or a reduction in the subsidies provided to the oil and gas industry may lead to rent taxation and therefore have only marginal effects on the the drilling and production of oil ..."

Help us better understand

a. As you can imagine, this is not the message we are hearing from the oil industry and their advocates. Can you help us understand this better?

3. The State of Alaska offers generous credits to the oil and gas industry and we have several bills currently before the legislature to expand tax credits. Please elaborate on the statement that, "a drilling expense credit may cost more than the incremental severance tax revenue obtained, although such credits may be worthwhile concessions if a state's objective is to generate greater support for increasing the severance tax rate."

4. You note that, "State and local tax burdens on oil producers are endlessly compared in state tax commission and legislative hearings as industry representatives make their case for more favorable tax treatment."

    a. This sounds familiar to the members of this committee and, indeed, all Alaskans. Can you please comment on the pros and cons of such comparisons?
    b. Besides the comparison of effective tax rates, what other economic indicators should be considered (e.g., IRR, ROI, etc.)? Which are most important to the investor?

5. You cited a study that found, "the response of production with respect to the tax change turns out to be highly inelastic (-0.06)." This is a very important concept for Alaskans to understand. Please explain.

6. Can you please help us understand Table 9.2 on page 322?

7. Can you please help us understand Figure 9.1 on page 323?

8. I am interested in a statement on page 330: "This outcome raises a question as to whether other public policy instruments, such as support for research to lower drilling costs or to increase finding rates, might spur drilling at a lower cost to the state." Please elaborate. Do you have examples from other states?

9. As a refresher to those of us who studied statistics many years ago, can you please give us a very brief review of "credibility" and "validity"? Respectfully, how can we be sure that this chapter, State Tax Policy and Oil Production, is relevant to Alaska?

Senate Resources Committee
Supplemental Questions
February 1, 2012

Effective Tax Rates on Oil and Gas Production: A Ten-State Comparison

Please talk about "property taxes on oil and gas reserves." Example.

"Taxes on reserves provide operators with strong incentives to accelerate production at times when oil and gas prices are rising, as they attempt to reduce the extent of their tax liability." If boosting throughput in the Trans Alaska Pipeline System (TAPS) is the highest priority of the State, might this be a "strong incentive" to boost throughput?

"The myriad of exemptions, incentives, different tax bases, special features and frequent changes in tax laws, at both the State and Federal government levels, create considerable complexity in understanding and tracking tax law over time." This does not seem to stop such state-to-state comparisons. Why?

Why do you say that, *"ranking states in terms of their total or cumulative tax burden on the oil and gas extraction industry is not particularly fruitful and may be misleading"*? Don't companies use the "cumulative tax burden" when deciding where to invest?

State Taxation, Exploration, and Production in the U.S. Oil Industry (2001)

What is meant by the *"optimal time path for exploration and production"*?

"The aim of exploration is to add to the reserve base, which is a form of geographically immobile capital." What is the significance of this concept?

In another paper of you co-authored in 2001 – State Taxation, Exploration, and Production in the U.S. Oil Industry – it was reported that, *"Analyzing taxes individually appears to overstate the effects on exploration and production by ignoring potential offsets and tax base interactions. These results suggest that taxes should not be analyzed independently without careful reference to the entire tax structure applied by all levels of government."* Please explain.

In the same 2001 study, you conclude that, *"General results of this study suggest that oil production is highly inelastic with respect to changes in production taxes. This inelastic response may provide incentives for state officials to substantially increase these taxes risking little in the way of reduced industry activity while gaining much needed tax revenue. State severance tax increases clearly reduce the net price faced by producers, but it is reserves, not net price, that drives production in this industry. Moreover, the effects of increased state severance taxes are partially offset by reduced tax collections by all other levels of government."* Please explain.

Senate Resources Committee

State Tax Policy and Oil Production

Dr. Shelby Gerking

University of Central Florida and Tilburg University

February 1, 2012

Introduction

- Nominal (legislated) severance tax rates
- Effective tax rates
  - (dollars collected)/(value of production)

Table 9.1. *Oil production (in Mbbl) and tax rates for selected U.S. states, 2007*

State	Production	Severance tax: Nominal rate	Severance tax: Effective rate	Corporate income tax rate[o]
Alaska	263,595	12.25–15%[a]	12%	1.0–9.4%
California	216,778	None	None	8.84%
Colorado	23,237	2–5%[b]	0.7%	4.63%
Kansas	36,490	4.33%[c]	3.0%[l]	4.0–7.35%
Louisiana	76,651	3.125–12.50%[d]	9.4%	4.0–8.0%
Montana	34,829	15.1%[e]	8.6%	6.75%
New Mexico	58,831	7.1%[f]	7.5%[m]	4.8–7.6%
North Dakota	45,058	5.0–11.5%[g]	–[n]	2.6–7.05%
Oklahoma	60,952	7.0%[h]	6.9%	6.0%
Texas	396,894	4.6%[i]	3.1%	1.0%[p]
Utah	19,520	3.0–5.0%[j]	2.4%	5.0%
Wyoming	54,130	4.0–6.0%[k]	5.3%	None

What is the effect of a change in the severance tax rate or a change in incentives to find new reserves?

- Oil Production
- Drilling Activity
- Severance Tax Collections

Simulation Model

- Based on Hotelling (1931) and Pindyck (1978)
- Profit maximization over time
  - Revenues earned by
    - Production from existing reserves
    - Exploration for new reserves
  - Costs
    - Drilling costs
    - Operating costs

Simulation Model (cont.)

- Key features
  - Compares costs to the amount produced
  - Accounts for interaction between state and federal tax collections
- Uses U.S. data on production, costs, proven reserves, federal and state corporate tax rates, etc. and discount rate of 4%
  - Not a model of a particular state
  - Not a model of Alaska

Four Scenarios

- Severance Tax Rate = 0% (Model A)
- Severance Tax Rate = 12% (Model B)
- Severance Tax Rate = 25% (Model C)
- Severance Tax Rate = 25% with credit of 22% of drilling costs against severance tax liabilities (Model D)

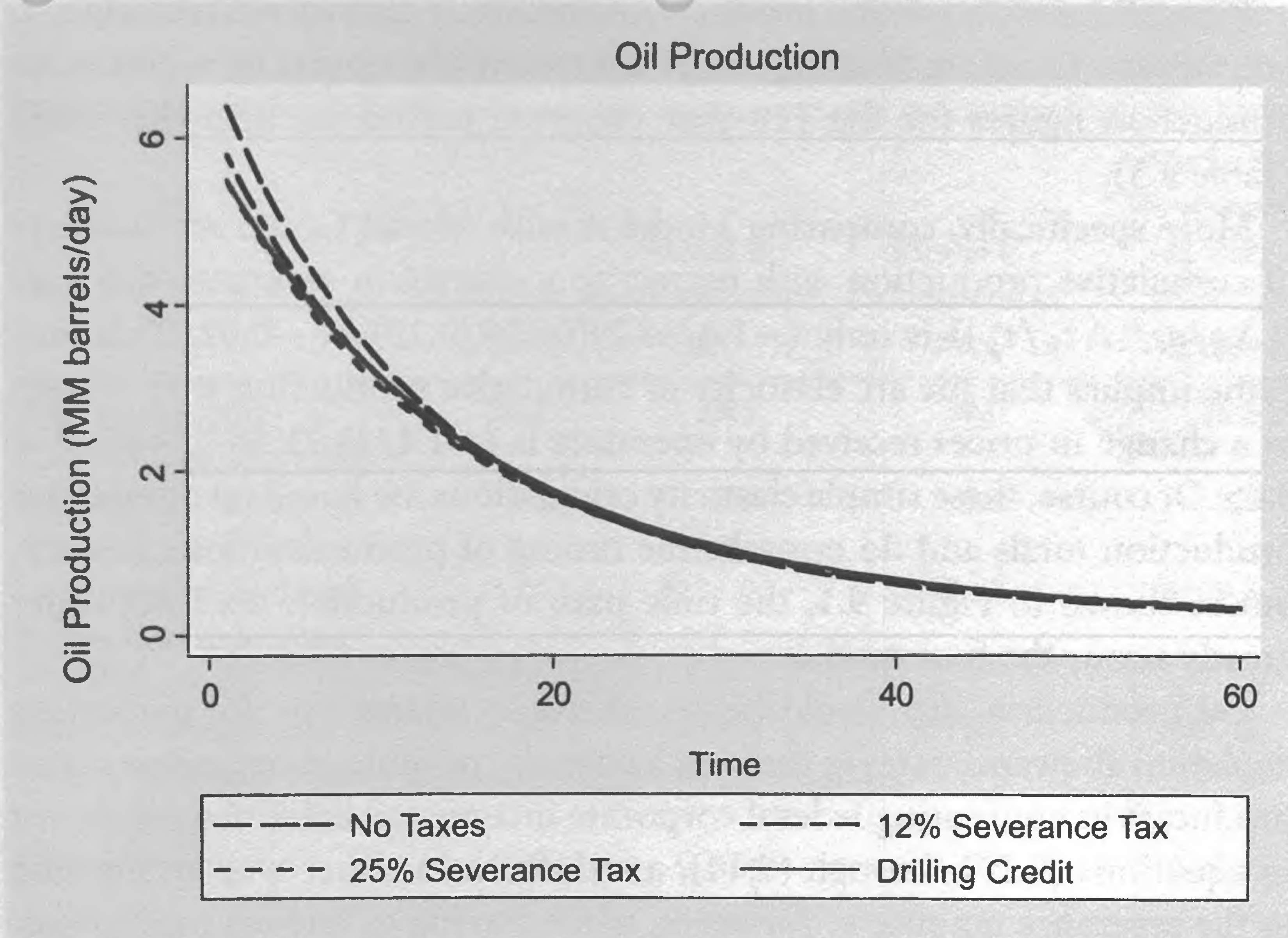
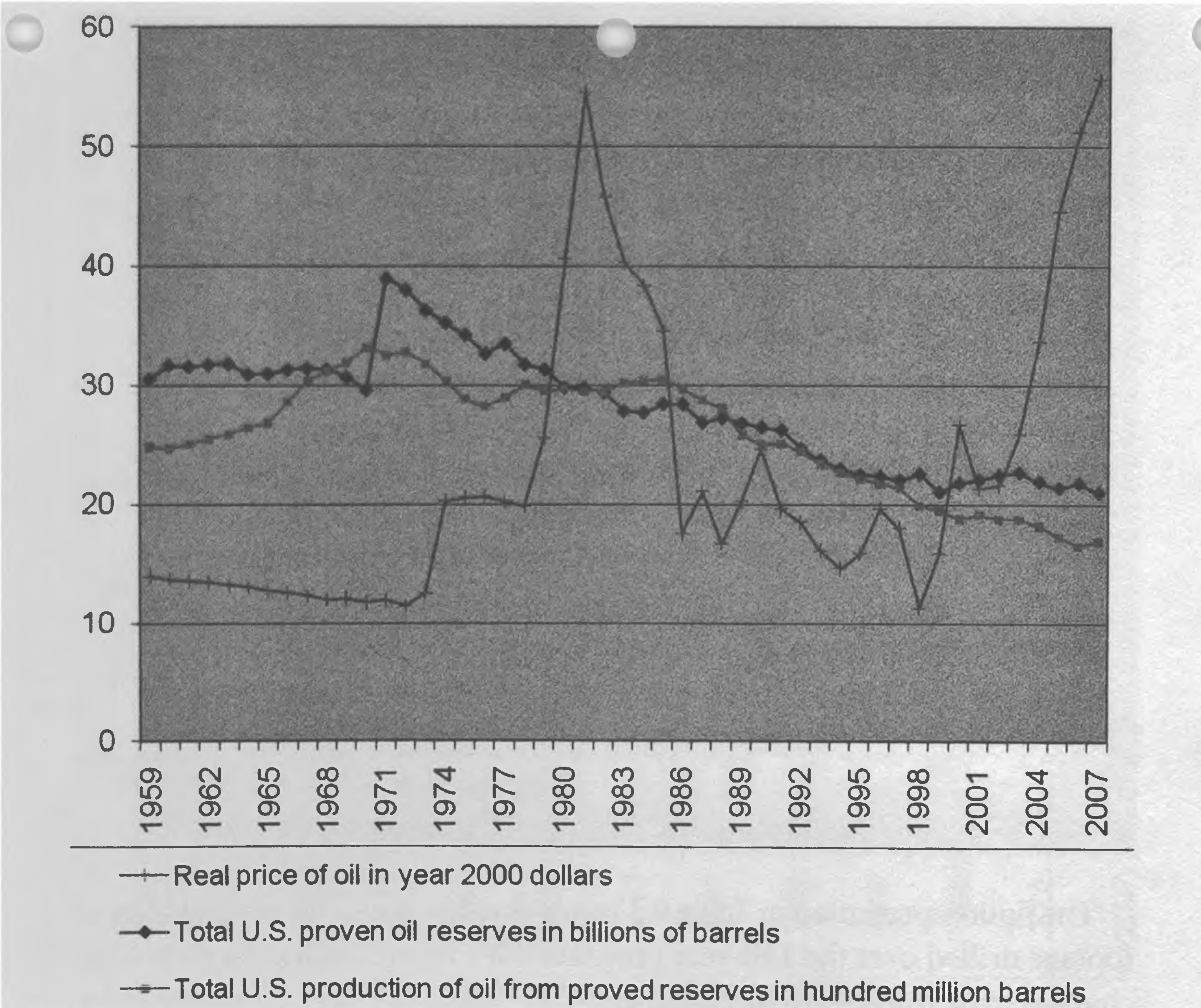


Figure 9.1. Oil production is quite insensitive to the tax structure in the U.S. case.

State Tax Policy and Oil Production



State Tax Policy and Oil Production

TABLE 9.3.

TOTAL DRILLING, PRODUCTION, TAX COLLECTIONS, PROFITS, AND RESERVES FOR FOUR MODELS OVER THE 110-YEAR PROGRAM

	Model A no taxes	Model B 12% severance tax	Model C 25% severance tax	Model D 25% severance tax with drilling subsidy
Total production (in billions of barrels)	39.4	38.5	38.0	38.6
Total footage drilled (in billions of feet)	4.5	3.9	3.6	3.9
Discounted public land royalties (in billions of dollars)	$0	$131.0	$126.3	$129.3
Discounted severance tax Collections (in billions of dollars)	$0	$159.0	$319.2	$307.5
Effective severance tax Rate	0	0.109	0.228	0.212
Discounted state corporate income tax revenue (in billions of dollars)	$0	$60.9	$49.6	$50.8
Discounted federal corporate income tax revenue (in billions of dollars)	$0	$230.0	$182.5	$188.4
Discounted depletion allowance deductions (in billions of dollars)	$0	$119.2	$114.9	$117.7
Discounted pre-tax total revenue (in billions of dollars)	$1,544	$1,456	$1,403	$1,437
Discounted extraction costs (in billions of dollars)	$186.3	$151.8	$130.1	$133.0
Discounted drilling costs (in billions of dollars)	$125.6	$84.4	$68.3	$88.3
Discounted firm profits (in billions of dollars)	$1,231	$638	$527	$539
Beginning reserves (in billions of barrels)	20	20	20	20

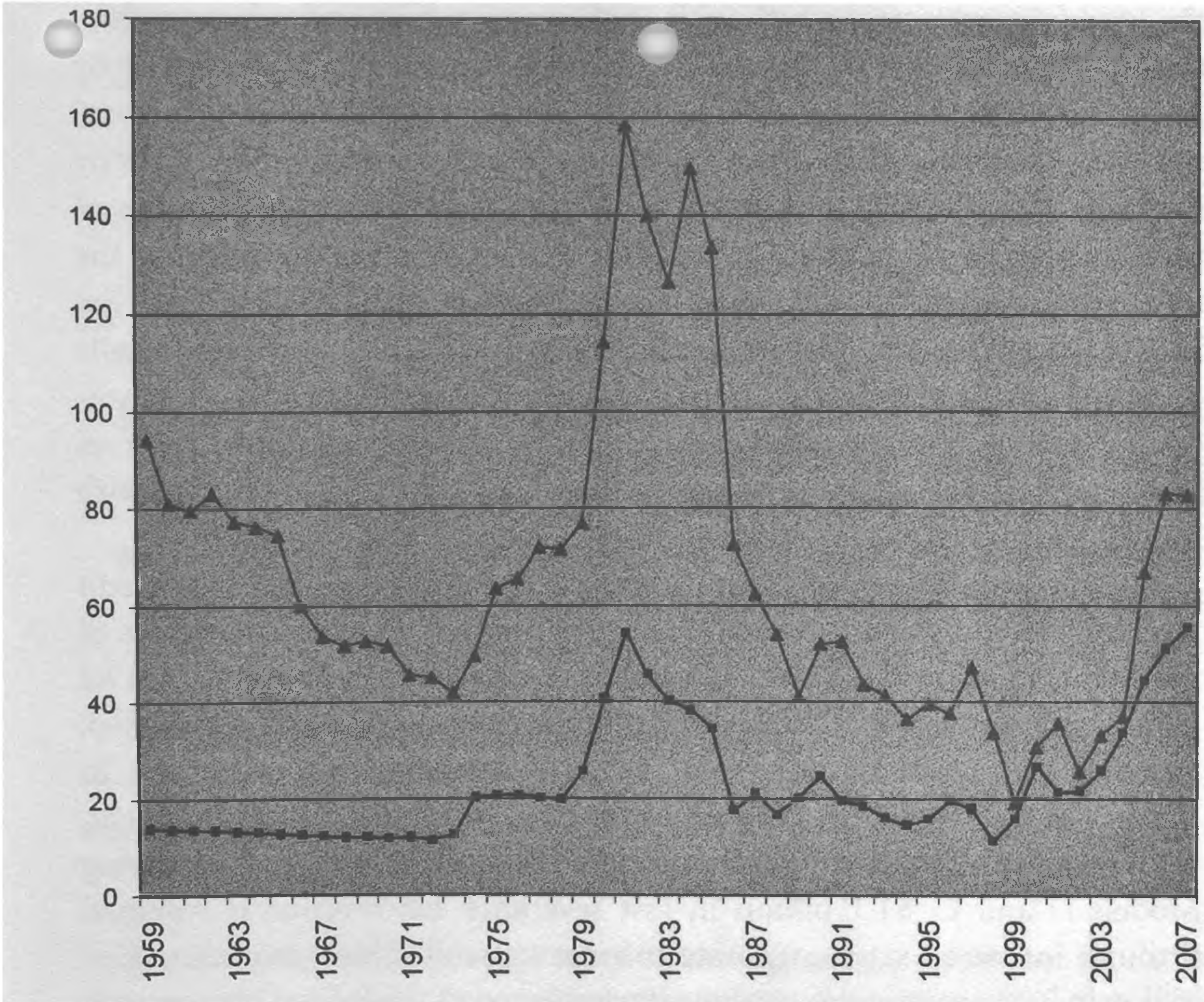


Figure 4. Price movements coincide with changes in footage of wells drilled.

State Tax Policy and Oil Production

still – but it is still clear that in the absence of such an alternative policy, a higher gas tax would clearly boost economic efficiency.

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Chapter Nine from

U.S. Energy Tax Policy

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NINE

State Tax Policy and Oil Production

The Role of the Severance Tax and Credits for Drilling Expenses

Ujjayant Chakravorty, Shelby Gerking, and Andrew Leach

9.1 Introduction

Although most energy-producing states have levied taxes on the value of oil, natural gas, and coal production for many years, changes in these taxes have become headline news as state governments grapple with budget shortfalls brought about by the current recession. For instance, Alaska has increased the severance tax on the value of its oil production and attempted to stimulate future production by allowing a credit against this tax for expenditures on capital items, including drilling rigs, infrastructure, exploration, and facility expansion (Alaska Department of Revenue 2008). In late 2008, California Governor Arnold Schwarzenegger proposed levying a 9.9 percent production tax on the value of most onshore oil production to help close a projected $24 billion budget deficit, but he subsequently reversed his position (Casselman 2009; Skelton 2009). The Pennsylvania legislature is considering a proposal to levy a 5 percent tax on the value of natural gas produced from the giant Marcellus shale deposit, but the bill is opposed by industry leaders who contend that it would result in 30 percent less drilling as well as revenue reductions to state and local governments totaling $880 million over the next decade (George 2009).

These measures, both enacted and proposed, raise a number of longstanding and important questions about the effects of state energy taxes that go well beyond their potential to provide a solid revenue base to support public services. Given the overlapping tax bases claimed by states and the federal government, to what extent do state energy tax increases result in lower collections of federal tax revenues, including the federal corporate income tax? Do state energy taxes restrict production and encourage "high-grading" of energy reserves and by how much? Do state taxes tilt the time path of energy production to the present or to the future? How do upstream subsidies for exploration and development work together with downstream taxes on production to influence the levels and time paths of production and tax collections? What are the implications of these taxes for the long-run sustainable use of nonrenewable natural resources? The analysis in this chapter bears directly on these questions. It also serves as a basis to examine proposed changes in federal tax policy, including the elimination of the percentage depletion allowance and the expensing of intangible drilling costs.

We adapt the Hotelling model developed by Pindyck (1978) to examine how a state's taxes and subsidies at different stages of resource exploration and production alter the behavior of oil producers and thus impact on exploration activity, additions to the reserve base, and the production of energy. In our model, returns to exploration are subject to diminishing returns, and the cost of production is affected both by the level of reserves and the level of output. Producers located in a given state are assumed to produce only a small fraction of world output and therefore face an exogenously determined price of oil. We calibrate the model using data from U.S. oil fields to evaluate the effects of alternative tax and subsidy policies on drilling and production, on tax revenue accruing to states and to the federal government, as well as on the time path of drilling expenditures and resource production.

A key result from the calibrated model is that oil production is closely linked to the size of the reserve base and is relatively insensitive to changes in oil prices. This outcome, which is broadly consistent with experience in the U.S. oil industry over the past 50 years, leads to the conclusion that the severance tax has little effect on production levels and serves mainly to redirect rents earned in the oil industry to the public sector. Thus, increases in severance taxes or a reduction in the subsidies provided to the oil and gas industry may lead to rent taxation and therefore have only marginal effects on the drilling and production of oil and few adverse impacts in terms of national security and increasing U.S. dependence on foreign oil.

Prior simulation studies (Deacon 1993; Kunce et al. 2003) also have considered aspects of these issues, but a novel feature here focuses on effects of combining subsidies for exploration and development with taxes on the value of energy production. The rationale for subsidizing exploration and development is to expand the reserve base and ultimately to stimulate oil production in much the same way as an investment tax credit (see Chirinko 2000) might increase capital formation and boost output in manufacturing. As previously indicated, this type of tax policy has been adopted by Alaska, and it has been suggested as a model for other states (Headwaters Economics

2009). It may also bear on national energy tax policy in light of the interest in stimulating drilling for new reserves.[1] The simulations suggest that a drilling expense credit may cost more than the incremental severance tax revenue obtained, although such credits may be worthwhile concessions if a state's objective is to generate greater support for increasing the severance tax rate.

The remainder of the chapter is organized into six sections. Section 9.2 reviews the issue of oil taxation in twelve major oil-producing states in the United States. Section 9.3 summarizes findings from the literature regarding temporal economic effects of state energy tax policies. Section 9.4 describes the extended Pindyck (1978) model that is used as a conceptual basis for our tax policy simulations. Section 9.5 discusses the way in which the model was parameterized. Section 9.6 presents simulation results, and Section 9.7 concludes.

9.2 Overview of State Taxation of the U.S. Oil Industry

Key taxes on nonrenewable resource development levied by state and local governments can be divided into three main groups: taxes on production, property, and income. In its simplest form, the production or severance tax is levied on the gross value (or volume) of production of the resource as it is "severed" from the ground. The severance tax is the most widely adopted state tax specifically applying to the U.S. oil industry and will receive the most attention in the discussion. State and local governments also levy property taxes on the assessed (quasi market) value of equipment *above* ground and/or reserves *beneath* the ground. Income taxes are levied against the accounting net income of extraction firms. Although these taxes are generally aimed at extracting economic rents earned by producers from the sale of nonrenewable resources, their effects on production, exploration, and development can differ substantially (see Section 9.3). The discussion in this section briefly summarizes how these taxes are applied in major oil producing U.S. states and how they interact with each other and with other taxes on energy producers levied at the federal level. A more detailed

[1] At the Republican National Convention in 2008, Michael Steele, former Lieutenant Governor of Maryland and currently Chairman of the Republican National Committee, underscored his view that more exploration for energy resources is needed with his now famous line, "Drill, Baby, Drill." This sentiment was echoed by Republican Vice-Presidential nominee, Sarah Palin, who as Governor of Alaska, signed legislation granting a partial credit for drilling expenses against severance tax liabilities paid at an increased tax rate. For further details, see Ball (2008).

state-by-state survey of taxation and regulation of oil and gas production is available from the Interstate Oil and Gas Compact Commission (2007) and a more up-to-date survey can be constructed from a Lexis-Nexis search of state statutes. Hellerstein (1983) provides a useful discussion of the legal basis for state taxation of natural resources.

Table 9.1 presents data on oil production, nominal (legislated) oil severance tax rates, effective severance tax rates, and nominal corporate income tax rates for the twelve U.S. states that produced the most oil in 2007.[2]

As shown, production in these states ranged from a high of 397 million barrels in Texas to a low of 20 million barrels in Utah. Nominal severance tax rates varied widely across states as well. All states except California levied a severance tax against the value of production.[3] As mentioned earlier, California is considering whether to adopt such a tax. In Alaska and Montana, nominal tax rates can exceed 10 percent. Other tax code features reflect important interstate differences.[4] Severance taxes are generally levied against the "net value" of production, where each state has its own definition of this concept. Some states, such as Wyoming, tax the value of production at the wellhead (the top of the well), whereas others, like Utah, tax the value of production at the wellfoot (the bottom of the well), which in effect allows a deduction for lifting costs. Most states subtract royalty payments (computed as a percentage of gross value of production) for production on public land in computing net production value for determining severance tax liabilities (Louisiana does not). Public land royalties are relatively more important in Alaska, Colorado, New Mexico, Utah, and Wyoming than in other states owing to their large shares of publicly owned land. State energy tax codes are subject to frequent changes as well. For instance, Alaska now allows producers to take a credit against severance tax liabilities for capital expenditures used in exploration and development, whereas this feature was not available in 2007 and thus is not reflected in Table 9.1.

In New Mexico and North Dakota, the severance tax is actually the sum of two or more different levies on net production value. In Colorado, severance taxes are paid at graduated rates that depend on the gross income of operators, and in Alaska, Oklahoma, and Utah prevailing rates depend on the price of oil. In Colorado, Kansas, and Wyoming, local governments levy a substantial tax against the value of energy production. Although this tax is generally called a property tax by tax administrators, it is in

[2] The year 2007 is the most recent year for which effective tax rate data could be assembled (see discussion below).

[3] California does levy a property tax on reserves in the ground (see below).

[4] See footnotes to Table 9.1.

Table 9.1. *Oil production (in Mbbl) and tax rates for selected U.S. states, 2007*

State	Production	Severance tax: Nominal rate	Severance tax: Effective rate	Corporate income tax rate[o]
Alaska	263,595	12.25–15%[a]	12%	1.0–9.4%
California	216,778	None	None	8.84%
Colorado	23,237	2–5%[b]	0.7%	4.63%
Kansas	36,490	4.33%[c]	3.0%[l]	4.0–7.35%
Louisiana	76,651	3.125–12.50%[d]	9.4%	4.0–8.0%
Montana	34,829	15.1%[e]	8.6%	6.75%
New Mexico	58,831	7.1%[f]	7.5%[m]	4.8–7.6%
North Dakota	45,058	5.0–11.5%[g]	–[n]	2.6–7.05%
Oklahoma	60,952	7.0%[h]	6.9%	6.0%
Texas	396,894	4.6%[i]	3.1%	1.0%[p]
Utah	19,520	3.0–5.0%[j]	2.4%	5.0%
Wyoming	54,130	4.0–6.0%[k]	5.3%	None

[a] Lower rate applies to fields in production less than 5 years; higher rate applies to fields in production more than 5 years.
[b] Rate depends on gross income of operator and excludes county ad valorem taxes at 4–10%.
[c] Excludes county ad valorem taxes of approximately 4%.
[d] Tax rate of 3.125% applies only to stripper well production.
[e] Rate applies to nonworking interest owners; working interest owners pay lower rates that vary by type of well.
[f] Rate is the sum of oil severance tax, oil school tax, and oil conservation tax; local ad valorem taxes at approximately 1.2% are excluded.
[g] Depends on the level of an oil extraction tax that varies by type of well; tax rate on stripper well production is 0%.
[h] Excludes ad valorem taxes that vary by county.
[i] Excludes county ad valorem levies and (small) state regulatory and conservation levies.
[j] Lower rate applies to first $13/bbl; higher rate applies above $13/bbl. Excludes county ad valorem levies; stripper well production is not subject to severance tax.
[k] Stripper well production taxed at 4%; other production taxed at 6%; excludes county levies at 5.9–7.7%.
[l] Effective rate is for oil and natural gas combined.
[m] Effective rate is for oil and gas combined.
[n] Insufficient information available.
[o] Tax rates depend on level of income before taxes for most states.
[p] This is the rate for a gross receipts tax that replaced the corporate income tax in 2007 (see Tax Foundation 2009a).

Sources: Production data from U.S. Department of Energy (2009b). Nominal severance tax rate data from Interstate Oil and Gas Compact Commission (2007). Effective severance tax rate data are authors' calculations (see text). State corporate income tax rate data from Tax Foundation (2009a).

effect a severance tax levied by local governments. Many states have granted innumerable exemptions and credits against state severance tax liabilities for special situations that may be encountered by operators. Production from stripper wells (wells that produce fewer than ten barrels per day), for example, is taxed at lower rates in some states than is production from better producing wells. Production from wells employing secondary or tertiary recovery methods is sometimes taxed at lower rates as well.

A further complicating feature in analyzing economic effects of state severance taxes is that states and the federal government levy other types of taxes on oil producers and tax bases interact, particularly at the state and federal levels. Except for Wyoming, all of the twelve states levy a corporate income or franchise tax that applies to oil producers. Nominal rates for this tax, taken from the Tax Foundation (2009a), are shown for each state in Table 9.1. State corporate income taxes often are levied on a similar base to that used in computing federal corporate income tax liabilities, but the state tax rates generally are lower than the top federal rates for this tax, which currently are in the 35 to 40 percent range (Tax Foundation 2009b). State corporate income tax payments are deductible against federal corporate income tax liabilities, and state and local production tax payments are deductible against both. In some states, federal corporate income tax payments are deductible in computing state corporation income taxes and in others it is not. Although local governments in most of the states utilize some form of a property tax on oil and gas extraction equipment, property taxes on reserves are levied only in relatively few states such as California and Texas.

State and local tax burdens on oil producers are endlessly compared in state tax commission and legislative hearings as industry representatives make their case for more favorable tax treatment. Yet, because of variations across states in the application of severance and other taxes, a comparison of nominal tax rates is not particularly useful. A judgment based on a comparison of nominal rates that one state's severance tax, for example, is higher than that in another state might easily be reversed once the potentially numerous exemptions, credits, incentives, deductibility, and other special features of tax law are accounted for. Instead, more meaningful comparisons across states can be obtained by computing effective tax rates expressed as the ratio of revenue collected from a particular tax to the value of production. The calculation of effective tax rates fully accounts for, without enumerating, state-specific aspects of tax treatment faced by producers and facilitates comparisons between states because the value of production is used as a common denominator.

Table 9.1 presents effective severance tax rates prevailing in 2007 for the twelve most important oil-producing states. Unfortunately, information regarding severance tax collections is neither available from a single source nor published in a common format. In consequence, data on severance tax collections needed for the numerators of the effective tax rates were obtained by searching state department of revenue reports available on the Internet and by directly contacting knowledgeable people in these agencies as questions arose. Estimates of the value of production in each state were obtained by multiplying production volumes by the average prevailing price per barrel of crude oil. State production volumes were obtained from the Energy Information Administration, U.S. Department of Energy (2009b). Average wellhead prices of oil in each state were taken from the American Petroleum Institute (2009). The price and production volume data exclude oil produced in the Outer Continental Shelf (OCS) that is not subject to state taxation. As shown in Table 9.1, among states that levy a severance tax, effective tax rates in 2007 vary from 0.7 percent in Colorado to 12 percent in Alaska. Because of the many special tax code features just discussed, these rates tend to be lower than corresponding nominal tax rates.

9.3 Prior Literature

A sizable literature deals with the economic effects of the three types of taxes discussed in the previous section. It may be useful to briefly describe this work before proceeding with the theoretical structure we assume in this chapter. Discussion is limited to intertemporal issues; thus, topics such as interstate tax shifting or "tax exporting" are ignored (Gerking and Mutti 1981; McLure 1969; Metcalf 1993). The severance tax is given the most detailed treatment because it has been widely adopted and because its effects are the focus of the simulations presented in Section 9.6.

9.3.1 Production Taxation

Hotelling's (1931) seminal analytic work considers a per unit severance tax in a model with an endogenous price (net of constant extraction costs) and the total exhaustion of fixed reserves. The severance tax is found to conserve the resource by extending the time it takes to exhaust the total pool. Herfindahl (1967) extends this result with a model that features an extraction cost function that depends on output. Under competition, the severance tax is shown to tilt production to the future (i.e., delay production), thereby extending the life of the pool. The pool is fully exhausted at a postponed terminal period.

Burness (1976) reformulates the dynamic framework by including severance tax rates that vary over time. In this model, price is exogenous, reserves are fully depleted, and extraction cost depends only on output. The general proposition derived is that the severance tax will tilt production to the future if the tax rate is held constant or rises at a rate less than the discount rate. A severance tax that rises with the discount rate will not distort the time path of production. Conrad and Hool (1984) show that introducing varying grades of the resource into the model make no difference to this result.

Levhari and Leviatan (1977) allow for an extraction cost function that depends on both current and cumulative production so that as more of the resource is extracted over time, the more it costs to produce an incremental unit. Thus, in this model, the resource may not be fully exhausted. The effect of per unit severance taxation on time to exhaustion now is ambiguous. If the resource price is constant over time, terminal time is shortened and high-grading (removing ore of the highest grade while leaving lower grade ore in the ground) may occur. Nonetheless, if tax rates vary over time, then, as Heaps (1985) demonstrates, total recovery of the resource and the economic life of the resource can either increase or decrease but in opposite directions. Because these two effects of the tax work against each other, the net impact on depletion cannot be determined.

If resource quality varies across pools but is the same within a pool, Conrad (1978, 1981) shows that mine lives are shortened and lower-quality resource is left in the ground when a per unit severance tax is levied. Krautkraemer (1990) examines the effect of production taxation in a finite reserve model when resource quality varies within a given deposit. In addition to firms choosing the rate of extraction, they also choose the marginal grade cutoff at each point in time. A production tax induces high-grading at each instant of time and not just at the end of the production program. Interestingly, a production tax reduces total resource recovery and a low-grade resource left in the ground will not be extracted, even if at some point in the future the production tax is eliminated.

Uhler (1979) includes a brief examination, for the first time, of the effects of production taxation in a model of nonrenewable natural resource extraction with both production and exploration. The possibility of exploration means that the reserve base is no longer fixed. Also, when the model allows for exploration and reserve additions, the dynamics of the process become complex and equilibrium conditions no longer have closed form solutions.

Effects of production taxation, therefore, were examined with simulations. The model was parameterized for a small oil- and gas-producing region in Alberta, Canada. When a severance tax is imposed at a constant rate, operators decrease production and exploration in all periods while the endogenous price of the resource rises.

Deacon (1993) also simulates effects of severance taxation using the model developed by Pindyck (1978) and later applied by Yücel (1986, 1989). In Deacon's formulation, the oil industry is taken to be competitive, so the time path of the resource price is treated as exogenous. In the simulations, the resource price is assumed to rise in the early years of the production program, but at a rate less than the assumed 5 percent discount rate. Similar to the analytic results derived by Burness (1976) and others in models that abstracted from exploration, the application of an ad valorem severance tax tilts production to the future in comparison to a no-tax base case. Over the life of the program, however, the tax reduces output, implying that an important effect of the production tax is to induce high-grading. In addition, simulations show that a production tax reduces drilling in all periods and that drilling shuts down prematurely in comparison to the no-tax case.

Kunce et al. (2003) also simulate effects of production taxation using the Pindyck (1978) framework, but they parameterize the model for a single state (Wyoming) rather than the nation as a whole, as was the case in the Deacon (1993) study. They consider the effect of doubling the state's production tax on oil extraction in a setting where oil producers are assumed to be price takers. A key feature of this study was to embed the production tax in a broader tax system that allowed for interactive tax bases and tax shifting between the local, state, and federal governments. Simulations demonstrate that a hypothetical doubling of Wyoming's production tax leads to reduced drilling and reduced oil production in each subsequent period. Estimated production declines, however, are comparatively modest; the response of production with respect to the tax change turns out to be highly inelastic (−0.06). Thus, the main effects of the tax increase would be to rather dramatically increase Wyoming's severance tax revenue and to reduce federal corporate income taxes paid by producers.

9.3.2 Property Taxation

Taxation of property, specifically reserves, has received little attention in the literature on production from nonrenewable resources. One reason for this may be the practical complexity of levying such taxes. Nonetheless, Hotelling (1931) demonstrates that a constant percentage tax on the value of reserves will induce firms to extract more rapidly as they attempt to "mine out from under the tax." Conrad and Hool (1981) show that a constant tax rate per unit of reserves encourages extraction of higher-grade resource in the early periods of the program, but the cutoff grades are lower, thus extending the life of the mine. The property tax is also examined by Heaps and Helliwell (1985) in a model that allows for new reserve investment. The tax is shown to tilt production to the present and to reduce investment in new deposits to avoid holding costs. Simulations by Gamponia and Mendelsohn (1985) show that a property tax on reserves results in tilting production to the present. Deacon (1993) obtains the same outcome in his simulation study and also confirms the Heaps and Helliwell (1985) result by showing that the property tax on reserves results in lower levels of drilling in the early years of the program.

9.3.3 Income Taxation

Burness (1976) analyzes a profits tax on a nonrenewable resource producer with fixed reserves and concludes that output trajectories will not change when the tax is applied at a constant rate. If the tax rate increases over time, however, firms will speed up depletion of the fixed reserve. Conrad and Hool (1984) model a progressive profits tax, finding that such a tax will not exhibit the neutrality of a flat rate profits tax with regard to the extraction path and grade selection. Deacon (1993) simulates a structure broadly similar to federal corporate income taxation with expensing of current and capitalized drilling costs. Simulated paths of extraction, drilling effort and reserves show little distortion from the no-tax base case. These results suggest that income taxation is the least distortionary among the three types of energy taxes imposed by U.S. states.

9.4 Conceptual Framework

We propose a simple dynamic model in the tradition of Hotelling (1931) and Pindyck (1978) with some modifications. The idea is to examine the producers' response when states or a social planner imposes a menu of taxes and subsidies on oil production. We consider three tax/subsidy instruments – a severance tax, a corporate income tax, and a subsidy on drilling expenditures. Producers choose the optimal amount of drilling (and therefore reserve additions) and production of oil to maximize profits.

The model is dynamic, with a known discount rate and no uncertainty. Resource producers face an output price of the commodity that is exogenously determined. Ideally, output prices should be endogenously determined through the process of dynamic optimization, as in Pindyck (1978). However, because our goal is to examine the effect of various tax regimes under assumptions of alternative petroleum prices and a single U.S. state produces only a small fraction of world output, the exogenous price assumption may be a reasonable approximation. In any case, a partial equilibrium model with endogenous prices may leave too many factors that critically affect oil prices out of the model (e.g., international financial markets, world economic growth).

Let the output price of petroleum be given by $p(t)$ where the argument t denotes time. Then the social planner imposes a set of taxes $(1-\alpha_p)$ such that the net price received by the producer is the fraction α_p times the price.[5] Thus, the production revenue accruing to producers of energy is given by $\alpha_p p q$ where q is the quantity of oil sold by the producer. We assume that whatever is extracted is sold – there is no storage.

Because we distinguish between production and exploration, we define reserves R at any given time t and the cumulative addition to the stock of petroleum given by x. The relationship between stocks and reserves is given by the differential equation

$$\dot{R}(t) = f(w, x) - q \tag{9.1}$$

That is, the change in reserves is equal to the addition in reserves net of production, as in Pindyck (1978). The function f represents the addition to reserves as a function of drilling effort w and cumulative additions to the stock x and we assume that $f_1 > 0$; $f_{11} > 0$; $f_2 < 0$ $f_{22} > 0$ and $f_{12} < 0$. More drilling effort (w) leads to higher reserve additions, but at a decreasing rate. Higher cumulative discoveries x cause current reserve additions to decline (at a decreasing rate). It is more difficult to add to the reserve base, the higher the discoveries made in the past. Finally, the marginal effect of reserve additions as a function of drilling decline with increases in cumulative stock. For convenience we assume that the stock of resource grows linearly with drilling effort. However, the cost of drilling increases in a convex fashion with drilling effort, given by $k(w)$ where $k'(w) > 0$; $k''(w) \geq 0$ and $k(0) = 0$. Finally, the total cost of extraction is given by $c(q, R)$ with $c_1 > 0$, $c_2 > 0$, $c_2 < 0$, $c_{22} > 0$ and $c_{12} < 0$.[6] That is, the total "lifting" cost increases with quantity produced – for instance,

[5] The tax parameter α_p and two other tax parameters to be defined momentarily are empirically specified in the next section.

[6] In Pindyck's (1978) original formulation, both average and marginal lifting costs depended on R but not on q.

as oil is extracted from greater depths – and it also decreases concavely with current reserves. This specification follows from the view that oil is produced using reserves (a form of capital) and nonreserve inputs (i.e., physical capital other than reserves and labor), so that extraction costs are positively related to output and negatively related to reserves. The cross-partial derivative c_{12} is assumed to be negative.

We introduce two other tax/subsidy parameters in this framework, namely, the portion $(1-\alpha_c)$ of the production cost that is deductible in computing tax liabilities, so that the net production cost faced by firms is $\alpha_c c(q, R)$ and the part $(1-\alpha_D)$ that is deductible by the firm, which implies that the net drilling cost payable by the firm is given by $\alpha_D k(w)$. The major goals in this chapter are to examine how the three different tax/subsidy policy instruments, given by α_p, α_c and α_D, affect drilling activity, reserve additions, and production, as well as to compare their corresponding revenue and welfare implications.

Finally, given a fixed discount rate $r > 0$ the social planner solves the following problem:

$$\underset{q,w,x,R}{Max} \int_0^\infty [\alpha_p p q - \alpha_c c(q,R) - \alpha_D k(w)] e^{-rt} dt \tag{9.2}$$

which is subject to the following equations:

$$\dot{x} = w \tag{9.3}$$

and

$$\dot{R} = f(w,x) - q \tag{9.4}$$

The current value Hamiltonian for this problem is

$$H = \alpha_p p q - \alpha_c c(q,R) - \alpha_D k(w) + \lambda w + \theta[f(w,x) - q] \tag{9.5}$$

so that the first-order conditions are given by

$$\alpha_p p \le \alpha_c c_q + \theta \; (= \; iff \; q > 0) \tag{9.6}$$

$$\theta f_w \le \alpha_D k_w - \lambda (= \; iff \; w > 0) \tag{9.7}$$

$$\dot{\lambda} = r\lambda - \theta f_x \tag{9.8}$$

$$\dot{\theta} = r\theta + \alpha_c c_R \tag{9.9}$$

along with transversality conditions not shown here. The co-state variable λ represents the shadow price of an additional unit of discovered oil. Note that the higher the cumulative discoveries, the lower the additions to reserves. Hence, the shadow price λ will be negative. The shadow price θ represents the discounted increment to profits resulting from the addition of one unit of reserves. Reserves decrease the cost of production and therefore θ should be positive.

An important implication of the model (see equation (9.6)) is that the firm will decide to produce $(q > 0)$ if the discounted after-tax wellhead oil price net of marginal extraction costs exceeds the present value of future profits from an additional unit of reserves (θ).[7] Condition (9.7) equates the marginal benefits and costs of an additional well drilled. The benefits are in the form of an increase in reserve additions, which are given by the expression θf_w. The costs are twofold: the marginal cost of drilling net of drilling subsidies denoted by the term $\alpha_D k_w$ plus the negative effect on reserve additions from an addition to the cumulative resource stock given by λ.

Equations (9.8) and (9.9) give the time path of the derivatives for the two shadow prices λ and θ. The rate of increase in the shadow price λ has two components – the discount rate r and the fact that taking out a unit of resource increases the "cost" in the future through lower marginal reserve additions. Because f_x is assumed to be negative, the first term $r\lambda$ is negative and the second term $-\theta f_x$ is positive. At least initially the latter term is likely to be large because of the high value of reserve additions, in which case $\dot{\lambda}(t)$ is likely to be positive and the value of lambda, which is negative, will decline over time. In this model, then, additions to stock adversely impact reserve formation; hence, the interpretation is completely different than in the standard Hotelling model with no exploration activity. The extra cost of drilling is that it decreases the future benefit of drilling. The time path of the marginal value of a unit of reserve θ also increases at the rate of discount but is tempered by its effect on lifting costs – additions to reserves have the added benefit of helping reduce the cost of production, net of production subsidies. This is given by the negative term $\alpha_c c_R$.

In this chapter we do not focus on the analytics of this model, which is similar to the model developed by Pindyck with some key differences. The

[7] Notice that condition (9.7) differs from the corresponding condition derived by Pindyck (1978) in that marginal lifting costs increase with increases in q. Consequently, rather than producing at some maximum rate subject to constraints given by reserve levels, geology, and technology, the firm pays attention to how its lifting costs are affected by the level of output.

main difference is that his production costs are independent of reserves, whereas in our case, production costs decline with cumulative reserves. Moreover, here the focus is on the three tax/subsidy instruments, and we show how they play different roles in influencing production and drilling behavior by firms.

9.5 Calibration of the Simulation Model

Simulations from the model developed in the previous section are constructed based on estimates of the drilling cost, lifting cost, and reserve additions equations, specifying values for the tax/subsidy and other parameters.

9.5.1 Equation Estimates

Estimation of $k(w)$ and $f(w, x)$ are treated together because they are used to compute the marginal cost of reserve additions (k_w/f_w), a key relationship in the model described above. Drilling cost per foot is assumed to be linearly related to footage drilled, as shown in equation (9.10):

$$k(w)/w = \phi w + u \tag{9.10}$$

where ϕ is the parameter to be estimated and the disturbance term u is normally distributed. This specification ensures that the marginal cost of drilling is positive and increasing in footage drilled as long as $\phi > 0$. Using annual data for the United States from 1959 to 2007, with drilling cost per foot measured in year 2000 dollars and footage drilled measured in millions of feet, the least squares estimate of ϕ is 1.23 with t-statistic of 8.17.[8]

The production function for gross reserve additions is specified as

$$f(w, x) = Aw^{\rho}e^{-\beta \cdot x}e^{v} \tag{9.11}$$

where A, ρ, and β are parameters to be estimated and the disturbance term e^v is assumed lognormally distributed with mean of unity and variance σ_v^2. Equation (9.11) is similar to the one describing the discovery process proposed by Uhler (1976) and later adopted by Pindyck (1978). The idea behind this equation is that the marginal product of drilling declines as footage drilled accumulates. Estimation of equation (9.11) used annual data from seven important oil-producing U.S. states (California, Kansas,

[8] Data were taken from American Petroleum Institute (2009).

Louisiana, New Mexico, Oklahoma, Texas, and Wyoming) for which complete information on the requisite variables was assembled for the period 1970–97.[9] Oil reserve additions are defined as extensions, new field discoveries and new reservoir discoveries in old fields. The footage drilled variable was defined as in equation (9.10) and the cumulative footage variable was created by adding year-by-year over the sample period for each state. After taking natural logarithms of equation (9.11) and with state-effects included, we obtain least squares estimates of $\rho = 0.95$ (t-statistic = 14.18) and $\beta = 0.000437$ (t-statistic = 1.37). The value of A (28.78) was selected so that the equation predicted U.S. reserve additions in 2007. This equation shows that the marginal product of drilling (f_w) decreases with footage drilled as well as with cumulative drilling, although the coefficient of cumulative drilling is insignificant at conventional levels.

Because data on oil extraction costs are weak, $C(q, R)$ could not be econometrically estimated. Instead, this equation was calibrated for the United States with a Cobb-Douglas functional form using methods described in Deacon (1993). Results show that if the output elasticity of nonreserve inputs is 0.35, then for 2007, $C/q = 458.1(q/R)^{1.86}$. The value of 458.1 is selected so that the right-hand side will predict average U.S. operating cost per barrel in 2007 of \$7.56.[10] Note that the Cobb-Douglas form implies that extraction costs rise without limit as reserves approach zero and fall as production declines.

9.5.2 Specification of Tax/Subsidy Parameters

Values for the parameters α_j ($j = p, c, D$) were specified by choosing representative rates of state and federal taxes faced by oil producers and then inserting these values into equations (9.12) through (9.14).

$$\alpha_p = (1-\tau_{us})(1-\tau_s)(1-\tau_r)(1-\tau_p) + \tau_{us}(1-\tau_r)\gamma \tag{9.12}$$
$$\alpha_c = (1-\tau_{us})(1-\tau_s) \tag{9.13}$$
$$\alpha_D = \{(1-\tau_{us}\eta - (1-\tau_{us})\delta)\} \tag{9.14}$$

In equations (9.12), (9.13), and (9.14), τ_{us} denotes the federal corporate income tax rate, τ_s is the state corporate income tax rate, τ_r denotes the royalty rate on production from public (state and federal) land, τ_p is the

[9] Data were taken from American Petroleum Institute (various years).
[10] Data were taken from U.S. Department of Energy (2009a).

state severance tax rate, and δ represents the percentage of drilling costs that may be taken as a credit against state severance tax liabilities. This credit is a prominent tax code feature in Alaska. Also, γ represents the federal percentage depletion allowance weighted by the percentage of production attributable to eligible producers (nonintegrated independents), and $\eta = e + (1 - e)f$ denotes the expensed portion of current and capitalized drilling costs attributable to current period revenues for purposes of computing federal corporate income tax liabilities, where e is the percentage of current period drilling costs expensed for tax purposes and f is the present value of cost depletion deductions per unit of depletable expense (see Deacon 1993 for further details).

These equations do not capture all aspects of the tax code facing oil producers. Instead, they merely reflect important tax features and relationships between taxes affecting the oil industry in most states and at the federal level: (1) severance taxes are levied on the wellhead price of oil; (2) royalty payments for production on public land are deductible in computing state severance tax liabilities; (3) public land royalty payments, state severance taxes, and extraction costs are deductible in computing state corporate income tax liabilities; and (4) public land royalty payments, state severance taxes, and state corporate income taxes are deductible in computing federal corporate income taxes. Federal corporate income tax payments are adjusted because of the percentage depletion allowance and special treatment of drilling costs. These equations highlight interaction between tax bases and are more detailed than the corresponding treatment given by Moroney (1997) and Deacon et al. (1990). The equations incorporate the entire tax structure into the model, rather than simply analyzing one tax at a time as in Deacon (1993). Equations (9.12) through (9.14), however, ignore local taxes on the value of production as well as possible property taxes on reserves (levied by relatively few states). As noted in Section 9.2, state tax treatment of the oil industry is not uniform; the specification of the parameters α_j ($j = p, c, D$) would require reformulation to represent the tax structure of a particular state.

9.5.3 Values of Tax/Subsidy Parameters Used in Simulations

Four simulations of the model are considered in the following section. The base case simulation considers a situation in which no taxes are levied and no subsidies are allowed (No-tax Model A); the values for the tax parameters are $\alpha_p = 1$, $\alpha_c = 1$, $\alpha_D = 1$. The Low-tax Model B considers a situation in which the nominal severance tax rate is $\tau_p = 0.12$, the state corporate income tax rate is $\tau_s = 0.06$, and public land royalty payments as a fraction of total production value is $\tau_r = 0.09$. These choices for state corporate income tax and severance tax rates are broadly representative of actual nominal rates for these taxes (see Table 9.1). The public land royalty payment fraction is similar to actual values for oil-producing states in the western United States (Gerking 2005). At the federal level, the effective federal corporate income tax rate is set at $\tau_{us} = 0.30$. The current nominal depletion rate of 15 percent applies to about 60 percent of U.S. oil production; thus, $\gamma = 0.09$.[11] The expensed portion of current period drilling costs is approximately 40 percent for the industry, and the present value of depletion deductions for capitalized drilling cost can be approximated by $(q/R)/(r + (q/R))$, assuming that it is approximately 8 percent; therefore $\eta = 0.40 + (1 - 0.4)^*(0.08/(0.04 + 0.08)) = 0.8$. The parameter δ is set to zero. Thus, the tax policy parameters for Model B are $\alpha_p = 0.55$, $\alpha_c = 0.67$, $\alpha_D = 0.76$.

The High-tax Model C sets all taxes equal to their Model B values, except for the severance tax, which is set at $\tau_p = .25$. Hence, $\alpha_p = 0.47$, $\alpha_c = 0.67$, $\alpha_D = 0.76$. The Drilling Subsidy Model D sets all tax parameters equal to their Model C values, except that δ is set to 0.22, so that $\alpha_p = 0.47$, $\alpha_c = 0.67$, $\alpha_D = 0.61$.

9.5.4 Other Parameters

Each model uses a discount rate of $r = .04$, an oil price of $p = \$70$ per barrel, and is run for 110 periods at which point drilling all but ceases in the four models because it is no longer profitable. The initial value of reserves (R) was set to 20 billion barrels. This value approximates the quantity of proven reserves for the United States in 2007. The initial value of cumulative footage drilled was arbitrarily set to 2 billion feet, which is roughly equal to the cumulative footage for oil wells drilled in the United States in the past 30 years.

9.6 Discussion of Simulation Results

Results of simulations are obtained from solving the first-order equations of the model (equations (9.6) and (9.9)) after substituting values of the

11 The percentage of production accounted for by nonintegrated independents was approximated by subtracting from unity the ratio of oil and natural gas liquids production by producers subject to USDOE financial reporting system (FRS) requirements to total oil and total natural gas liquids production. For 2007, this ratio was 0.612. Data were taken from U.S.Department of Energy (2009c, 2009d, 2009e).

Table 9.2. *Selected values from solutions for the four models: Year 1*

	Model A	Model B	Model C	Model D
Production in billions of barrels (q)	2.33	2.16	2.03	2.03
Drilled footage in millions of feet (w)	92.44	72.21	63.43	74.26
After-tax price per barrel received by producers ($\alpha_p P$)	\$70.00	\$38.50	\$32.90	\$32.90
After-tax marginal extraction cost of one additional barrel ($\alpha_c C_q$)	\$24.03	\$13.98	\$12.46	\$12.46
Reserve additions from drilling an additional million feet in billions of barrels (f_w)	0.0091	0.0092	0.0093	0.0092
Total reserve additions in billions of barrels (wf_w)	0.841	0.664	0.588	0.683
After-tax marginal cost of drilling one additional foot ($\alpha_D k_w$)	\$227.40	\$135.00	\$118.59	\$111.43
Beginning reserves in billions of barrels (R)	20	20	20	20
Ending reserves (R)	18.55	18.50	18.56	18.65
θ	\$45.80	\$24.50	\$20.50	\$20.50
λ	\$227.00	\$135.00	\$119.00	\$111.00

tax/subsidy parameters and specific equations for drilling costs (equation (9.10)), reserve additions (equation (9.11)), and lifting costs. Table 9.2 shows selected solution values for year 1 for the four models.

In year 1 for Model A, for example, solutions for the level of production and footage drilled are 2.3 billion barrels per year (6.4 million barrels per day) and 92.44 million feet, respectively. These values, together with initial reserves set to 20 billion barrels and $P = \$70$, imply that the marginal cost of extracting an additional barrel of oil is $c_q = \$24.03$ and the marginal cost of drilling an additional foot is \$227.40. Over the course of year 1, reserves fall because production exceeds reserve additions. The present value of future profits from an additional barrel of reserves is $\theta = \$45.80$ (see equation (9.6)), and the present value of drilling cost reductions from an additional unit of reserves is the negative of $\lambda = \$227$ (see equation (9.7)). Both of these two shadow prices steadily converge toward zero over time.

Values presented in Table 9.2 for Models B and C are interpreted similarly. In these two models, production and drilling are lower than in Model A, in part because the severance tax causes prices received by producers to fall disproportionately relative to extraction and drilling costs. In Model D, production is the same as for Model C because tax rates and initial values

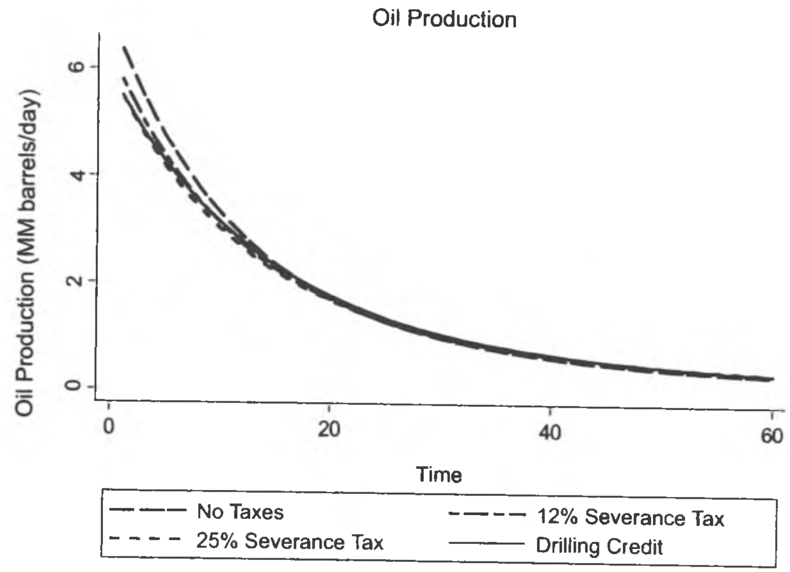

Figure 9.1. Oil production is quite insensitive to the tax structure in the U.S. case.

of reserves are the same, but footage drilled is higher because of the drilling expense subsidy. In all three models, the shadow values λ and θ converge toward zero over time, just as in Model A.

Figure 9.1 shows the time profile of oil production in millions of barrels per day for each of the four models.

In each model, production declines substantially over time. The no-tax case (Model A) shows the highest production rates. The introduction of taxes in Model B tilts production (slightly) to the future, as predicted by models of extraction from fixed reserves (see Section 9.4). Numerical calculations indicate that production rates for Model B are lower than for Model A until year 26, at which point production rates become higher for Model B than for Model A. In Model C, tilting of production to the future is more pronounced in comparison to Model A than it is for Model B because of the higher severance tax rate assumed. Production in Model C is lower in the early years of the program, but begins to exceed production in Model B by year 27. Introduction of the subsidy for drilling expenses tilts production back to the present in comparison with Model C. Model D production initially exceeds that for Model C, but is lower than that for Model C after year 48.

Figure 9.1 also shows that production is relatively insensitive to changes in tax rates and therefore to changes in prices received by operators. Cumulative production figures for the 110-year program period confirm this result (Table 9.3).

More specifically, comparing Model A with Model C, the arc elasticity of cumulative production with respect to a change in severance tax rates $((\Delta q/q)/(\Delta \tau_p/\tau_p))$ is only $(-1.4/38.7)(0.125/0.25) = -0.02$. This outcome implies that the arc elasticity of cumulative production with respect to a change in prices received by operators is $(-1.4/38.7)(56.7/-26.6) = 0.05$. Of course, these simple elasticity calculations are based on cumulative production totals and do not take the timing of production into account, but as shown in Figure 9.1, the time path of production does not differ greatly across the four models.

Oil production also would be insensitive to changes in the percentage depletion allowance rate (η) that can be used by nonintegrated independent producers in computing federal corporate income tax liabilities. As shown in equations (9.12) through (9.14), a reduction in either η or an increase in the severance tax rate τ_p lowers α_p while leaving α_c and α_D unchanged. In fact, given the values of the tax parameters used for Models B, C, and D, eliminating the percentage depletion allowance would have the same effect on production as a four percentage point increase in the severance tax. This parallel between changes in severance tax rates and the changes in the percentage depletion allowance may be of interest in light of the Obama Administration's proposal to eliminate the latter tax preference (see Krueger 2009). Of course, changes in the severance tax and changes in the oil depletion allowance will not have equivalent effects on the collection of other taxes at the state and federal levels.

Insensitivity of oil production to severance tax increases would be to some extent expected in these simulations because a key effect of the tax simply is to reduce industry profits. The assumed price of oil ($70/bbl) is relatively high by historical standards; thus, discounted profit is a relatively large percentage (80 percent) of discounted total revenue. In consequence, the array of taxes imposed in Model B can cut into profits without substantially altering drilling or production. Kunce et al. (2003) found somewhat greater responsiveness of oil production to changes in severance tax rates when setting P (P = $23) at a lower value than the one used in this study. In their simulations, which envision a lower ratio of profit to total revenue, the long-run elasticity of production to changes in the severance tax rate was −0.06.

Table 9.3. *Total drilling, production, tax collections, profits, and reserves for four models over the 110-year program*

	Model A no taxes	Model B 12% severance tax	Model C 25% severance tax	Model D 25% severance tax with drilling subsidy
Total production (in billions of barrels)	39.4	38.5	38.0	38.6
Total footage drilled (in billions of feet)	4.5	3.9	3.6	3.9
Discounted public land royalties (in billions of dollars)	$0	$131.0	$126.3	$129.3
Discounted severance tax Collections (in billions of dollars)	$0	$159.0	$319.2	$307.5
Effective severance tax Rate	0	0.109	0.228	0.212
Discounted state corporate income tax revenue (in billions of dollars)	$0	$60.9	$49.6	$50.8
Discounted federal corporate income tax revenue (in billions of dollars)	$0	$230.0	$182.5	$188.4
Discounted depletion allowance deductions (in billions of dollars)	$0	$119.2	$114.9	$117.7
Discounted pre-tax total revenue (in billions of dollars)	$1,544	$1,456	$1,403	$1,437
Discounted extraction costs (in billions of dollars)	$186.3	$151.8	$130.1	$133.0
Discounted drilling costs (in billions of dollars)	$125.6	$84.4	$68.3	$88.3
Discounted firm profits (in billions of dollars)	$1,231	$638	$527	$539
Beginning reserves (in billions of barrels)	20	20	20	20

In any case, the inelasticity of production with respect to severance tax and price changes suggests that severance tax collections computed as $s = \tau_p(1 - \tau_r)pq - \delta k(w)$ should increase roughly in proportion to changes in the tax rate when $\delta = 0$. As shown in Table 9.3, discounted (at 4 percent) severance tax collections over the 110-year program period total \$159.0 billion for Model B and \$319.2 billion for Model C. Effective severance tax rates for these two models are 0.109 and 0.228, respectively. These figures suggest that the arc elasticity of discounted severance tax collections with respect to a change in the effective tax rate is 0.95 (assuming unchanged royalty rates and oil prices). Model D, which includes the credit ($\delta = 0.22$) for drilling expenses, reflects smaller severance tax collections than Model C.

Table 9.3 indicates that severance tax rate increases result in lower collections of both state and federal corporate income taxes. Because of the deductibility of severance tax payments against these two taxes, discounted state corporate income tax collections fall from \$60.9 billion in Model B to \$49.6 billion in Model C, and discounted federal corporate income tax collections fall from \$230.0 billion in Model B to \$182.5 billion in Model C. Notice that the decline in federal corporate income tax collections is cushioned by declines in depletion allowance deductions (\$119 billion to \$114.9 billion) and in deductions for current and capitalized drilling costs. The value of these two deductions declines because both production and drilling are lower in Model D than in Model C. Also, discounted oil industry profits fall sharply when all taxes are imposed (compare Model A with Models B and C). In any case, the main effects of severance tax rate increases are to redirect (1) oil industry profits to the public sector and (2) tax payments from the federal level to the state level.

Although the specific way in which the model is parameterized may be responsible for the relative insensitivity of production to changes in oil prices and severance tax rates, results shown in Figure 9.1 and Table 9.3 are broadly consistent with U.S. experience over the past half-century. Figure 9.2 shows this by plotting total U.S. proven reserves (in billions of barrels), total U.S. production from proven reserves (in hundred millions of barrels), and the real price of crude oil (in year 2000 dollars).

Proven reserves stood at roughly 30 billion barrels from 1959 to1970, increased to nearly 40 billion barrels in 1971 with the discovery of oil in Prudhoe Bay, and then declined steadily thereafter to 20.9 billion barrels in 2007. Over this time period, production followed a similar pattern, remaining between 8 percent and 11 percent of reserves in each year; on average, production represented 9.2 percent of reserves with standard error

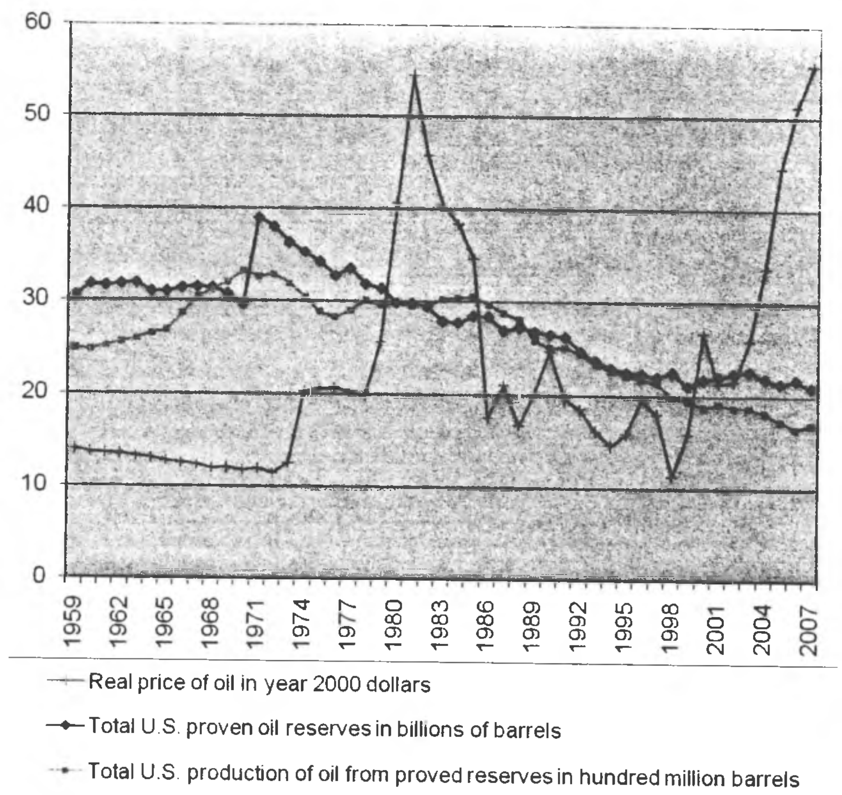

Figure 9.2. U.S. oil production has been insensitive to oil prices over the past 50 years.

of 1.34. Real crude oil prices, on the other hand, exhibited greater variability, but neither the spike in the late 1970s and early 1980s nor the price increase seen in recent years appears to have had much effect on production.

Drilling activity during the 110-year program shows greater percentage differences across the four models (see Figure 9.3 and Table 9.3) than were computed for production.

Model A has the most drilling in each year of the simulation period. Total drilling in Models B and C are lower by 13.3 percent and 20.0 percent, respectively, than in Model A, because the imposition of severance taxes reduces the future payoff from this activity. The effect of the 22 percent drilling expense credit in Model D is to increase drilling above the levels predicted for Model B, but still 13.3 percent below the level predicted for Model A. Total drilling over the 110-year simulation period (net of the starting value of 2 billion feet) is 4.5 billion feet for Model A, 3.9 billion feet for Model B, 3.6 billion feet for Model C, and 3.9 billion feet for Model D.

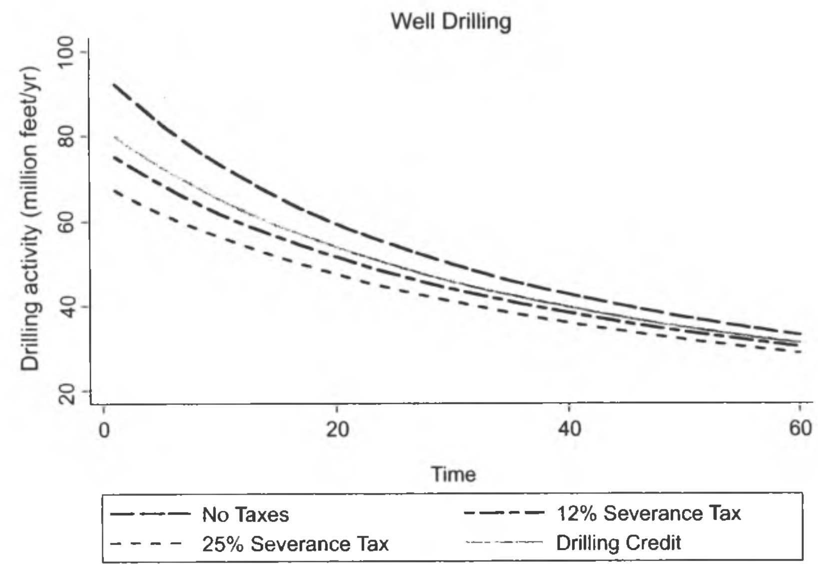

Figure 9.3. Drilling activity is more sensitive to the tax regime.

The figures presented in Table 9.3 imply that the long-run arc elasticity of footage drilled over the 110-year program with respect to the severance tax changes contemplated in Models B and C is −0.07. The corresponding price elasticity is 0.91. Thus, in percentage terms, drilling is more responsive to tax and price changes than is production. Figure 9.4 shows that these results are roughly consistent with the observed relationship between drilling footage and real oil prices (defined as in Figure 9.2) in the United States over the past 50 years.

As shown, drilling footage responds positively to changes in the real oil price, and a regression of the natural logarithm of footage drilled on the natural logarithm of the real price of crude oil yields a coefficient of the latter variable of 0.44 (t-statistic = 3.38). This estimate compares favorably with estimates produced by the simulation model.

Another perspective on the results for the time path of drilling and production can be obtained by focusing on the behavior of reserves. In all four models, initial reserves are set to 20 billion barrels. Drilling leads to annual reserve additions, and reserve additions are highest when more drilling is carried out. In consequence, reserve additions tend to be higher for Model A than for either Models B or C. Reserve additions also are higher for Model D than for Model B, again illustrating the effect of the drilling expense

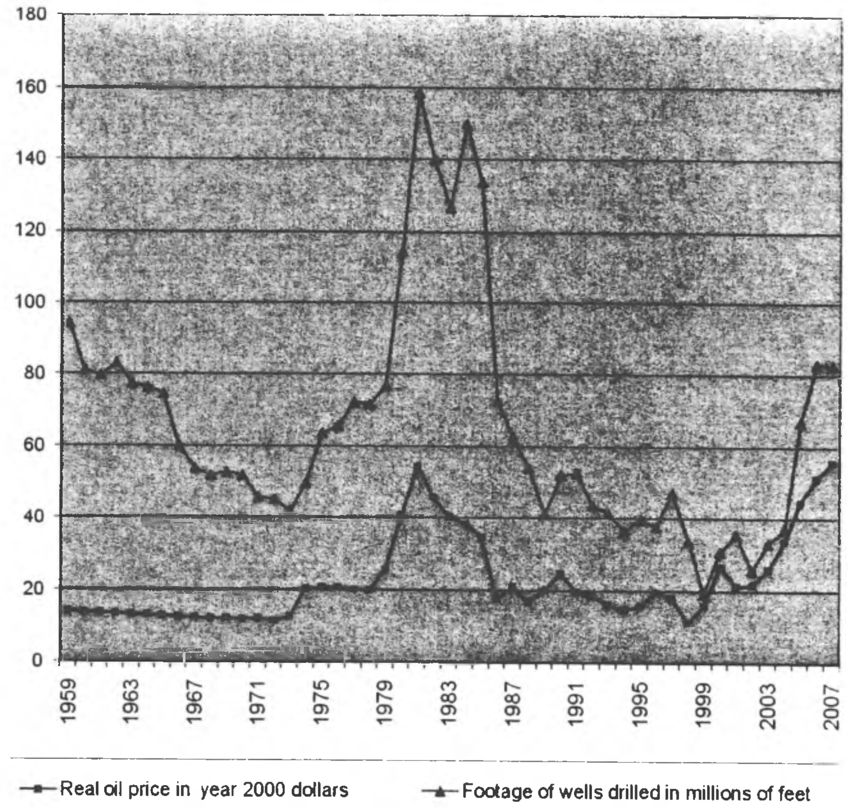

Figure 9.4. Price movements coincide with changes in footage of wells drilled.

subsidy. In all four models, however, annual reserve additions always are exceeded by annual production and thus reflect declining reserves over time. This outcome can be seen in Table 9.3 by comparing beginning reserves with the much smaller corresponding figures for ending reserves.[12] Moreover, this outcome is consistent with the previously discussed trends presented in Figure 9.2, which illustrate that U.S. proven reserves have declined by about 50 percent over the past half-century.

Table 9.3 presents additional information concerning the effect of the 22 percent drilling expense credit subsidy on drilling, production, reserves, and tax collections.[13] As discussed previously, the credit spurs drilling over

[12] The ending values for reserves reflect high-grading brought about by the severance tax, as discussed in the theoretical literature. For instance, ending reserves in Models B and C are 38 percent and 63 percent higher, respectively, than for Model A.

[13] Results presented below concerning effects of a drilling expense credit may also inform the current debate about the proposed elimination of the possibility to expense intangible

the life of the program, which adds to the reserve base and raises production (compare Models C and D). Discounted drilling expenditures rise by 29 percent ($20 billion), but because drilling expenditures rise at an increasing rate with footage drilled (see equation (9.10)), footage drilled rises by a smaller percentage (8 percent or 0.3 billion feet). The 0.6 billion barrel increase in production associated with the credit approximately offsets the effect on production of increasing the severance tax rate from 12 percent to 25 percent (compare Models B and D). Application of the credit results in 14 percent fewer remaining reserves at the end of the program (compare Models C and D) and roughly offsets the effect on ending reserves that results from the severance tax increase in Model C as compared with Model D.

The incremental production resulting from the drilling expense credit results in an increased present value of severance tax collections (gross of the credit) in Model D ($326.9 billion) as compared with Model C ($319.2 billion). Once the present value of drilling expense credits are subtracted, however, the net-of-credit present value of severance tax collections in Model D ($307.5 billion) ends up lower than in Model C by 3.7 percent, yet they are 93.4 percent higher in Model D than in Model B. Comparing Models D and C, $1.2 billion in lost severance tax revenue is regained through increased state corporate income tax collections; however, $5.9 billion in lost severance tax revenue is transferred to the federal government in the form of higher federal corporate income tax payments. In any case, the drilling expense credit results in a net loss in discounted state tax revenue of $10.5 billion. It costs about $17.50 in lost discounted state tax revenue (both severance tax and state corporate income tax) to produce an additional barrel of oil and about $35.00 of lost discounted state tax revenue to drill an additional foot. Additionally, each dollar of discounted state tax revenue lost because of the credit is associated with a $1.90 increase in drilling expenditures.

This outcome raises a question as to whether other public policy instruments, such as support for research to lower drilling costs or to increase finding rates, might spur drilling at lower cost to the state. Nonetheless, if a state's objective in granting the drilling expense credit is to gain support for increasing the severance tax rate from 12 percent to 25 percent, it is a relatively inexpensive concession. On the other hand, a state that expects the drilling expense credit to more than pay for itself through severance

drilling costs in computing federal corporate income tax liabilities. Both types of policies operate through α_D while leaving the other two tax parameters unchanged.

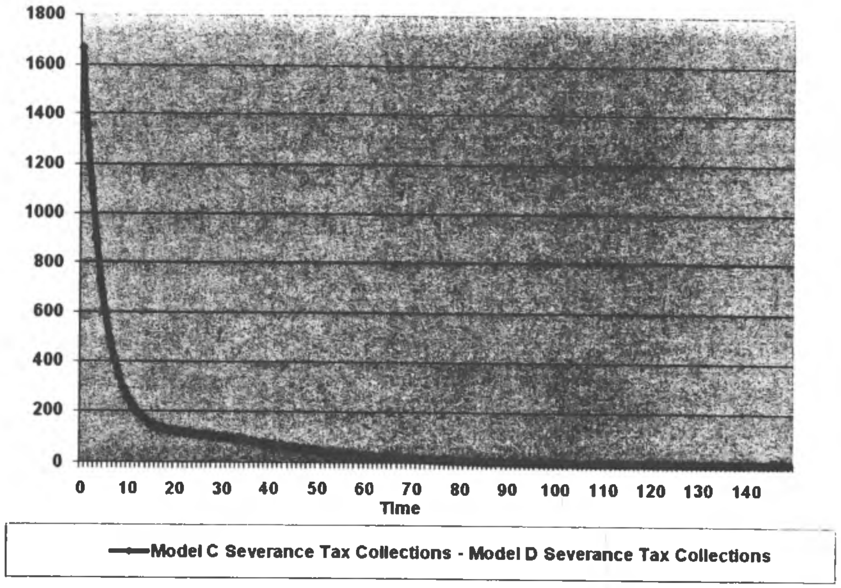

Figure 9.5. Discounted severance tax losses from the drilling expense credit accumulate over time.

tax collections will be disappointed because it simply generates too little incremental oil production. In fact, the drilling expense credit is not only cost-ineffective when evaluated over the entire program, it is cost-ineffective in each program year, as shown in Figure 9.5.

As can be seen from Table 9.2, the credit results in a 17 percent increase in drilling in year 1 (compare Models C and D), but no additional production and thus no additional revenue. Model D production begins to reflect the additional drilling in year 2 and exceeds that for Model C until year 48. During these years, severance tax losses in Model D compared to Model C are smaller than the value of the credit. As indicated, beginning in year 49, production in Model C is larger than that for Model D. Thus, in years 49 to 110, the loss in severance tax revenue in Model D compared to Model C exceeds the value of the credit.

A possible concern about these calculations is that they pertain to a model that is parameterized using U.S. oilfield data. In particular, one conjecture might be that a drilling credit might be financially more attractive in an area that has been less extensively explored, so that the marginal product of drilling in identifying new reserves would be higher. To check this idea, the simulation model was recalibrated by assuming that cumulative drilled footage prior to the start of the program was 500 million feet, rather than

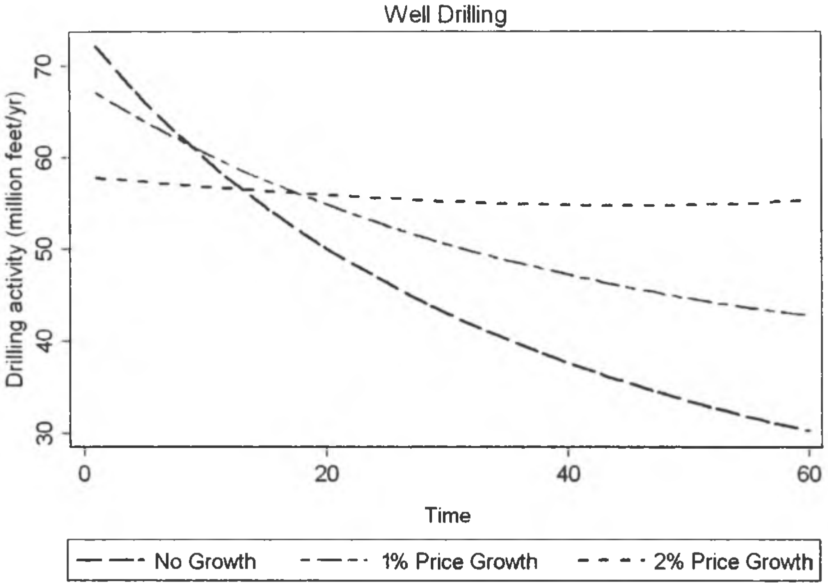

Figure 9.6. Oil drilling tilts to the future with exogenous growth in oil prices.

2 billion feet. This alteration roughly doubles the marginal product of drilling in identifying new reserves, which in turn stimulates drilling, reserve additions, and production. Therefore, Model C discounted severance tax collections are higher than those shown in Table 9.3. Model D discounted severance tax collections also are higher than in Table 9.3, but still lower than the comparable value for Model C. Thus, in both absolute and percentage terms, severance tax losses from the drilling expense credit are larger when cumulative footage drilled totals 500 million feet as compared with 2 billion feet.

It would also be of interest to construct a simulation using the actual path of oil prices over the last several decades. This price, however, exhibits sharp increases and decreases over time (see Figure 9.2), causing the simulation algorithm to break down. As a second choice, we performed a set of sensitivity analyses to reflect a forecast that oil prices will rise over time, at two exogenously given rates. Of course, with perfect foresight, prices cannot go up faster than the rate of discount, because then oil production will be postponed to the future. We thus assume exogenous growth rates in oil prices of 1 percent and 2 percent. As shown in Figure 9.6, drilling activity flattens out with a 2 percent growth in prices.

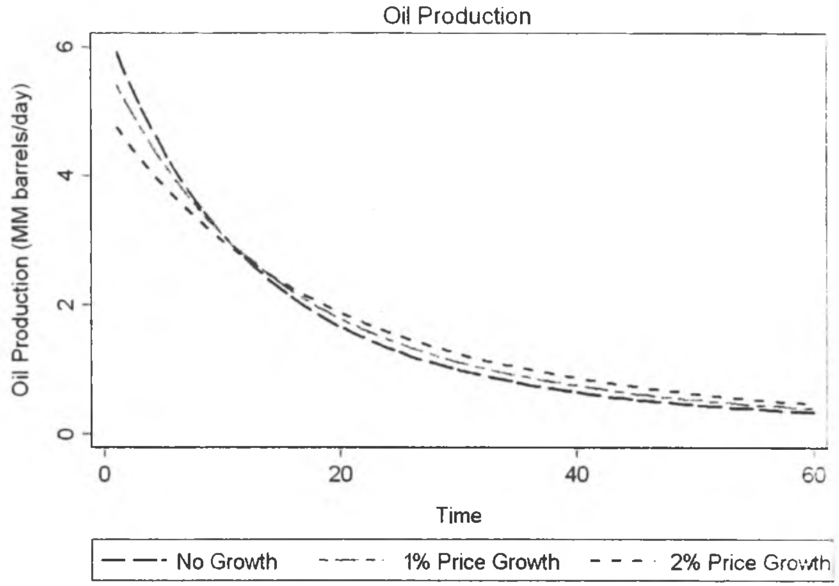

Figure 9.7. Oil production does not change appreciably with growth in oil prices.

However, oil production is relatively insensitive to oil price growth, as shown in Figure 9.7. This is because even though drilling activity shifts out to the future with an increase in prices, the decline in returns from cumulative drilling keeps production from leveling out in time. Production continues to fall, as in the case with constant prices. Figure 9.8 shows the change in reserve additions in the price growth scenario.

9.7 Concluding Remarks

This chapter described tax policies pursued by U.S. states that impact the oil industry. Three types of taxes are discussed: (1) the severance or production tax, (2) the property tax, and (3) the corporate income tax. The severance tax then is further analyzed in light of its widespread use in energy-producing states and its potential to generate revenues to support public services. The analysis is carried out using an adaptation of a conceptual model (Pindyck 1978) of exploration/development and production of exhaustible resources in which oil prices are taken as exogenous. This perspective is a useful simplification for an analysis of state taxes because no state produces enough oil to appreciably affect the world price. Simulations obtained from calibrating the model suggest that oil production volumes will be quite insensitive to

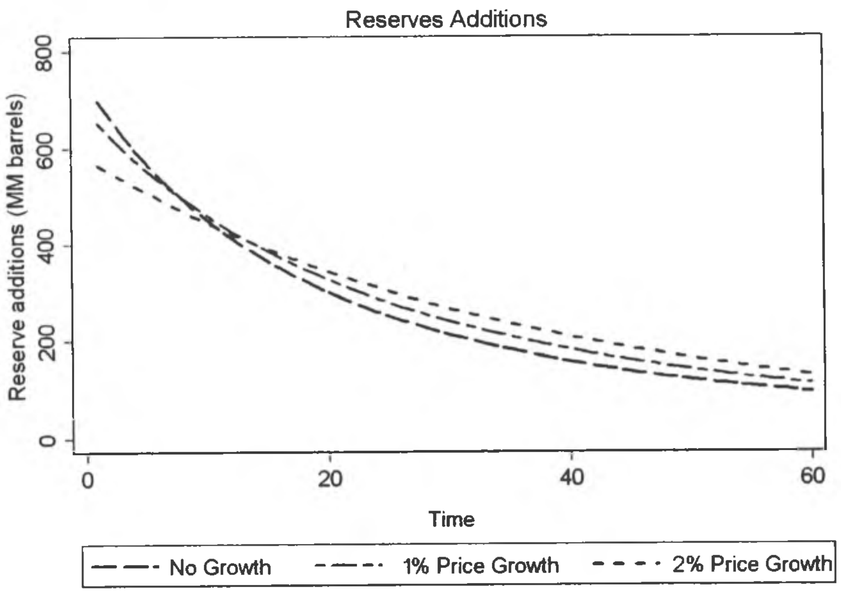

Figure 9.8. Reserve additions change only marginally with growth in oil prices.

price and severance tax rate changes. Thus, an increase in the severance tax rate is seen to generate proportionally more severance tax revenue, as its main effect is to redirect economic rents earned in the oil industry towards the public sector. An implication of this result turns out to be that the proposed elimination of the percentage depletion allowance, available to nonintegrated independent oil producers, may have much the same effect on production as a severance tax increase, although changes in the two types of tax measures may have quite different effects on the distribution of tax revenue between the state and federal levels of government.

Simulations based on the U.S. experience demonstrate that the credit for drilling expenses does turn out to increase drilling as intended. However, if the credit is applied in the United States, particularly in areas where a great deal of drilling has already occurred, its contribution to identifying new reserves may be rather limited. In other words, much of the continental United States has been extensively explored, so the chances of large oil discoveries probably are small. Simulations of the model show that the drilling expense credit does not generate enough incremental severance tax revenue to pay for itself. Additional work needs to be carried out to see whether alternative public policies to stimulate exploration and development might be more cost-effective as well as the extent to which the results presented continue to hold when the model is parameterized differently.

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EFFECTIVE TAX RATES ON OIL AND GAS PRODUCTION: A TEN STATE COMPARISON

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1. Overview

The purpose of this report is to compare taxation of the oil and gas industry in ten major producing states: (1) Alaska, (2) California, (3) Colorado, (4) Kansas, (5) Louisiana, (6) New Mexico, (7) Oklahoma, (8) Texas, (9) Utah, and (10) Wyoming. In 2003, production of oil and gas varied considerably across these states. As shown in Table 1, Texas is the nation's leading state in both oil and gas production.

Table 1: Production of oil and natural gas for top producing states: 2003[a]

STATE	PRODUCTION OF NATURAL GAS (IN BCFs)	PRODUCTION OF CRUDE OIL (in thousands of barrels)
Alaska	456	355,582
California	323	250,000
Colorado	978	21,109
Kansas	384	33,944
Louisiana	1,225	90,111
New Mexico	1,493	66,130
Oklahoma	1,483	65,356
Texas	4,911	405,801
Utah	265	13,096
Wyoming	1,470	52,407

[a] Source: Energy Information Administration, U.S. Department of Energy, www.eia.doe.gov.

Utah produces the smallest quantities of oil and gas among the ten states listed.

Additionally, among major oil and gas producing states, tax structures vary considerably and tax bases interact, particularly between the state and federal level. For example, among the ten states listed in Table 1, all states except California levy severance taxes against the value of production. Severance taxes dominate other forms of state/local taxation of oil in Alaska, Oklahoma, Texas, Wyoming, and Louisiana. Conservation taxes, levied by virtually all energy producing states on the value of production, are included in the analysis below but revenues generated by such taxes generally are relatively small. All of the ten states levy a corporate income tax that applies to oil and gas producers except for Wyoming and Texas. In some states, the federal corporate income tax liability is deductible in computing state corporation income taxes and in others it is not. While local governments in most of the states utilize some form of a property tax on oil and gas extraction equipment, property taxes on oil and gas reserves are levied only in California, Kansas, Texas, and Utah. Taxes on reserves provide operators with strong incentives to accelerate production at times when oil and gas prices are rising, as they attempt to reduce the extent of their tax liability. Most states treat royalty payments (computed as a percentage of gross value of production) for production on public land as deductible items in computing severance tax liabilities (Louisiana does not). Public land royalties are relatively more important in Alaska, Colorado, New Mexico, Utah, and Wyoming than in other states due to their large shares of publicly owned land. Also, states have granted innumerable exemptions and credits (which differ by state and year) against various tax liabilities for special situations that may be encountered by operators.

The myriad of exemptions, incentives, different tax bases, special features and frequent changes in tax laws, at both the state and federal government levels, create considerable complexity in understanding and tracking of tax law over time. Rather than itemize tax code details, economists have a simple and straightforward way of dealing with taxes that does not require a comprehensive understanding of each state's tax law or an itemization of specific tax incentives. This method involves computation of what are called effective tax rates. Effective tax rates can be expressed as the ratio of taxes (or royalties) collected from a particular tax to the value of production. Thus, the calculation of effective tax rates fully account for all tax incentives granted against all types of taxes faced by oil and gas industry as well as the fact that different states compute tax liabilities based on values at different points in the production/distribution chain. Also, use of a common denominator (value of production at the wellhead) makes it easier to compare tax burdens between states, and for a given state, makes it possible to simply add effective property tax, severance tax, and royalty rates together if desired.

Effective rates are computed in this study for all types of taxes and royalties, except for state corporate income taxes. State corporate income taxes differ from other forms of state taxation of oil and gas, because production costs and other expenses are deductible items in determining liabilities. Because data on such costs are unavailable, only nominal state corporate income tax rates are presented.

Data on state severance taxes, state and local property taxes, and royalty payments for production on state lands are not available from a single source nor are they published in a common format. In consequence, these data were obtained by searching through state agency annual reports available on the internet and by directly contacting knowledgeable people in these agencies as questions arose. Information regarding nominal state corporate income tax rates was obtained from the Tax Foundation for the year 2003. Data on federal royalty payments from oil and gas production on federal lands, which consists of onshore mineral leases, Indian mineral leases, and leases on military lands and National Petroleum Reserve Lands were obtained from the U.S. Department of the Interior, Minerals Management Service. The Energy Information Administration, U.S. Department of Energy publishes annual data on oil and gas production volumes together with average wellhead prices of oil and gas in each state. These data exclude oil and gas produced in the Outer Continental Shelf (OCS) that is not subject to taxation by states. Use of the Department of Energy data permits the wellhead value of production of oil and gas to be determined from a common source for each state in each year. These value of production figures are used as the denominators in making the effective tax rate calculations.

One aspect of data collection for state and local taxes was to ensure that the year of production matched to the year of valuation of tax liabilities or collection of tax revenue. In several states, state severance and/or local ad valorem tax collections are based on the previous year's production. Additionally, in the case of Wyoming, Texas and Louisiana adjustments were made to the tax revenue data to account for several large tax protests or appeals. In the latter two states, tax revenue is reported in the year of the legal settlement rather than adjusting revenue for the year in which the tax liability was generated. Accordingly, the data were adjusted to reflect the latter concept. In the case of Wyoming, tax revenue from tax protest and appeal settlements is assigned to the year the tax liability was created. Adjustments for tax protests and appeals were not possible for the state of Alaska and to some extent represent a potential source of error (probably small) in computing effective tax rates for all states.

Tax administration procedures created problems in several states with respect to being able to obtain tax data, particularly information on local property tax liabilities.

Property taxes are administered at the local government level, but in most states, at least in recent years, the state government has had an increasing amount of oversight. The oversight takes various forms from establishing property tax assessment procedures or assessing the property directly to collecting information and reporting statewide values of assessed property by category, including oil and gas extraction equipment, and average statewide mill levies for non-municipal property. This development makes it easier to compute effective property tax rates today as compared with earlier years when local assessor's offices were the only source of these data in many states.

2. Tax Rate Measurement in each State

The general aspects of the tax structure for each of the ten major producing states as it applies to oil and gas are outlined below for the years 2001-2003. The tax structures differ by state depending on the particular taxes employed and the base for each tax. The taxes relevant to oil and gas and selected additional data collection issues are discussed for each state below.

Alaska. Alaska has a state corporation income tax, a severance tax and a property tax on capital improvements and equipment. The federal corporation income tax is not deductible in computing state corporation income tax liabilities. Royalties from production on public lands are deductible in computing the severance tax. The state has an alternative minimum specific severance tax of $.80 per barrel or oil. In consequence, when the ad valorem tax falls below $.80/bbl., the specific tax is used. Most of the tax revenue and royalty information is available on the internet at www.revenue.state.ak.us. An explanation of the data was obtained from officials at the Alaska Department of Revenue, Oil and Gas Audit Division.

California. The focus of the tax analysis for California is oil since California is not a major gas producing state. At the state level the key tax on the oil industry is the corporation income tax; the federal corporate income tax is not deductible. There is no severance tax in California, although there is a conservation tax of $0.05/ bbl of production. The property tax is administered at the county level and includes surface property, equipment and the estimated value of mineral reserves. Since there are no statewide tax revenue data on oil property, information from Kern County, which accounts for seventy percent of oil production in California, was used to represent the state-wide average. A time series of the estimated property tax expressed in cents per barrel of oil produced was obtained from the Chief Appraiser, Oil and Gas Division of Mineral Rights, Kern County. Total state property tax revenue was estimated by multiplying the property tax per barrel times the total number of barrels of oil produced in California. Royalty information relating to production on public lands was obtained from the California State Lands Commission. The royalty rate for production on state lands is about eighteen percent with a floor of one sixth. However, California produces relatively little oil from state lands. Also, this floor can be reduced if it can be demonstrated by a study that it is economically feasible for old wells to continue production if the royalty rate is reduced. California's taxation of oil and gas differs substantially from the tax treatment applied in other states. Thus, California taxes on oil and gas should be compared to those levied in other states with caution.

Colorado. The state of Colorado levies a severance tax on the value of oil and gas produced. Tax rates range from 2%-5% depending on gross income from oil and gas sales of the producer. Local governments also levy a property tax on the value of land, improvements and other property used in the production of oil and gas. Oil and gas land is valued differently than other classes of Colorado property subject to property taxation. Rather than being appraised according to its market value, the value of land producing oil and gas is calculated as a percentage of the sale price obtained for the product at the wellhead. The percentage of the sale price subject to taxation depends on whether the production is classified as primary or secondary. Working and/or royalty interest owners in Colorado are permitted take a credit of 87.5% of property taxes against their state severance tax liabilities. This means that the local property tax generates considerably more revenue than does the state severance tax. Data were taken from published records of the Colorado Department of Revenue, the Colorado Department of Local Affairs (Property Tax Division), Colorado Oil and Gas Conservation Commission, and the Colorado State Land Board. Comparatively little oil and gas production in Colorado occurs on state property, so state royalties account for only a small percentage of total public revenue generated by oil and gas activity.

Kansas. In Kansas, the key taxes at the state level are a severance tax on oil and gas production and a corporation income tax. Royalties from production on public lands are not deductible in computing severance tax liabilities. Royalties from production on state lands are unimportant, amounting to less than $80 thousand annually. A local property tax is levied on royalty, working interest, itemized equipment, and reserves in the ground. The Kansas Department of Revenue, Mineral Tax Bureau provided data on severance taxes. Property tax information was obtained from the Kansas Department of Revenue, Mineral Tax Division. Additional information was obtained from the Kansas Corporation Commission and from the Kansas Geological Survey.

Louisiana. The state of Louisiana levies a severance tax on the value of oil and the volume of gas production. Louisiana also levies a corporation income tax. Royalties from production on public lands are not deducted in computing severance tax liabilities. The federal income tax is deductible in computing state corporate income tax liabilities. The property tax is levied on oil and gas wells and surface equipment, and it is administered at the parish (country) level. The State Department of Revenue, Severance Tax Division provided the severance tax information. The Louisiana Tax Commission provided information about property tax collections. These data were used to calculate property tax liabilities for oil and gas combined. Information on royalties and production of oil and gas on state lands was provided by the State of Louisiana, Department of Natural Resources, Technology Assessment Division.

New Mexico. The state of New Mexico levies a number of separate production taxes on oil and gas, referred to as oil and gas extraction taxes. The taxes consist of the Oil and Gas Severance Tax, Oil and Gas Emergency School Tax, Oil and Gas A*d Valorem* Production Tax, and the Oil and Gas Production Equipment Tax. The revenues collected are reported for oil and gas combined. An additional tax is levied on natural gas, the Natural Gas Processors Tax. For purposes of the analysis here the separate taxes are combined to form one production tax whose effective tax rate is total tax collections per year divided by the annual value of production. The New Mexico Taxation and Revenue Department, Oil and Gas Division provided information concerning severance taxes. Royalties from production on public lands are deductible in establishing valuation for the production taxes. Information on royalties from production on state lands also was obtained from the New Mexico Taxation and Revenue Department. There is no separate property tax on oil and gas equipment. Equipment is taxed through the Oil and Gas Production Equipment Tax mentioned above. Additionally, the state of New Mexico levies a corporation income tax. Federal corporate income tax liabilities are not deductible in computing the state tax liability.

Oklahoma. The state of Oklahoma levies a severance tax on oil and gas production, and a corporate income tax is applied. Royalties from production on public lands are deductible in computing severance tax liabilities, but federal corporate taxes are not deductible in the computation of state corporate income tax liabilities. The severance tax is levied in lieu of a property taxes, although a property tax is levied on equipment if a well is shut in for 13 consecutive months or more. In any case, the property tax generates little revenue and is ignored in the effective tax rate calculations. Severance tax revenue data were obtained from the Oklahoma Tax Commission. Data are reported for oil and gas combined. The Oklahoma Tax Commission provided the information to calculate the value of production from public lands, and the Commissioner of the Land Office provided the data on oil royalty and gas royalty from production on school lands in directly useable form.

Texas. The state of Texas levies a state severance tax on oil and gas production, and a property tax is levied at the local level on the estimated present value of minerals in the ground as well as structures and equipment. Severance tax revenue for oil and natural gas reported separately were obtained from published reports of the Railroad Commission of Texas and the Texas Comptroller of Public Accounts. The state does not levy a corporate income tax. Royalties from public lands are deductible in computing severance tax liabilities. In addition to a school property tax, counties and special districts levy property taxes. School property tax revenue is available for oil and gas combined on an annual basis. At the recommendation of officials at the Texas Taxpayer and Research Association, school tax revenue was grossed up by five eighths to approximate total oil and natural gas property tax revenue statewide. This total was allocated between oil and gas based on the estimated gross value of oil reserves relative to gas reserves (price of oil, or gas, times the estimated volume of reserves, by year).

Royalties from production on state lands are allocated to The Permanent School Fund which was established to provide investment income to support public education for students in grades K-12, and the Permanent University Fund which has a similar purpose for public higher education in Texas. The data were obtained from the administrators of these funds.

Utah. The State of Utah levies a severance tax on oil and gas production at the state level. For oil, the tax rate is 3% of value of the first $13 per barrel and 5% of value above $13. For natural gas, the tax rate is 3% of value up to the first $1.50 per mcf and 5% of value above $1.50 per mcf. Information regarding severance tax collections on oil and gas combined was taken from the Annual Reports of the Utah Tax Commission. Severance tax collections on oil production then were separated from those on natural gas production using supplementary data on net taxable values furnished by the Commission. These supplementary data also contained information regarding royalties paid for production on federal, state, and tribal lands. Production of oil and gas on state land is relatively unimportant, but production from federal and tribal lands is much more prominent. Property taxes charged against oil and gas extraction and the value of reserves in the ground are taken from tables showing the total of such taxes charged against various classes of property presented in the Utah Property Tax: Annual Statistical Reports for 2001, 2002, and 2003. Additional information on the Utah tax structure for oil and gas is available in the History of the Utah Tax Structure, compiled by the Utah Tax Commission. Utah levies a corporate income tax at the rate of 5%.

Wyoming. The state of Wyoming levies a severance tax on oil and gas production and a production tax is levied at the local level, too (the local *ad valorem* production tax). In Wyoming, royalty payments from production on state and federal lands are deductible in computing production tax liabilities. Data on royalty payments from production on state lands were obtained from the State Land Office. Additionally, a local government property tax is levied on oil and gas equipment, including drilling rigs, oil and gas well equipment, gathering lines and tank batteries. Total property tax liabilities were estimated by year by multiplying the total statewide assessed valuation for oil and gas equipment combined by the average statewide mill levy for all purposes (not including municipality levies). The total estimated property tax liability for oil and gas equipment combined was portioned between oil and gas based on the annual value of oil production and natural gas production in Wyoming. The average effective property tax rate on equipment is expressed as the ratio of the estimated tax liability for oil (or gas) equipment to the value of oil (or gas) production. Wyoming does not levy a state corporation income tax. The tax data were obtained from the Wyoming Department of Revenue. The average effective tax rate is expressed as the ratio of taxes collected to total value of production for both the state severance tax and the local *ad valorem* tax.

3. Comparison of Effective Rates of Oil and Gas Taxation

State tax structures are compared based on effective rates of taxation. These effective rates fully account for all tax incentives that have been granted to oil and gas operators in each state. Thus, the effective rates calculated generally are lower than the nominal rates of tax that would prevail if no incentives had been granted. Effective rates were computed annually for the period 2001-2003 and are shown in Table 2. Effective tax rates for oil and gas are presented for those states that provide separate collections information. Federal royalty information was available from the U.S. Department of Interior, Minerals Management Service only for the year 2001. In the case of production and property taxes, and state and federal royalties, the effective tax rate is the ratio of tax collections or liabilities to gross value of production.

Comparisons of the effective tax rates highlight the substantial differences in the tax structures of the energy producing states, and in the relative importance of production on public lands. Beginning with oil, Table 2 shows that Wyoming relies on state and local production taxes as major sources of oil revenue. Royalties from production on public lands are a major revenue source for the federal government, as a large share of Wyoming's oil and gas production is on federal land. State production and local property taxes are the major revenue sources in Texas. In the case of Louisiana, state production taxes and royalties from production on state lands and waters are the important sources of revenue. Louisiana also levies a state corporation income tax. In Oklahoma, the state production tax is most important. Oklahoma also levies a state corporate income tax. Property and production taxes are major revenue sources in Kansas and a corporate income tax is levied. The state production tax and royalties from production on state lands are most important in Alaska, and a corporate income tax exists. In California the property tax on reserves is most important and a corporation tax is levied. Royalties from production on state lands have diminished in importance in California over the past 20 years. In New Mexico, production taxes and royalties from production on both federal and state lands are important, and a corporation income tax exists. In Colorado, the property tax is most important and the state levies a corporate income tax. Utah's effective severance tax rates on oil and gas production are in the 3.5%-4% range and the state levies a 5% corporate income tax.

Another useful perspective is a comparison of each source of revenue across states. Regarding production taxes, the effective taxes are highest in Alaska, Wyoming (state and local combined) and Louisiana, all with effective tax rates in excess of ten percent in 1997. Effective rates are lowest in Colorado, Utah, Kansas, and Texas. California does not levy a production tax on oil and gas. In 2003, effective property tax rates were highest in Colorado (4.7%), Kansas (5.4%), and California (3.4%). The highest effective tax rates on operating profits of the oil and gas extraction industry, and industry in general, are levied in Alaska and California. Again, Texas and Wyoming do not levy corporation income taxes. The key factor determining effective royalty rates is the volume of production on public lands. In 2003, Alaska (9.3%), and Louisiana (4.6%) had the highest effective state royalty rates. In 2001, the highest effective federal royalty rate occurs in Wyoming (7.1% for oil and 9.1% for gas) followed by New Mexico (5.0% for oil and 9.6% for gas) and Utah (4.4% for oil and gas combined).

The tax structures for natural gas are quite similar to oil, although nominal production tax rates differ between oil and gas in some states. Notable differences occur in Louisiana in which the severance tax is levied on the value of oil production, but on the quantity of gas produced. State corporate income tax rates are the same for natural gas and oil.

A comparison of effective rates by tax across states shows a pattern somewhat similar to oil. In 2003, Wyoming (state and local combined) and Texas had the highest effective tax rates on natural gas production, 10.1% and 8.1%, respectively. Effective state royalty rates were highest in Louisiana and New Mexico, and federal rates were highest in Wyoming, Utah, and New Mexico, reflecting the importance of production on public lands in these states.

Extending the comparisons of taxes among the energy producing states further, to the point of ranking states in terms of their total or cumulative tax burden on the oil and gas extraction industry, is not particularly fruitful and may be misleading. The three types of taxes, production, property and income, have different effects on production, exploration and development. Moreover, extraction, exploration and development costs differ among the energy producing states, too. Stated differently, state and local taxes are but one element affecting decisions to produce, explore and develop nonrenewable resources and should not be considered in isolation from other key factors.

One form of inter-state tax comparison, called hypothetical tax bill studies, is based on a profile of a hypothetical firm, producing a certain amount of product, generating a given amount of sales revenue with specified capital, labor and other costs. Hypothetical tax bills are calculated for this firm based on the tax structures of different states in which the firm might locate. There are several important problems associated with such studies. First, the analysis assumes that all costs except taxes are the same across states, and normally this is an incorrect assumption, particularly in the case of oil and gas exploration, development and production. Second, such studies assume that the firm uses the same factor inputs in the same proportions, such as capital and labor, irrespective of the geographic location. Stated differently, it is assumed that the production function is fixed and identical irrespective of where the firm locates. Again, this is usually an incorrect assumption, particularly since production costs differ across locations. Finally, the hypothetical firm seldom exists, and it is misleading to infer tax or other costs for other plant or firm profiles different from the hypothetical firm created for the tax comparison.

Table 2: Effective Tax and Royalty Rates for Selected States, 2001-2003

Alaska

Year	*Production Oil*	*Property Oil*	*State Corporate Petroleum*	*State Royalty Oil*	*Federal Royalty Oil*
2001	0.105	<0.01	0.050	0.116	<0.01
2002	0.067	<0.01	0.024	0.079	<0.01
2003	0.094	<0.01	0.017	0.0934	<0.01

California

Year	*Property Oil*	*State Royalty Oil*	*Conservation Tax*	*Federal Royalty Oil*	*Corporate Income*
2001	0.035	0.01	<0.01	<0.01	
2002	0.031	0.01	<0.01	<0.01	
2003	0.038	0.01	<0.01	<0.01	8.84%

Colorado

Year	*Production Oil and Gas*	*Property Oil and Gas*	*State Royalty Oil and Gas*	*Federal Royalty*	*Corporate Income*
2001	0.016	0.046	<0.01	0.018	
2002	0.014	0.047	<0.01		
2003	0.010	0.047	<0.01		4.63%

Kansas

Year	*Production Oil and Gas*	*Property Oil and Gas*	*State Royalty Oil and Gas*	*Federal Royalty Oil and Gas*	*Corporate Income*
2001	0.042	0.044	<0.01	<0.01	
2002	0.030	0.043	<0.01		
2003	0.027	0.054	<0.01		4%-7.35%[a]

[a]nominal rate depends on amount of corporation income

Louisiana

Year	*Production Oil*	*Production Gas*	*Property*	*State Royalty Oil*	*State Royalty Gas*	*Federal Royalty Oil*	*Federal Royalty Gas*	*Corporate Income*
2001	0.128	0.020	<0.01	0.048	0.043	<0.01	<0.01	
2002	0.109	0.032	<0.01	0.043	0.043			
2003	0.115	0.020[a]	<0.01	0.046	0.042			4%-8%[b]

[a]natural gas taxed by volume, not according to value
[b]nominal rate depends on amount of corporation income

New Mexico

Year	*Production Oil and Gas*	*State Royalty Oil and Gas*	*Federal Royalty Oil*	*Federal Royalty Gas*	*State Corporate Income*[a]
2001	0.081	0.036	0.050	0.096	
2002	0.074	0.035			
2003	0.079	0.026			4.8%-7.6%

[a]nominal rate depends on amount of corporation income

Oklahoma

Year	*Production Oil and Gas*	*State Royalty Oil and Gas*	*Federal Royalty Oil and Gas*	*Corporate Income*
2001	0.094	<0.01	<0.01	
2002	0.068	<0.01		
2003	0.064	<0.01		6.0%

Texas

Year	*Production Oil*	*Production Gas*	*Property Oil and Gas*	*State Royalty Oil and Gas*	*Federal Royalty Oil and Gas*
2001	0.045	0.051	0.030	<0.01	<0.01
2002	0.035	0.042	0.024	<0.01	<0.01
2003	0.042	0.055	0.029	<0.01	<0.01

Utah

Year	*Production Oil*	*Production Gas*	*Property Oil and Gas*	*State Royalty Oil and Gas*	*Federal Royalty Oil*	*Federal Royalty Gas*	*Corporate Income*
2001	0.035	0.039	0.014	<0.01	0.023	0.053	
2002	0.035	0.032	0.019	<0.01			
2003	0.038	0.038	0.011	<0.01			5.0%

Wyoming

Year	*State Production Oil*	*State Production Gas*	*Local ad valorem Oil*	*Local ad Valorem Gas*	*Local Property*	*State Royalty —Oil and Gas*	*Federal Royalty Oil*	*Federal Royalty Gas*
2001	0.060	0.059	0.054	0.062	<0.01	<0.01	0.071	0.091
2002	0.045	0.034	0.058	0.062	<0.01	<0.01		
2003	0.049	0.038	0.059	0.063	<0.01	<0.01		

STATE TAXATION, EXPLORATION, AND PRODUCTION IN THE U.S. OIL INDUSTRY*

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STATE TAXATION, EXPLORATION, AND PRODUCTION
IN THE U.S. OIL INDUSTRY

Abstract

How do firms in nonrenewable resource industries respond to changes in state taxes? This paper employs state-specific estimates of Pindyck's (1978) widely cited model of natural resource supply to simulate effects of changes in state production (severance) tax policy on the timing of exploration and output by firms in the U.S. oil industry. The framework developed can be applied to any of 15 states that produce significant quantities of oil, and allows for interactions between taxes levied by different levels of government. Results of this study suggest that oil production is highly inelastic with respect to changes in production taxes. A production tax rate increase is shown to decrease early period exploration effort, affect little change in reserve additions and future production, and substantially increase discounted tax revenue. Policy implications of this outcome suggest that state officials may consider raising production tax rates as a way to increase revenue while risking little in the way of loss to future oil activity.

1. Introduction

How do firms in nonrenewable resource industries respond to changes in state taxes? It may be tempting to look for answers to this question in the empirical literature on effects of state taxation (see, for example, Bartik 1985, Helms 1985, Papke 1991, 1994, and Holmes 1998). These papers focus on firms with mobile capital that choose where to locate on the basis of factors affecting revenues and costs. This perspective, however, is not particularly relevant when looking at the behavior of firms extracting nonrenewable natural resources. Such firms cannot change location because they are tied to a geographically immobile reserve base that makes up a key component of their capital stock. On the other hand, extractive firms can and probably do alter the timing of their activities when state taxes and other public policies change. Yet, little is known about the extent to which they do this even though commercially valuable deposits of natural resources are found in most U.S. states and some states such as Texas, Oklahoma, Louisiana, Wyoming, and Alaska rely heavily on taxation of oil, gas, and/or coal production to fund public services.

This paper uses state-specific estimates of Pindyck's (1978) widely cited model of natural resource supply to simulate effects of changes in state production (severance) tax policy on the timing of exploration and output by firms in the U.S. oil industry. The framework developed can be applied to any of 15 states that produce significant quantities of oil, and allows for interactions between taxes levied by different levels of government. It is arguably superior to and more comprehensive than previous efforts to develop econometric and/or simulation models of taxation and natural resource exploration and production. For example, Deacon, DeCanio, Frech, and Johnson (1990) and Moroney (1997) focus only on one state (California and Texas, respectively), and estimate econometric equations that may not be consistent with a dynamic profit-maximizing framework. Pesaran (1990) estimates an econometric model of offshore oil production in the UK that can be better justified theoretically, but does not consider the role of taxes. Simulation studies conducted by Yucel (1989) and Deacon (1993) examine effects of various types of tax changes on exploration and production, but do not consider interactions between tax bases claimed by different levels of government. Additionally, these studies do not allow for possible interstate differences in exploration and extraction costs and are aimed mainly at assessing the generality of theoretical results obtained in more limited settings (see, for example, Burness 1976, Conrad and Hool 1980, and Heaps 1985) rather than analyzing possible outcomes of changes in state tax policies.

Results of this study suggest that oil production is highly inelastic with respect to changes in production taxes so deadweight losses from altering these taxes are likely to be small. As a consequence, state officials may consider raising production tax rates as a way to increase revenue. It is worth noting in this context that because state production taxes are deductible against federal corporate income tax liabilities, increases in production tax rates increase state revenues partly at the expense of federal tax collections. These points are more fully discussed in Section 3 after developing the framework for the simulation model in the next section.

2. The Simulation Model

This section shows how Pindyck's (1978) model of nonrenewable resource development is adapted to simulate effects of state production tax changes. The discussion begins with a brief overview of the Pindyck model and then discusses estimation of key equations and tax parameters.

Conceptual Model

The model assumes that perfectly competitive producers maximize the discounted present value of future operating profits from the sale of resources and because one such firm is chosen to represent the industry, the common pool problem and well-spacing regulations are not considered (see McDonald 1994 for discussion of these issues). The firm's problem is to take the future time path of output prices and taxes as given and then choose optimal time paths for exploration and production. This approach is similar to that taken in previously cited econometric studies of effects of changes in state tax policy on state economic growth and ignores the possibility that choices of tax bases and rates are endogenous (i.e., that governments consider the firm's objective function in choosing taxes that maximize community welfare). Also, the model defines exploration to include resource development, although the two activities clearly are not the same (Adelman 1990). The aim of exploration is to add to the reserve base, which as indicated in the introduction, is a form of geographically immobile capital.

The firm's maximization problem is

$$\max_{q,w} \Omega = \int_0^{\infty} [qp - C(q,R) - D(w) - \gamma R]e^{-rt}\, dt \tag{1}$$

subject to

$$\dot{R} = \dot{x} - q \tag{2}$$

$$\dot{x} = f(w, x) \tag{3}$$

$$q \geq 0, w \geq 0, R \geq 0, x \geq 0 \tag{4}$$

where a dot over a variable denotes a time rate of change, q denotes the quantity of oil extracted measured in barrels, p denotes the exogenous market price per barrel net of all taxes, $C(\cdot)$ denotes the total cost net of taxes of extracting the resource, which is assumed to depend on production (q) and reserve levels (R), $D(w)$ denotes total cost of exploration for additional reserves net of taxes, w denotes exploratory effort, γ denotes the net of all tax constant effective property tax rate on reserves, r denotes the discount rate which represents the risk-free real rate of long-term borrowing, x denotes cumulative reserve additions (discoveries), $f(\cdot)$ denotes the production function for gross reserve additions ($\dot{x}$), and $\dot{R}$ denotes reserve additions net of production (q).[1] In this formulation, the net-of-tax price per barrel is related to the wellhead (pre-tax) price (p^*) according to $p = \alpha_p p^*$, where α_p is a tax policy parameter such that $0 < \alpha_p < 1$. Correspondingly, $C(q, R) = \alpha_c C^*(q, R)$ and $D(w) = \alpha_D D^*(w)$, where α_c and α_D also are tax policy parameters that lie on the unit interval. These tax policy parameters are discussed more fully later on in this section.

Model Implementation

To implement the model, equations for exploration costs (D^*), production of reserve additions (f), and extraction costs (C^*) are estimated and then substituted into the model along with estimates of the tax parameters α_p, α_c, α_D, and γ. Effects of tax changes then are obtained by simulation. Estimates of the tax parameters are described first followed by discussion of estimates of equations for D^*, f, and C^*.

Tax Parameters

General considerations in developing estimates of the four tax policy parameters for major oil producing states are briefly outlined below and technical details are described in Appendix A. Among major oil producing states, tax structures vary considerably and tax bases interact, particularly between the state and federal level. For example, among the eight states responsible for about 89% of U.S. oil production (Alaska, California, Kansas, Louisiana, New Mexico, Oklahoma, Texas, and Wyoming), all states except California levy production taxes against the value of output. Production taxes dominate other forms of local taxation in Alaska, Wyoming, and Louisiana. Most states do not levy property taxes on the value of reserves in the ground (Texas and California do). Most states treat royalty payments (computed as a percentage of gross value of production) for production on public land as deductible items in computing severance tax liabilities (Louisiana does not). Public land royalties are prominent in Alaska, New Mexico, and Wyoming due to the large shares of publicly owned land. Most states levy a corporate income tax that applies to oil operators (Wyoming and Texas do not). Also, states have granted innumerable exemptions and credits (which differ by state) against various tax liabilities for special situations that may be encountered by operators. Within states, counties apply their own mill levies to compute property taxes on equipment at different rates. However, taxation of structures and equipment are usually less important than other sources of revenue and are ignored below.

Regarding federal taxes, all incorporated producers file federal corporate income tax returns that allow deductions for various types of operating costs and for state and local tax payments. Independent producers (those without downstream refining or retail interests) are permitted to take a percentage depletion allowance, while major producers are allowed only cost depletion, which is significantly less generous. Both major and independent incorporated producers can expense intangible drilling costs incurred on their federal corporate income tax returns. The fact that some smaller producers are not incorporated and may therefore face alternative state and federal tax treatment is ignored.

The myriad of state-specific special features described above creates considerable complexity in tracking tax law over time. Rather than itemize tax code details, effective tax rates are used to translate dynamic tax policy into a tractable form. Effective rates can be expressed as the ratio of taxes (or royalties) collected from a particular tax to the value of production. Thus, the calculation of specific effective tax rates fully account for exemptions, incentives, different tax bases, and frequent changes in tax law both at the state and federal level. For a detail account of the taxation of the oil industry see Gerking, Morgan, Kunce, and Kerkvliet (2000), Chapter 2.

Marginal Cost of Reserve Additions

The before-tax marginal cost of reserve additions (D_w^* / f_w) is computed from estimates of equations for drilling costs and for the production of reserve additions. Drilling costs are assumed to be proportional to drilling effort as shown in equation (5)

$$D^*(w) = \phi w e^u \tag{5}$$

where ϕ is the parameter to be estimated and the disturbance term e^u is lognormally distributed with mean of unity and variance σ_u^2. The production function for reserve additions is specified as

$$f(w, x) = A w^{\rho} e^{-\beta \cdot x} e^{v} \tag{6}$$

where A, ρ, and β are parameters to be estimated and the disturbance e^v is assumed lognormally distributed with mean of unity and variance σ_v^2. Equation (6) is similar to the equation describing the discovery process proposed by Uhler (1976) and later adopted by Pindyck (1978) and Pesaran (1990). The idea behind this equation is that the marginal product of exploration declines as reserve discoveries cumulate.

Estimation used annual data from the 15 U.S. states for which complete information on variables needed could be assembled for the period 1970-98.[2] These states accounted for 96.5% of total U.S. oil production over this time period. Drilling costs are measured by total real costs (both tangible and intangible) of each well completed, including dry holes.[3] Nominal cost values were deflated using the 1995 GDP deflator. Oil reserve additions are defined as extensions, new field discoveries and new reservoir discoveries in old fields. The total number of wells drilled for each state since 1859 (when the first oil well was drilled in Pennsylvania) is used as a proxy for x. Data sources and sample means of variables used in the analysis are presented in Table 1.

Equation (5) and equation (6) were estimated in natural logarithms. Both equations used an instrument for the number of wells drilled because w is an endogenous variable in the model presented in Section 2. The instrument was obtained from the predicted values from a regression of the number of wells on cumulative drilling and the wellhead price as shown in Appendix A. Estimates of the drilling cost equation, equation (5), are obtained by regressing drilling cost per well on dummy variables for states and years. Coefficients of state and year dummies are jointly significant at the 1% level and the R^2 is 0.90. The idea behind using this approach is to get state- and time-specific estimates of ϕ. This parameter is expected to vary across states because of differences in geologic conditions, geographic remoteness of on-shore oil resources, and whether drilling occurs in off-shore coastal waters (note that most states in the data set are landlocked). Time varying factors common to all states may include technological advancement and macroeconomic cycles. State-specific estimates of ϕ test different from each other, except Texas and Oklahoma, at the 5% level.

Estimates of equation (6), shown below in equation (7), allow for state-specific intercept terms (time-specific effects were jointly insignificant), common slope coefficients across states, and are corrected for first-order serial correlation (ρ =0.431).

$$\ln(\mathit{ADDED\ RESERVES}) = \ln A + \underset{(5.33)}{0.69}*\ln(\mathit{PREDWELLS}) - \underset{(-1.37)}{0.000006}*\mathit{CWELLS}\,. \qquad (7)$$

(t)

State-specific estimates of A are jointly significant at the 1% level and $R^2 = 0.40$.[4] These results show that the marginal product of drilling (f_w) decreases with wells drilled as well as with cumulative drilling, although the coefficient of cumulative drilling is insignificant at conventional levels.

Estimates of equations (5) and (6) combined show that the marginal cost of reserve additions (D_w^*/f_w) increases with drilling activity. As w increases, the marginal cost of drilling is constant, but the marginal product of drilling in finding new reserves (f_w) falls. Table 2 reports values of D_w^*, f_w, and D_w^*/f_w by state for seven major oil producing states. These estimates use 1998 values for numbers of wells drilled and cumulative drilling and are corrected for conversion from logarithms (see Greene 1997, p. 279). Estimates of D_w^* and f_w reflect considerable variation across the seven states. Estimates of marginal drilling cost range from \$127,943 in Kansas to \$1,218,758 in Louisiana. Marginal reserve additions from drilling (f_w) range from 7,460 barrels in Kansas to 64,862 barrels in Louisiana. Thus, while drilling in Louisiana is relatively more expensive than in Kansas, Louisiana experiences a greater payoff from these more costly exploration and development efforts. Values of D_w^*/f_w for the seven states range from a low of $17.15 per barrel in Kansas to a high of $26.04 in Texas.

Extraction Costs

Because data on oil extraction costs are weak, *C(q, R)* could not be econometrically estimated. Instead, this equation was calibrated for each state with a Cobb-Douglas functional form using methods described in Deacon (1993). Cost parameter calibration specifics are described in Appendix A. Results show that the 1998 marginal extraction costs range from a low of $4.89 per barrel in Kansas to a high of $8.81 per barrel in Louisiana. Additionally, the Cobb-Douglas form implies that extraction costs rise without limit as reserves approach zero and that a positive level of reserves will remain at any terminal time *T*. Thus, boundary conditions used in the simulations reported in Section 3 allow production to continue after incentives for further exploration vanish so that the terminal date for the exploration/production program must be set arbitrarily. This fixed program period could be interpreted as the producer's relevant planning horizon.

3. Simulation Results

The model presented in Section 2 can be simulated to obtain responses of exploration and production to changes in various types of taxes in any of 15 oil producing states. Simulations presented below focus on production tax changes in Wyoming. The production tax is the most important tax levied on the oil industry by oil producing states (see Section 2) and changes in production taxes turn out to have quite similar effects in all major oil producing states so results from one state are used to represent the others (for results of tax changes in other major oil producing states, see Gerking, Kunce, Morgan, and Kerkvliet 2000). Also, simulations reported are based on the assumption that tax changes in one state do not affect the wellhead price of oil seen by operators in other states. This assumption probably is not unreasonable in view of the fact that oil prices are internationally determined and even the largest producing U.S. state (Texas) accounts for only a small percentage (4.2% from 1970-98) of world output.[5] Moreover, as shown below, tax changes considered lead to comparatively small changes in output, so these interstate effects are not likely to be important in any case.

Simulations for Wyoming were performed using the instrumental variable estimates of equations (5) and (6), the calibrated production cost function and the tax parameters, both derived in Appendix A. The discount rate, r, was set at 4% to reflect the risk-free real rate of long-term borrowing and the future price path was fixed at $23.00 per barrel each year reflecting the real sample mean for all 15 states. Other price trajectories were simulated, but the alternative paths have little or no effect on the comparative results presented below. The initial value of reserves and cumulative wells drilled were fixed to year-end 1998 levels at 550 million barrels and 40,439 wells, respectively. To obtain numerical solutions for the optimal time paths of drilling, production, and reserves, difference equation approximations are derived for the time rates of change in exploratory effort ($\dot{w}$), production ($\dot{q}$), and for the state variable evolution equations (2) and (3). For example, the evolution of reserves, equation (2), is approximated by the difference, $R_{t+1} - R_t = f_t - q_t$. The model is then solved recursively by iterating over the initial values of the control variables, q and w, until transversality conditions are satisfied. Under these base conditions, exploratory effort approaches zero after approximately 40 years, thus the terminal time is set to 40 periods. The solver algorithm in Microsoft Excel was used to generate numerical solutions.

Before the simulation results are discussed, a historical analysis of Wyoming's oil experience is warranted. Figure 1 depicts the actual time paths of real price, drilling, production, and reserves for Wyoming from 1970-98. In this figure, the vertical axis shows price per bbl (dotted line) in $\$1995 \times 10$, drilling (dashed line) in total wells, production (solid line) in bbls $\times 10^5$, and reserves (bold line) in millions of barrels (MMbbls). In reviewing these data, several observations are noteworthy. Historical drilling appears sensitive to price. Total wells drilled increases markedly during the high price period of the early 1980s. Extraction activity, however, appears to map the declining proved reserve level in the state. In fact, oil production continued to decline during the late 1970s and early 1980s even though real prices increased 2 1/2 fold. The increased drilling experienced in the early to mid 1980s failed to replenish the depleting oil reserve in the state and production closely followed the reserve decline.

This apparent historical insensitivity of production to changes in price raises an interesting policy question: If severance tax changes are reflected in net price (as modeled in section 2), what are the effects of a severance tax increase? Many oil states, as previously described — including Wyoming, rely heavily on production taxes to fund local public goods and officials may have incentives to raise production taxes for the revenue. The inherent trade off to severance tax increases is the purported loss of economic activity generated by the industry within the state. To examine this, the first simulation conducted shows the effects of *doubling* Wyoming's effective state severance tax rate for the full 40-year program. Results detailing the simulated differences in the timing of drilling, production, and discounted severance tax revenue for the full tax interaction model (outlined above) are presented in the top section of Table 3. Comparative individual program year results, divided into 10-year increments, show that doubling the state severance tax markedly decreases early period drilling. Drilling decreases by 19.4% in the first year of the simulated program and this difference converges to zero by year 40. Interestingly, 10 year fractional results show that 63.8% of the total 1208 well decrease occurs in the first 20 years of the program. Figure 2 graphically compares the effects of the tax increase (dotted line) to the base drilling solution (bold line). With less drilling in the early years of the program, fewer new reserves are identified and, as shown in Figure 3, future production of oil slightly diverges downward from the base solution. Production results presented in Table 3 show this gradual divergence — a 2.4% drop in year one falling to an 11.8% decline in year 40. Through the life of the program, doubling the state severance tax decreases total production by about 48 MMbbls or 5.7% below the base solution.

The largest change associated with doubling the state oil severance tax appears to come from discounted severance tax collections. As shown in Table 3, the tax increase results in an increase in the present value of Wyoming severance tax collections from $609 million to $1165 million, an increase of over 91%. The majority (87.6%) of this $556 million increase occurs in the first half of the simulated program due to the relatively small production loss generated by the tax increase and discounting. Because severance taxes are deductible in computing federal corporate income tax liabilities, discounted tax payments to the federal government decrease by $60 million or about 11% below the base simulation. Also, the severance tax increase transfers local government revenue to the state because of the production decline. Discounted local production taxes decrease by $34 million or 5% below the base solution. The same can be said for discounted public land royalties which decrease by 4.6% ($50 million) because of the decrease in future production.

The tax interactions described above highlight a key feature of the model developed here — oil producers do not face the full effect of an increase in the severance tax rate. As shown, tax base and rate interactions partially offset the pure-effect of the severance tax rate increase. To illustrate this clearly, counterpart simulations were conducted where all tax effects, other than state level production tax rates, were effectively *zeroed out*. The lower section of Table 3 presents the counterpart Wyoming results. When all tax interactions are ignored, doubling the state severance tax decreases relative drilling by 32.8% and production by 11.2%, a decrease in activity roughly 2 times larger than found in the full tax interaction model examined above. Timing effects are similar to the full tax interaction model results. Because the severance tax increase now invokes a larger production loss, discounted state severance taxes increase by 83% as compared to the 91% increase in the full tax interaction model. Analyzing taxes individually appears to overstate the affects on exploration and production by ignoring potential offsets and tax base interactions. These results suggest that taxes should not be analyzed independently without careful reference to the entire tax structure applied by all levels of government.

General results of this study suggest that oil production is highly inelastic with respect to changes in production taxes. This inelastic response may provide incentives for state officials to substantially increase these taxes risking little in the way of reduced industry activity while gaining much needed tax revenue. State severance tax increases clearly reduce the net price faced by producers but it is reserves, not net price, that drives production in this industry. Moreover, the effects of increased state severance taxes are partially offset by reduced tax collections by all other levels of government.

4. Conclusions

This paper has adapted Pindyck's (1978) model of nonrenewable natural resource production to take account of taxation at the federal and state-local government levels. Equations of the model are estimated from panel data on production, exploration and reserve additions for 15 states over the period 1970-98. The model is designed so that effects of changes in existing state production tax rates on the timing and evolution of exploration and production can be simulated into the mid-21st century. Results of this study suggest that oil production is highly inelastic with respect to changes in production taxes. A production tax rate increase is shown to decrease early period exploration effort, invoke little change in reserve additions and subsequently future production, and substantially increase discounted tax revenue. Policy implications of this outcome suggest that state officials may consider raising production tax rates as a way to increase revenue while risking little in the way of loss to future oil activity.

Endnotes

[1]Pindyck's (1978) original specification of the extraction cost function is retained here in spite of the logical inconsistencies discussed by Livernois and Uhler (1987), Livernois (1987), and Swierzbinski and Mendelsohn (1989). These authors argue that Pindyck's extraction cost function is defensible when reserves are of uniform quality but in the presence of exploration, reserves must be treated as heterogeneous because the most accessible deposits are added to the reserve base first. They show that aggregation of extraction costs across heterogeneous deposits is not valid except under special circumstances. Another problem with this function is that extraction costs should be a function of γ. The extraction cost function derived from profit-maximization at a point in time subject to a production constraint would have γ as an argument because the reserve base is an input to oil and gas production. These complications are ignored in the analysis below because of severe data constraints on estimating the extraction cost function.

[2] The Energy Information Administration and the American Petroleum Institute report annual production data for 31 states over this period, but data on reserve additions, cumulative drilling, and drilling costs are not available in all years for the 16 smallest producing states. The 15 states included in the panel are Alaska, Alabama, California, Colorado, Kansas, Louisiana, Michigan, Mississippi, Montana, North Dakota, New Mexico, Oklahoma, Texas, Utah, and Wyoming.

[3] Major cost items are for labor, materials, supplies, machinery and tools, water, transportation, fuels, power, and direct overhead for operations such as permitting and preparation, road building, drilling pit construction, erecting and dismantling derricks/drilling rigs, drilling hole, casing, hauling and disposal of waste materials and site restoration. For additional details, see Joint Association Survey on Drilling Costs, Appendix A (1998).

[4] Corrected (see Greene 1997, p. 279) state-specific intercept terms (and t-statistics) for 7 major producing states are: CA 0.17(2.01), KS 0.06(1.06), LA 0.57(2.21), NM 0.19(1.68), OK 0.07(1.94), TX 0.01(1.11), WY 0.29(2.03). Equation (6) was also estimated allowing for both state-specific intercepts and state-specific coefficients for ρ and β. This strategy was unsuccessful as it yielded mostly insignificant estimates of state-specific slope interactions.

[5]Source of world oil production for 1970-98, www.eia.doe.gov/emeu/international/ petroleu.html.

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Table 1
Variable Definitions, Data Sources, and Sample Means
(Excludes federal OCS activity.)

Variable	*Definition*	*Source*	*Mean*
TRCOST	Total drilling cost in millions of 1995 dollars, by state and year.	American Petroleum Institute, *Joint Association Survey on Drilling Costs.* Annual.	427.6
ADDED RESERVES	Oil reserve extensions, new field discoveries and new reservoir discoveries in old fields, by state and year in millions of barrels.	US Energy Information Administration, *U.S. Crude Oil, Natural Gas and Gas Liquids Reserves Annual Report.* Annual	42.0
WELLS	Oil wells drilled in a state by year.	American Petroleum Institute, *Joint Association Survey on Drilling Costs.* Annual.	943
CWELLS	Cumulative total wells drilled in a state beginning in 1859.	American Petroleum Institute, *Petroleum Facts & Figures.* 1971 Ed.	1.07E+5
PRICE	Average well head oil price, by state and year, in 1995 dollars per barrel.	American Petroleum Institute, *Basic Petroleum Data Book.* Annual.	22.80
PRICE2	Average real price per barrel squared.	- -	656.3
CWELLS2	Cumulative oil wells squared.	- -	4.3E+10
*PRICE * CWELLS*	Interaction of real price and cumulative wells.	- -	2.5E+6

Table 2
Pre-Tax Marginal Drilling Cost, Marginal Reserve Additions, and Pre-Tax Marginal Cost of Reserve Additions for 7 Major Producing States

State	**D_w^* (in $)**	**f_w (in bbls)[a]**	**D_w^* / f_w [a]**
California	274,675	11,464	23.96
Kansas	127,943	7,460	17.15
Louisiana	1,218,758	64,862	18.79
New Mexico	485,698	22,148	21.93
Oklahoma	345,706	15,223	22.71
Texas	342,266	13,144	26.04
Wyoming	593,162	34,627	17.13

[a] Assumes wells drilled at the actual 1998 count. State-specific cumulative wells total is set to actual 1998 values in all calculations.

Table 3
Timing of Drilling, Production,
and Discounted Severance Tax Revenue

Full Tax Interaction Model

	Individual Program Year:					
	Year 1	***Year 10***	***Year 20***	***Year 30***	***Year 40***	***Total***
Drilling (Base Solution, in wells)	211	203	187	132	2	6274
Drilling (Double Tax)	170	165	152	116	2	5066
Change from Base	-19.4 %	-18.7 %	-18.7 %	-12.1 %	0.0 %	-19.2 %
Production (Base, in MMbbls)	57.7	27.0	15.9	12.1	7.6	834.3
Production (Double Tax)	56.3	25.9	14.7	10.8	6.7	786.6
Change from Base	-2.4 %	-4.1 %	-7.5 %	-10.7 %	-11.8 %	-5.7 %
Severance Tax Revenue (Base, $MM)	66.6	21.3	8.2	4.2	1.9	608.6
Severance Tax Revenue (Double Tax)	130.2	41.0	15.2	7.4	3.3	1165.2
Change from Base	95.5 %	92.5 %	85.4 %	76.2 %	73.7 %	91.5 %

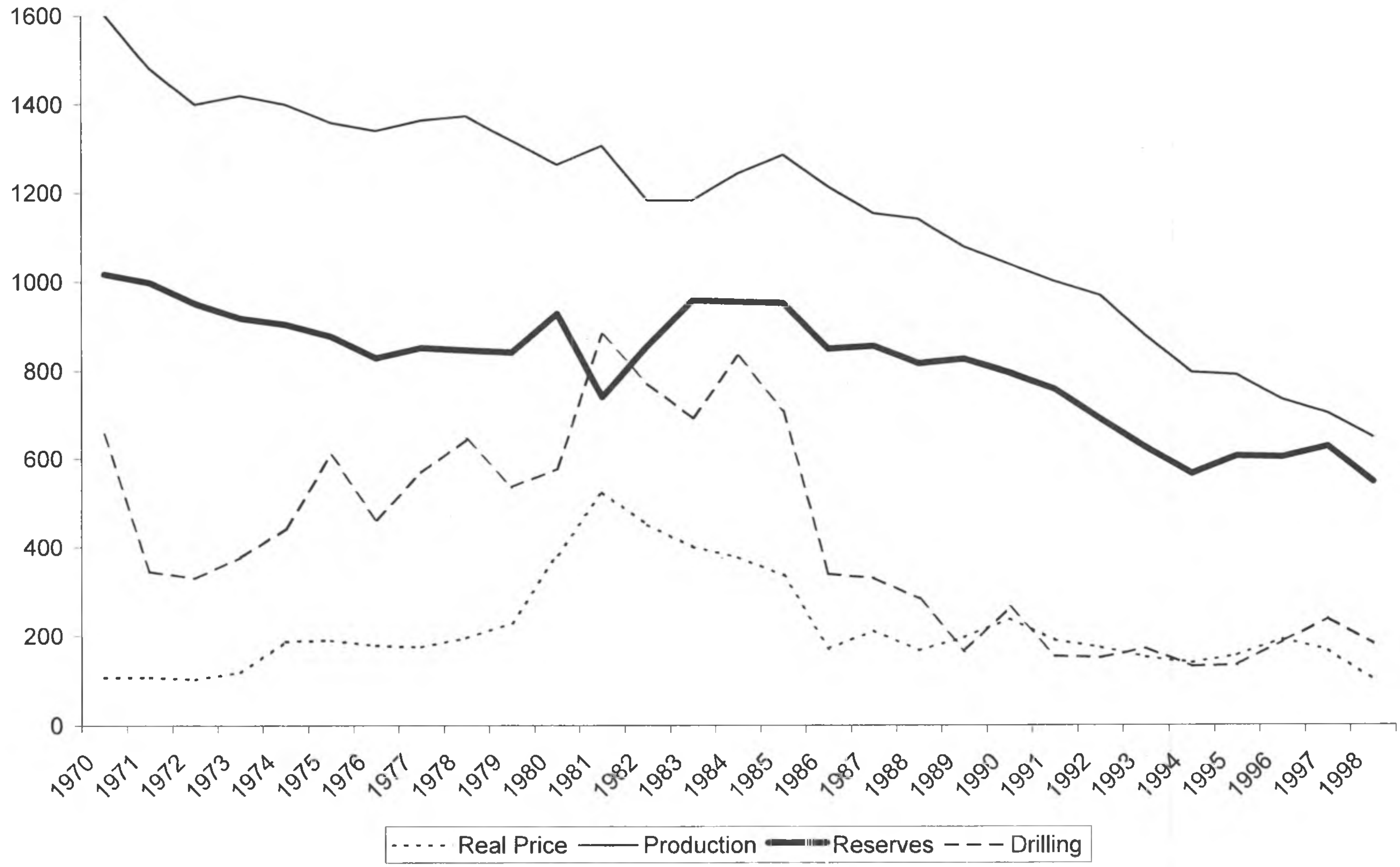
	10 Year Fractions of Total Change from Base Solution:			
	Years 1-10	***Years 11-20***	***Years 21-30***	***Years 31-40***
Drilling	33.0 %	30.8 %	25.9 %	10.3 %
Production	21.2 %	24.8 %	27.0 %	27.0 %
Severance Tax Revenue	67.2 %	20.4 %	8.4 %	4.0 %

No Tax Interaction Model

	Individual Program Year:					
	Year 1	***Year 10***	***Year 20***	***Year 30***	***Year 40***	***Total***
Drilling (Base Solution, in wells)	283	271	249	175	1	8363
Drilling (Double Tax)	189	183	168	119	1	5624
Change from Base	-33.1 %	-32.6 %	-32.4 %	-32.0 %	0.0 %	-32.8 %
Production (Base, in MMbbls)	59.6	28.8	18.0	14.2	9.0	911.0
Production (Double Tax)	57.0	26.4	15.3	11.4	7.2	809.3
Change from Base	-4.4 %	-8.3 %	-15.0 %	-19.7 %	-20.1 %	-11.2 %
Severance Tax Revenue (Base, $MM)	75.6	24.9	10.2	5.3	2.5	714.3
Severance Tax Revenue (Double Tax)	144.7	45.9	17.4	8.6	3.9	1307.8
Change from Base	91.4 %	84.3 %	70.6 %	62.3 %	56.0 %	83.1 %

	10 Year Fractions of Total Change from Base Solution:			
	Years 1-10	***Years 11-20***	***Years 21-30***	***Years 31-40***
Drilling	33.2 %	30.9 %	25.9 %	10.0 %
Production	21.0 %	25.1 %	26.9 %	27.0 %
Severance Tax Revenue	68.1 %	20.1 %	8.0 %	3.8 %

Figure 1. Wyoming Oil, 1970-98



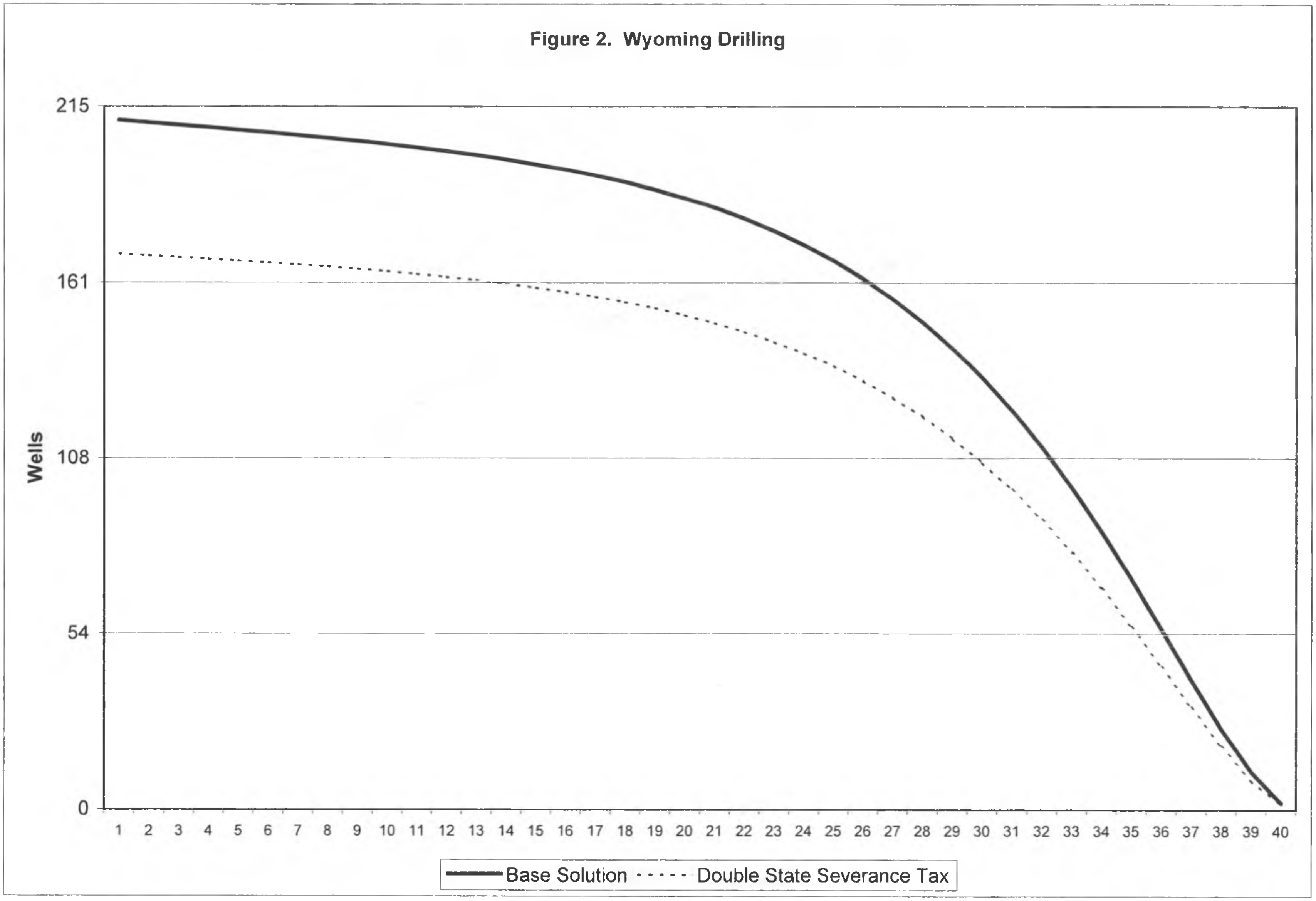


Figure 2. Wyoming Drilling
Wells
215
161
108
54
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Base Solution
Double State Severance Tax

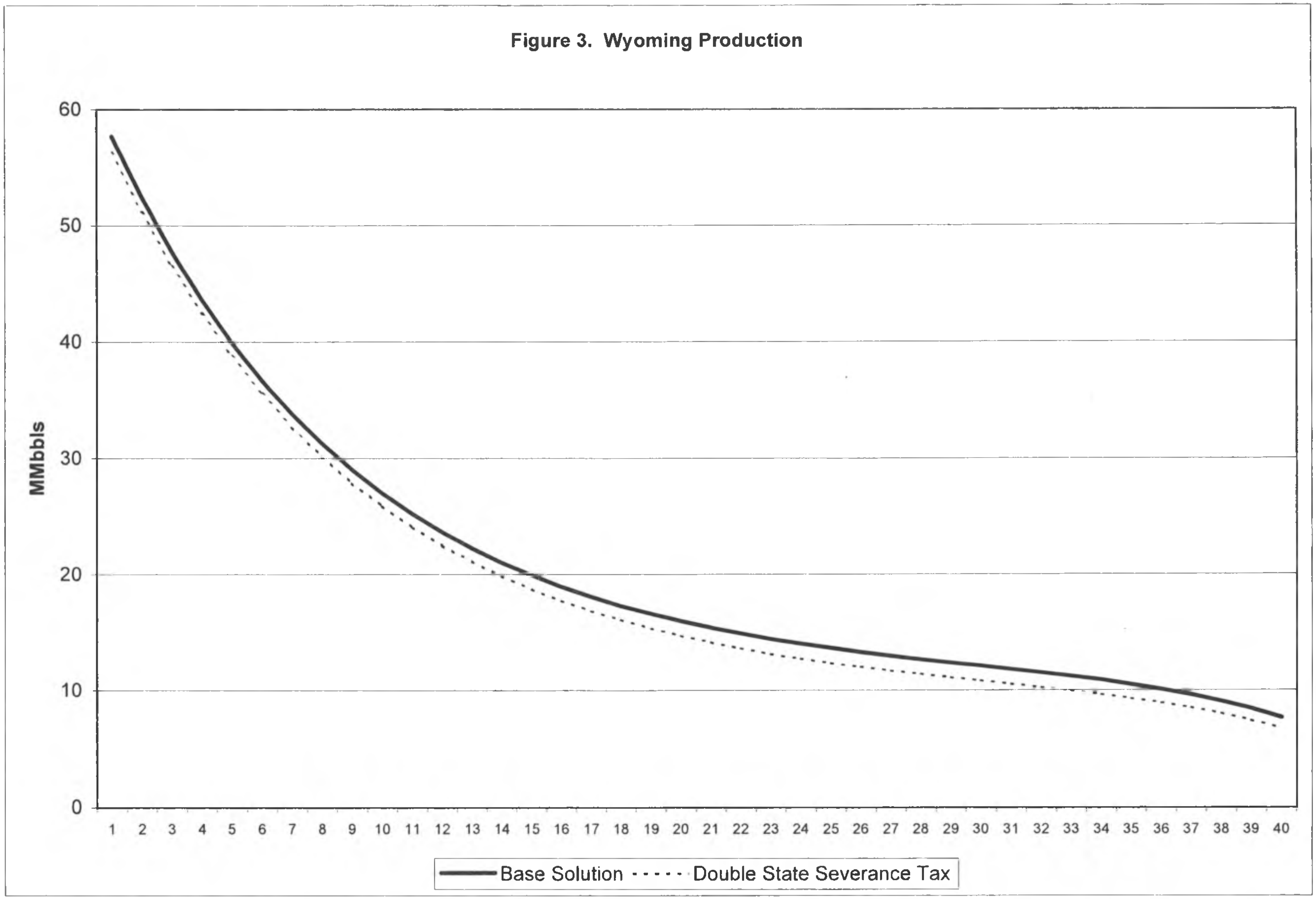


Figure 3. Wyoming Production
MMbbls
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Base Solution
Double State Severance Tax

Appendix A

Tax Policy Parameters

For most states in most years, γ and α_j $(j=p,c,D)$ can be specified by noting whether reserves are subject to a property tax (see text equation (1)) and then evaluating equations (A.1)-(A.4).

$$\gamma = \{(1-\tau_{us})(1-\tau_s)\tau_R\} \qquad \text{(A.1)}$$

$$\alpha_p = \{(1-\tau_{us})(1-\tau_s)(1-\tau_r)(1-\tau_p)+\tau_{us}(1-\tau_r)\delta\} \qquad \text{(A.2)}$$

$$\alpha_c = \{(1-\tau_{us})(1-\tau_s)\} \qquad \text{(A.3)}$$

$$\alpha_D = \{(1-\tau_{us})(1-\tau_s)\eta\} \qquad \text{(A.4)}$$

A derivation of equations (A.1)-(A.4) can be found in Gerking, Morgan, Kunce, and Kerkvliet (2000), Appendix C. In (A.1)-(A.4), τ_{us} denotes the federal corporate income tax rate, τ_s denotes the state corporate income tax rate, τ_R denotes the property tax rate on reserves weighted by the per unit assessed value, τ_r denotes the royalty rate on production from public (state and federal) land, τ_p denotes the production (severance) tax rate, δ denotes the federal percentage depletion allowance weighted by the percentage of production attributable to eligible producers (nonintegrated independents), and η denotes the expensed portion of current and capitalized drilling costs attributable to current period revenues. η is made up of two components: (1) the percentage of current period drilling costs expensed and (2) the estimated present value of cost depletion deductions for the capitalized portion of current and past drilling expenditures. Producers are allowed to expense costs associated with drilling dry holes along with certain intangible costs (e.g., labor and fuel) for completed wells as they are incurred. All direct (tangible) expenditures for completed wells must be capitalized then depleted over the life of the producing well. In the illustration at hand, equations (A.1)-(A.4) can be simplified because Wyoming does not have a state corporate income tax ($\tau_s=0$) and does not levy a property tax against reserves in the ground ($\tau_R=0$).

This formulation captures several aspects of the U.S. tax structure as it applies to the oil industry. (1) Federal royalty payments are deductible in computing state production tax liabilities. (2) Federal royalty payments, state production taxes, state property taxes on reserves, extraction costs, and certain drilling costs (described above) are deductible in computing both state and federal corporate income tax liabilities. (3) State corporate income taxes are deductible against federal corporate income tax liabilities. As noted in text section 2, state tax treatment of the oil industry is not uniform and there are a number of situations in which these equations would have to be modified. Notice that this treatment of taxes in the model highlights the interaction between tax bases and is more detailed than the corresponding treatment given by Moroney (1997) or Deacon, DeCanio, Frech, and Johnson (1990). Also, the entire tax structure is incorporated into the model, rather than simply analyzing one tax at a time as in Deacon (1993).

All tax parameters in equations (A.1)-(A.4) are effective rather than nominal rates. States grant numerous credits and exemptions against taxes levied, so nominal rates generally overstate amounts actually paid. State and local data required for these effective rate calculations are neither available from a central source nor compiled in a common format, so they were obtained directly from tax officials in each state (see Gerking, Morgan, Kunce, and Kerkvliet 2000, Chapter 2). In developing the *base* *solution* for Wyoming, royalty rates are computed as the sum of state and federal royalty payments divided by the gross value of production and averaged 9% for oil in the late 1990s. This percentage is higher than for other oil producing states because of the comparatively large share of Wyoming's production on public lands. Production tax rates are computed as total production tax collections divided by the prior year's gross value of production net of public land royalties. In Wyoming, there are both local and state levies against this one-year-lagged net value of production. The sum of the two average effective rates in the late 90's totaled approximately 11.9% (local 6.7% and state 5.2%). At the federal level, data from Statistics of Income (U.S. Department of Treasury, 1997-1998) for the oil and gas sector show that federal corporate taxes paid averaged about 10% of *net operating* income in 1998. Also, the current nominal percentage depletion rate of 15% applied to about 58% of Wyoming oil producers in 1998, thus δ = 8.7%. Also, the expensed portion of current period drilling costs is approximately 40% for the industry and the present value of depletion deductions for capitalized drilling cost can be approximated by $(q/R)/(r+(q/R))$, assuming that the ratio of production to reserves is constant (Deacon 1993). Wyoming's mean value of q/R was approximately 8% for the sample period 1996-1998, therefore $\eta = 0.40 + (1 - 0.4)*(0.08 / (0.04 + 0.08)) = 0.8$. The base tax policy parameters for Wyoming are $\alpha_p = 0.73$, $\alpha_c = 0.90$, $\alpha_D = 0.72$, $\gamma = 0$.

Estimate of an Instrument for WELLS

An instrument for the natural logarithm of *WELLS* was used as an explanatory variable in estimating both text equations (5) and (6) with *CWELLS* entering equation (6) as the proxy for x. Instrumental variable estimation is appropriate because w is an endogenous variable in the model presented in Section 2. An instrument for w was obtained by predicting the natural logarithm of the number of wells drilled from the one-way fixed-effects regression reported in Table A.1. Time-specific effects tested insignificant at conventional levels and $R^2 = 0.91$. *PRICE* and *CWELLS* were included as explanatory variables because they are exogenous variables in the model. *PRICE2, CWELLS2,* and *PRICE*CWELLS* were included to account for non-linearities expected in light of relationships in the model (see Table 1 for descriptions). All estimated coefficients are significantly different from zero except the interaction term *PRICE*CWELLS*. The marginal effect of *WELLS* with respect to *PRICE* increases at a decreasing rate. The Pearson correlation between the actual values of ln*(WELLS)* and the corresponding predicted values, ln*(PREDWELLS)*, is 0.96.

Table A.1
Construction of Instrument ln*(PREDWELLS)*

Explanatory Variable	***Coefficient* (t-statistic)**
PRICE	0.064 (6.49)
PRICE2	-0.45E-3 (-2.90)
CWELLS	-0.22E-4 (-5.19)
CWELLS2	0.15E-10 (4.17)
*PRICE*CWELLS*	0.18E-7 (1.51)

Extraction Cost Function

Direct operating (lifting) cost for oil by region at depths of 2,000, 4,000, 8,000, and 12,000 feet are available from annual cost index studies published by the DOE/EIA for the period 1970-1998. However, these data are of limited value for two reasons. First, cost estimates are not always disaggregated to the state level and cost estimates for other states may not be representative of all production. Second, through the mid-1980s, price controls on oil and/or gas distorted production incentives, making historical extraction costs difficult to compare with extraction costs in more recent years. As a compromise, following Deacon (1993), values of extraction cost parameters are calibrated for the following Cobb-Douglas function,

$$C(q, R) = \kappa q^{\varepsilon} R^{1-\varepsilon} \ , \qquad \text{(A.5)}$$

where $\varepsilon = 1/\mu$, μ is the production share of non-reserve inputs, and κ is a constant value that drives the production cost modeled to an average level of *lifting costs* representative of the 1998 DOA/EIA surveyed estimates described above. State-specific estimates for μ are established from the data on operating cost, drilling cost, production, reserve additions, and reserve levels described above (see Kunce, Gerking, and Morgan 2001 for specific calibration methods). Marginal extraction costs per barrel using 1998 data for 7 major producing states are: CA \$6.12, KS \$4.89, LA \$8.81, NM \$6.27, OK \$6.89, TX \$6.71, and WY \$6.43. The 1998 calibrated oil production cost parameters for Wyoming are $\varepsilon = 2.93$ and $\kappa = 141$.