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Born: January 5, 1945 **Citizenship:** USA

Education: S.B., Electrical Engineering and Physics, M.I.T., 1966
S.M., Electrical Engineering, M.I.T., 1967
Ph.D., Economics, M.I.T., 1971

Academic and Research Appointments:

1971-1975 Assistant Professor, Sloan School of Management, M.I.T.
1975-1979 Associate Professor, Sloan School of Management, M.I.T.
1979-1988 Professor, Sloan School of Management, M.I.T.
1988-2000 Mitsubishi Bank Professor, Sloan School of Management, M.I.T.
2000- Bank of Tokyo-Mitsubishi Professor, Sloan School of Management, M.I.T.
1983- Research Associate, National Bureau of Economic Research
1985-1986 Visiting Professor of Economics and Fellow, Institute of Advanced Studies,
Tel-Aviv University
2000-2001 Visiting Professor, Harvard University, Graduate School of Business
2008 Visiting Professor, Columbia University, Graduate School of Business
2013- Associate Scholar, Harvard Environmental Economics Program, Harvard Kennedy
School of Government

Professional Organizations:

American Economic Association
American Finance Association
Econometric Society (Fellow)
International Association for Energy Economics
Association of Environmental and Resource Economists (President 1984, and Fellow)

Honors and Awards:

Mortimer and Raymond Sackler Fellow, Tel-Aviv University (1985, 1987)
 Outstanding Teaching Award, Graduate Student Council, M.I.T. (1989)
 Elected Fellow of the Econometric Society (1993)
 Graduate Teaching Award, Graduate Student Council, M.I.T. (1994)
 Alumni/ae Award for Innovation and Excellence in Management Education (1994)
 Outstanding Teaching Award, M.I.T. Sloan School (1995)
 Outstanding Contributions to the Profession Award, Internat. Assoc. for Energy Economics (1997)
 Excellence in Teaching Award, M.I.T. Sloan School (2002)
 “All Star Paper Award”, *Journal of Financial Economics*, for “Time to Build, Option Value, and Investment Decisions” (2002)
 Outstanding Teaching Award, M.I.T. Sloan School (2005)
 Teacher of the Year Award, M.I.T. Sloan School (2007)
 Adelman-Frankel Award for Unique Contributions to Energy Economics, U.S. Association for Energy Economics (2012)
 Elected Fellow of the Association of Environmental and Resource Economists (2013)

Editorial Boards:

Advisory Editor, *Journal of Economic Dynamics and Control* (1978-1987, 1995-)
 Associate Editor, *Energy Economics* (1978-)
 Advisory Editor, *The Journal of Energy and Development* (1978-)
 Editorial Board Member, *Energy Systems and Policy* (1980-2000)
 Associate Editor, *Journal of Industrial Economics* (1995-1998)
 Co-Editor, *Review of Economics and Statistics* (1996-2002)
 Associate Editor, *The Journal of Energy Markets*, (2007-)

Consulting - Public Organizations (Partial List):

Institute for Applied Economic Research, Montreal (1971-1981)
 Ministry of Planning, Government of Tunisia (1971-1973)
 Federal Reserve Board of Governors, Division of Research and Statistics (1972-1974)
 Federal Energy Administration (1975-1976)
 Member, Energy Facilities Siting Council, Commonwealth of Massachusetts (1975-1977)
 The World Bank (1976-1981, 1988-1991)
 Ministry of Foreign Affairs, Government of Japan (1979-1980)
 Tennessee Valley Authority, Office of the General Counsel (1980-1984)
 Federal Trade Commission (1981)
 Special Consultant, U.S. Department of State (1987-1990)
 Petroleos de Venezuela (1992)
 U.S. Department of Energy (1993)
 U.S. Department of Justice, Antitrust Division (1997-1999)
 Ministry of Energy and Mines, Government of Ecuador (2000-2001)
 Federal Energy Regulatory Commission (2002-2003)
 National Association of Attorneys General (2003-2008)
 Ministry of Finance, State of Israel (2010-2011, 2013-2014)

Consulting - Private Organizations (Partial List):

Director, Dynamics Associates, Inc. (1969-1977)
 New England Electric System (1977-1978, 1987-1988, 1993-1995)
 American Telephone & Telegraph Co. (1978-1979)
 International Business Machines (1983-1984)
 National Economic Research Associates (1986-1988)
 Analysis Group, Inc. (1988-)
 The Mitsubishi Bank, Tokyo (1989)
 Nippon Steel Company (1990-1991)
 Microsoft Corporation (1992)
 Siemens Corporation (1992)
 Lotus Development Corporation (1993-1995)
 Compaq Computer Company (1995-1996, 1999-2002)
 British Airways (1994-1999, 2007-)
 Biogen, Inc. (1997-2000)
 Cadence Design Systems (1998-1999)
 Hasbro, Inc. (1998-1999)
 MasterCard International (1998-2003)
 Verizon Communications, Inc. (2003-2005)
 Medtronic, Inc. (2011-2015)
 Aeromexico (2015-2017)

PUBLICATIONS**Books:**

Optimal Planning for Economic Stabilization, North-Holland Publishing Company, Amsterdam, 1973.

The Economics of the Natural Gas Shortage: 1960-1980 (with P.W. MacAvoy), North-Holland Publishing Company, Amsterdam, 1975.

Price Controls and the Natural Gas Shortage (with P.W. MacAvoy), American Enterprise Institute, Washington, DC, 1975.

Econometric Models and Economic Forecasts (with D.L. Rubinfeld), McGraw-Hill Book Company, New York, 1976; Second Edition, 1981; Third Edition, 1991; Fourth Edition, 1998.

Editor: *Advances in the Economics of Energy and Resources*, Vol. 1: *The Structure of Energy Markets*, Vol. 2: *The Production and Pricing of Energy Resources*, JAI Press, Greenwich, CT, 1979.

The Structure of World Energy Demand, M.I.T. Press, Cambridge, MA, 1979.

Microeconomics (with D.L. Rubinfeld), Prentice Hall Publishing Company, Upper Saddle River, NJ, 1989; Second Edition, 1992; Third Edition, 1995; Fourth Edition, 1998; Fifth Edition, 2001; Sixth Edition, 2005; Seventh Edition, 2009; Eighth Edition, 2013; Ninth Edition, 2017.

Investment under Uncertainty (with A.K. Dixit), Princeton University Press, Princeton, NJ, 1994.

Articles:

- “Application of the Linear-Quadratic Tracking Problem to Economic Stabilization Policy,” *IEEE Transactions on Automatic Control*, June 1972.
- “The Discrete-Time Tracking Problem with a Time-Delay in the Control,” *IEEE Transactions on Automatic Control*, June 1972.
- “Optimal Stabilization Policies via Deterministic Control,” *Annals of Economic and Social Measurement*, October 1972.
- “A Generalized Approach to Estimation for the TROLL/1 System,” (with M. Eisner), *Annals of Economic and Social Measurement*, January 1973.
- “Optimal Policies for Economic Stabilization,” *Econometrica*, May 1973.
- “Alternative Regulatory Policies for Dealing with the Natural Gas Shortage,” (with P.W. MacAvoy), *Bell Journal of Economics and Management Science*, Fall 1973.
- “Optimal Policies for Monetary Control,” (with S.M. Roberts), *Annals of Economic and Social Measurement*, January 1974.
- “The Econometrics of U.S. Natural Gas and Oil Markets,” *Energy Policy*, April 1974.
- “The Regulatory Implications of Three Alternative Econometric Supply Models of Natural Gas,” *Bell Journal of Economics and Management Science*, Fall 1974.
- “An Optimal Control Model for Multi-Sectoral Investment Planning in Tunisia,” (with A. Martens), *Journal of Development Economics*, April 1975.
- “Should the Federal Government Enter the Oil Business?” *Challenge*, May 1976.
- “The Cost of Conflicting Objectives in Policy Formulation,” *Annals of Economic and Social Measurement*, Spring 1976.
- “Instruments, Intermediate Targets, and Monetary Controllability,” (with S.M. Roberts), *International Economic Review*, October 1976.
- “Pricing Policies for a Two-Part Exhaustible Resource Cartel: The Case of OPEC,” (with E. Hnyilicza), *European Economic Review*, September 1976.
- “The Conflicting Goals of National Energy Policy,” (with R.E. Hall), *The Public Interest*, Spring 1977.
- “Optimal Stabilization Policies under Decentralized Control and Conflicting Objectives,” *IEEE Transactions on Automatic Control*, August 1977.
- “Higher Energy Prices and the Supply of Natural Gas,” *Energy Systems and Policy*, Fall 1977.

- “Cartel Pricing and the Structure of the World Bauxite Market,” *Bell Journal of Economics*, Fall 1977.
- “Gains to Producers from the Cartelization of Exhaustible Resources,” *Review of Economics and Statistics*, May 1978.
- “OPEC's Threat to the West,” *Foreign Policy*, Spring 1978.
- “The Optimal Exploration and Production of Nonrenewable Resources,” *Journal of Political Economy*, October 1978.
- “Interfuel Substitution and the Industrial Demand for Energy: An International Comparison,” *Review of Economics and Statistics*, May 1979.
- “The Cartelization of World Commodity Markets,” *American Economic Review*, May 1979.
- “Some Long-Term Problems in OPEC Oil Pricing,” *Journal of Energy and Development*, Spring 1979.
- “Should the Government Subsidize Non-Conventional Energy Supplies?” (with P.L. Joskow), *Regulation*, September/October 1979.
- “International Comparisons of the Residential Demand for Energy,” *European Economic Review*, January 1980.
- “The American Energy Debate,” *The Public Interest*, Spring 1980.
- “Energy Price Increases and Macroeconomic Policy,” *The Energy Journal*, October 1980.
- “Uncertainty and Exhaustible Resource Markets,” *Journal of Political Economy*, December 1980.
- “Oil Shocks and Western Equilibrium,” (with R.E. Hall), *Technology Review*, May 1981.
- “The Optimal Production of an Exhaustible Resource When Price Is Exogenous and Stochastic,” *Scandinavian Journal of Economics*, June 1981.
- “Models of Resource Markets and the Explanation of Resource Price Behavior,” *Energy Economics*, July 1981.
- “The Pricing of Durable Exhaustible Resources,” (with D. Levhari), *Quarterly Journal of Economics*, August 1981.
- “What to Do When Energy Prices Rise Again,” (with R.E. Hall), *The Public Interest*, Fall 1981.
- “Adjustment Costs, Uncertainty, and the Behavior of the Firm,” *American Economic Review*, June 1982.

“The Optimal Phasing of Phased Deregulation,” *Journal of Economic Dynamics and Control*, August 1982.

“Jointly Produced Exhaustible Resources,” *Journal of Environmental Economics and Management*, December 1982.

“Dynamic Factor Demands under Rational Expectations,” (with J. Rotemberg), *Scandinavian Journal of Economics*, July 1983.

“Dynamic Factor Demands and the Effects of Energy Price Shocks,” (with J. Rotemberg), *American Economic Review*, December 1983.

“Energy Shocks and the Macroeconomy,” (with J. Rotemberg), *Natural Resources Journal*, April 1984, and reprinted in A. Alm and R. Weiner (Eds.), *Managing Oil Shocks*, Ballinger, 1984.

“Uncertainty in the Theory of Renewable Resource Markets,” *Review of Economic Studies*, April 1984.

“Risk, Inflation, and the Stock Market,” *American Economic Review*, June 1984.

“The Measurement of Monopoly Power in Dynamic Markets,” *Journal of Law and Economics*, April 1985.

“Time to Build, Option Value, and Investment Decisions,” (with S. Majd), *Journal of Financial Economics*, March 1987.

“Are Imports to Blame? Attribution of Injury under the 1974 Trade Act,” (with J. Rotemberg), *Journal of Law and Economics*, April 1987.

“On Monopoly Power in Extractive Resource Markets,” *Journal of Environmental Economics and Management*, June 1987.

“Risk Aversion and Determinants of Stock Market Behavior,” *Review of Economics and Statistics*, May 1988.

“Irreversible Investment, Capacity Choice, and the Value of the Firm,” *American Economic Review*, December 1988.

“The Learning Curve and Optimal Production under Uncertainty,” (with S. Majd), *Rand Journal of Economics*, Autumn 1989.

“The Excess Co-movement of Commodity Prices,” (with J. Rotemberg), *The Economic Journal*, December 1990.

“Irreversibility, Uncertainty, and Investment,” *Journal of Economic Literature*, September 1991.

- “Investments in Flexible Production Capacity,” (with H. He), *Journal of Economic Dynamics and Control*, August 1992
- “A Note on Competitive Investment under Uncertainty,” *American Economic Review*, March 1993.
- “The Present Value Model of Rational Commodity Pricing,” *The Economic Journal*, May 1993.
- “Investments of Uncertain Cost,” *Journal of Financial Economics*, August 1993.
- “The Comovement of Stock Prices,” (with J. Rotemberg), *Quarterly Journal of Economics*, November 1993.
- “Economic Instability and Aggregate Investment,” (with A. Solimano), *NBER Macroeconomics Annual*, 1993.
- “Inventories and the Short-Run Dynamics of Commodity Prices,” *RAND Journal of Economics*, March 1994.
- “Valuing Flexibility in Utility Planning,” (with T. Kaslow), *The Electricity Journal*, March 1994.
- “The Options Approach to Capital Investment,” (with A.K. Dixit), *Harvard Business Review*, May/June 1995.
- “Uncertainty, Investment, and Industry Evolution,” (with R. Caballero), *International Economic Review*, August 1996.
- “Options, the Value of Capital, and Investment,” (with A. Abel, A. Dixit, and J. Eberly), *Quarterly Journal of Economics*, August 1996.
- “A Markup Interpretation of Optimal Investment Rules,” (with A. Dixit and S. Sødal), *The Economic Journal*, April 1999.
- “The Long-Run Evolution of Energy Prices,” *The Energy Journal*, April 1999.
- “Irreversibilities and the Timing of Environmental Policy,” *Resource and Energy Economics*, July 2000.
- “The Dynamics of Commodity Spot and Futures Markets: A Primer,” *The Energy Journal*, August 2001.
- “Optimal Timing Problems in Environmental Economics,” *Journal of Economic Dynamics and Control*, July 2002.
- “Consumption Externalities and Diffusion in Pharmaceutical Markets: Antiulcer Drugs,” (with E.R. Berndt and P. Azoulay), *Journal of Industrial Economics*, June 2003.
- “Volatility and Commodity Price Dynamics,” *The Journal of Futures Markets*, November 2004.

- “Volatility in Natural Gas and Oil Markets,” *Journal of Energy and Development*, November 2004.
- “Uncertainty in Environmental Economics,” *Review of Environmental Economics and Policy*, Winter 2007.
- “Mandatory Unbundling and Irreversible Investment in Telecom Networks,” *Review of Network Economics*, September 2007.
- “Solving Optimal Timing Problems in Environmental Economics,” (with M. Balikcioglu and P. Fackler), *Resource and Energy Economics*, March 2011.
- “Fat Tails, Thin Tails, and Climate Change Policy,” *Review of Environmental Economics and Policy*, Summer 2011.
- “Uncertain Outcomes and Climate Change Policy,” *Journal of Environmental Economics and Management*, February 2012.
- “The Climate Policy Dilemma,” *Review of Environmental Economics and Policy*, Summer 2013.
- “Pricing Carbon Emissions When We Don’t Know the Right Price,” *Regulation*, Summer 2013.
- “Determining Benefits and Costs for Future Generations,” (with K. Arrow, M. Cropper, et. al.), *Science*, July 26, 2013.
- “Climate Change Policy: What Do the Models Tell Us?” *Journal of Economic Literature*, September, 2013.
- “The Economic and Policy Consequences of Catastrophes,” (with N. Wang), *American Economic Journal: Economic Policy*, November 2013.
- “Should Governments Use a Declining Discount Rate in Project Analysis?” (with K. Arrow, M. Cropper, et. al.), *Review of Environmental Economics and Policy*, Summer 2014.
- “Risk and Return in the Design of Environmental Policy,” *Journal of the Association of Environmental and Resource Economists*, September 2014.
- “Averting Catastrophes: The Strange Economics of Scylla and Charybdis,” (with I. Martin), *American Economic Review*, October 2015.
- “The Simple Economics of Commodity Price Speculation,” (with C. Knittel), *American Economic Journal: Macroeconomics*, April 2016.
- “The Use and Misuse of Models for Climate Policy,” *Review of Environmental Economics and Policy*, Winter 2017.
- “Taxes, Targets, and the Social Cost of Carbon,” *Economica*, June 2017.

Chapters in Books:

- “Market Structure and Regulation: The Natural Gas Industry,” in M. Macrakus (Ed.), *Energy: Demand, Supply, and Institutional Problems*, M.I.T. Press, 1974.
- “Sequential Open-Loop Optimal Control of a Non-linear Macroeconomic Model,” (with M. Athans et al.), in M. Intriligator (Ed.), *Frontiers of Quantitative Economics*, Vol. 3, North-Holland Publishing Company, Amsterdam, 1977.
- “Prices and Shortages: Evaluating Policy Options for the Natural Gas Industry,” in L. Chickering and H. Rowen (Eds.), *Options for U.S. Energy Policy*, Institute for Contemporary Studies, San Francisco, 1977.
- “An Econometric Approach to Forecasting Demand and Firm Behavior: Canadian Telecommunications,” (with V. Corbo), in S. Markridakis and S. Wheelwright (Eds.), *Forecasting, TIMS Studies in the Management Sciences*, Vol. 12, North-Holland Publishing Company, 1979.
- “The Critical Issues in U.S. Energy Policy,” in R. Day and N. Kamrany (Eds.), *Economic Issues of the Eighties*, Johns Hopkins University Press, Baltimore, 1979.
- “The Characteristics of the Demand for Energy,” in J. Sawhill (Ed.), *Energy Conservation and Public Policy*, Prentice Hall, 1979.
- “Energy Demand and Energy Policy: What Have We Learned?” in B. Kursunoglu and A. Perlmutter (Eds.), *Directions in Energy Policy*, Ballinger, 1979.
- “An Agenda for American Energy Policy,” in A. Meltsner (Ed.), *Politics and the Oval Office: Towards Presidential Governance*, Institute for Contemporary Studies, San Francisco, 1981.
- “Energy, Productivity, and the New U.S. Industrial Policy,” in M.L. Wachter and S.M. Wachter (Eds.), *Toward a New U.S. Industrial Policy*, University of Pennsylvania Press, 1981.
- “Energy Policy and the American Economy,” in N. Kamrany (Ed.), *U.S. Options for Energy Independence*, Heath-Lexington, 1982.
- “OPEC Oil Pricing and the Implications for Producers and Consumers,” in J. Griffin and D. Teece (Eds.), *OPEC Behavior and World Oil Prices*, Allen & Unwin, 1982.
- “Behavioral Assumptions in Decentralized Stabilization Policies,” (with J. Neese), in A.J. Hughes Hallett (Ed.), *Applied Decision Analysis and Economic Behavior*, Kluwer and Nijhoff, 1984.
- “Cartel Theory and Cartel Experience in International Minerals Markets,” (with J. MacKie-Mason), in *Energy Markets and Regulation: What Have We Learned?, Essays in Honor of M.A. Adelman*, M.I.T. Press, 1986.
- “Capital Adjustment Costs, Monopoly Power, and the Regulated Firm,” in *Antitrust and Regulation*, R.E. Grieson (Ed.), Lexington Books, 1986.

“Irreversibility and the Explanation of Investment Behavior,” in D. Lund and B. Øksendal (Eds.), *Stochastic Models and Option Values*, North-Holland, 1991.

“Expandability, Reversibility, and Optimal Capacity Choice,” (with A.K. Dixit), in *Project Flexibility, Agency, and Competition*, M.J. Brennan and L. Trigeorgis (Eds.), Oxford University Press, 1999.

“Sunk Costs and Real options in Antitrust,” in *Issues in Competition Law and Policy*, W. D. Collins, Ed., ABA Press, 2008.

“Governance, Insurance Restrictions, and Competition in Payment Card Networks,” NBER Working Paper, June 2007, in J. Kwoka and L. White, Eds., *The Antitrust Revolution*, 5th Edition, Oxford University Press, 2009, revised for 6th Edition, 2013.

“Modeling the Impact of Warming in Climate Change Economics,” in G. Libecap and R. Steckel, Eds., *The Economics of Climate Change: Adaptations Past and Present*, University of Chicago Press, 2011.

Book Reviews:

Review of Morgenstern, Knorr, and Heiss, *Long Term Projections of Power*, in *The Journal of Business*, April 1975.

Review of Turvey and Anderson, *Electricity Economics*, in *Journal of Political Economy*, October 1978.

Review of Kemp and Long, *Essays in the Economics of Exhaustible Resources*, in *The Economic Record*, June 1985.

Review of R. Mikesell, *Nonfuel Minerals: Foreign Dependence and National Security*, in *The Journal of Economic Literature*, December 1988.

Review of J. Williams and B. Wright, *Storage and Commodity Markets*, in *The Journal of Economic Literature*, December 1992.

Review of M. Weitzman, *Income, Wealth, and the Maximum Principle*, in *The Journal of Economic Literature*, March 2005.

Reports and Working Papers:

“Energy Demand Growth and Economic Activity: Through the Year 2000,” presented at American Association for the Advancement of Science, Symposium on Energy Policy and the Future of Nuclear Power, February 1976.

“World Energy Demand and the Demand for Nuclear Power,” December 1976.

- “Stabilization Policies with an Imperfect Model and Sequential Control,” (with M. Athans and E. Kuh), May 1977.
- “Higher Energy Prices and Economic Growth,” presented at the RFF/IAEE International Energy Conference, Washington, DC, June 1979.
- “Adjustment Costs and Uncertainty in the Theory of the Regulated Firm,” M.I.T. Sloan School of Management Working Paper No. 1142-80, September 1980, revised January 1981.
- “An Analysis of U.S. Sectoral Production Activity: Preliminary Results,” (with J. Rotemberg and T. Stoker), M.I.T. Energy Laboratory Working Paper No. 83-012WP, March 1983.
- “Competitive and Monopoly Resource Production with Stochastic Reserves,” M.I.T. Energy Laboratory Working Paper No. 83-019WP, July 1983.
- “Capital Risk and Models of Investment Behavior,” M.I.T. Sloan School of Management Working Paper No. 1819-86, September 1986.
- “Options, Flexibility, and Investment Decisions,” M.I.T. Center for Energy Policy Research Working Paper, March 1988.
- “Sunk Costs and Sunk Benefits in Environmental Policy,” M.I.T. Center for Energy Policy Research Working Paper No. 95-003WP, March 1995; revised April 1996, December 1998.
- “Pricing Capital under Mandatory Unbundling and Facilities Sharing,” NBER Working Paper No. 11225, March 2005.
- “Sunk Costs and Risk-Based Barriers to Entry,” NBER Working Paper No. 14755, Feb. 2009.
- “Risk and Return in Environmental Economics,” NBER Working Paper No. 18262, July 2012.
- “Pricing with Limited Knowledge of Demand,” (with M. Cohen and G. Perakis), NBER Working Paper 21679, October 2015.
- “The Social Cost of Carbon Revisited,” NBER Working Paper No. 22807, November 2016, revised October 2017.
- “Tropical Forests, Tipping Points, and the Social Cost of Deforestation,” (with Sergio Franklin), NBER Working Paper No. 23272, March 2017.
- “Averting Catastrophes that Kill,” (with Ian Martin), NBER Working Paper No. 23346, April 2017.