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China Economic and Environmental Modeling Workshop

Proceedings

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Jae Edmonds
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Acknowledgments

This publication documents the China Economic and Energy Modeling Workshop held in Beijing on 18-19 January 1999. The workshop brought together over 70 modeling experts from both countries to review existing tools, identify future challenges, and strengthen the cooperation among modelers between countries and within each country.

The workshop was made possible through support from the U.S. Environmental Protection Agency (EPA). Paul Schwengels leads EPA's efforts to improve technical cooperation between Chinese and U.S. modeling experts with assistance from Richard Garbaccio.

China's Energy Research Institute (ERI) and the Beijing Energy Efficiency Center (BECon) made the arrangements in China for the workshop. Jiang Kejun of ERI provided herculean organization skills, as well as technical expertise. Zhou Dadi and his colleagues at BECon, including Shi Yingyi and Guo Yuan, deserve thanks. Xinhua News Agency provided superb simultaneous translation services during the workshop.

Jeff Logan, in cooperation with Dale Jorgenson and Mun Ho, organized the participation of experts from the United States and helped plan the agenda. Chris MacCracken helped convert presentation material into a more useful format and Karen King helped organize the event. Susan Legro edited an earlier version of this document.

We would especially like to thank the experts who gave presentations at the workshop. Their presentations generated excellent discussion and made the workshop a success. Finally, we offer our thanks to each of the workshop attendees for helping to strengthen the community of economic and energy modeling experts in China.

William U. Chandler
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Forward

I am pleased to have this opportunity to call attention to a new aspect of cooperation between the United States and China, and to reaffirm the support of the U.S. Environmental Protection Agency, and the U.S. Government generally, for cooperation among economic modelers and analysts in our two countries on analysis of economic development and protection of the local and global environment. This document provides a record of the first of what I hope will be a series of meetings, joint activities and products under a China-US program on economic and environmental modeling.

The United States Environmental Protection Agency, and other U.S. agencies, have been collaborating with Chinese agencies for nearly two decades to help address the environmental problems associated with rapid economic growth. This cooperation has become more significant and detailed over time. I believe that the joint development and application of state of the art analytic tools and approaches for integrating environmental improvement into sustainable economic development policy is a powerful and needed addition to this cooperation.

Over the past several years the U.S. Government and other institutions have invested major human and financial resources in analysis of the economic implications of alternative policies for responding to domestic and global environmental concerns. In the climate change area, economic modeling and analysis have played an important role in development of U.S. policy. In the process US analysts and policy makers have learned a number of valuable lessons. The complexity of this policy issue has required a range of analytic tools including top-down, economic and bottom-up, technology-rich models at national, regional, sectoral and international scales.

These analyses have demonstrated that realistic targets and timetables, consistent with economic decision making and capital turnover horizons, and including flexibility measures, can substantially reduce costs and enhance political feasibility of needed climate actions. They have also illustrated the global nature of the problem, and the benefits of global cooperation in the solutions. These analytic tools are beginning to address the role of technological change in determining the levels and types of economic activity, energy use and pollution in the medium to long term, and to illustrate the importance of technology policies in reducing long term economic impacts. Economic models with other tools have also been used to quantify the relationships between strategies which reduce both greenhouse gases and “ancillary” reductions in other pollution burdens, public health and economic impacts.

All of these results have contributed to the identification of policy options which can achieve environmental goals most efficiently and effectively, consistent with continued economic growth. This is, in fact, part of a larger trend in environmental policy in the U.S. and around the world -- the movement toward integrating environmental goals into basic policy and economic activity through market mechanisms and other innovative pollution prevention incentives.

I believe that the hard earned insights and methods developed through decades of environmental and economic policy analysis in the United States, and especially the developments of the last few years, can be of great value to our Chinese colleagues as they struggle with even more challenging environmental concerns. China's remarkable economic growth over the past two decades has captured attention across the globe. Economic reforms initiated in the late 1970s have quadrupled the country's gross domestic product, lifting millions of Chinese out of poverty and improving the standard of living for many more. Rapid change has brought with it dislocations in society and the environment, and China is beginning to address seriously some of these problems.

Environmental pollution and degradation are beginning to receive serious attention at the highest level of government in China. Many Chinese leaders have begun to realize that economic growth cannot proceed at the expense of the environment and the health of the Chinese people. Ensuring the quality urban air and water resources may be two of the most critical challenges in China's future. Additionally, greenhouse gas emissions in China will likely surpass those of the United States in approximately 20 years.

Economic, energy and environmental modeling will become increasingly important in China as market reforms continue to reshape the economy. Policymakers will need realistic models to explore energy and climate change policy options and to minimize total costs. As demonstrated in this workshop, China has made significant progress in building models to analyze energy, environmental, and climate issues, and a number of very talented U.S. modeling groups are working with Chinese colleagues to further this development. Nonetheless, the workshop has also shown that more work is needed to capture accurately the unique characteristics of China’s hybrid economy while accounting for international flows of capital and technology.

While the U.S. government clearly recognizes the need for China to carry out its policy development and decision-making independently, I believe that continued collaboration on the development of methods, data bases, models and other analytic tools can provide better information, and better inform policy makers in both countries. The U.S. Environmental Protection Agency in cooperation with other U.S. Government and non-governmental partners will continue to work with China’s State Development Planning Commission and other ministries and technical institutions to help address these technical and analytic needs.

I am greatly impressed with the quality and diversity of the presentations and the progress which has been made in this first workshop. On behalf of the U.S. Environmental Protection Agency and the U.S. Government, I would like to thank all of the participants in both countries for their efforts, and encourage them to continue and expand the work. I look forward to future joint products with great interest.

Al McGartland
Director
Office of Economy and Environment
U.S. Environmental Protection Agency

Contents

Executive Summary

The China Economic and Energy Modeling Workshop was held at the Beijing Friendship Hotel on 18-19 January 1999. It brought together over 70 Chinese and U.S. experts to discuss technical modeling issues and to build bridges between practitioners in both countries. During the two-day workshop, a dozen experts from China and the United States gave presentations on their modeling efforts that led to lively discussions and sharing new information.

The following experts made presentations on economic and energy modeling topics:

1. Paul Schwengels: Key Issues in U.S. Economic Modeling and Climate Change Policy
2. Jae Edmonds: Climate Change and Economic Modeling
3. Dale Jorgenson: The Jorgenson-Wilcoxen Model of the U.S. and Its Use for Policy Making
4. Phillip Tseng: The Application of MARKAL-MACRO Model in the Analysis of Reducing Carbon Emissions
5. Li Shantong: Modeling Activities in the Development Research Center
6. Robert Shackleton: The Economic Effects of International Carbon Emissions Trading Under the Kyoto Protocol: What We Have Learned From the G-Cubed Model
7. Richard Garbaccio and Mun Ho: A CGE Model for Analyzing CO_2 Emissions Reduction Strategies in China
8. Jiang Kejun: Post Kyoto: Analysis from AIM
9. Ron Sands and Jiang Kejun: The China Second Generation Model
10. Ma Gang: Impact of Carbon Tax and CO_2 Abatement on Chinese Economy: A Static CGE Analysis
11. Hu Xiulian and Jiang Kejun: Modeling Demands for Energy and Environment in China.

The collection of presentations and the discussions which ensued provided a very useful basis for future cooperation and documented a substantial number of high- quality existing models and ongoing activities with application to China's economic and environmental policy issues. Substantial capacity and expertise exists and great progress has been made over the past few years in development of economic and environmental models. There was a clear consensus that this event should be the start of an ongoing effort to continue and expand technical cooperation of economic, environmental and climate policy modeling.

One of the central conclusions of the meeting was that current models do not yet accurately capture the unique characteristics of China's domestic economy while accounting for international capital flows, carbon permit trading, and technology transfer. Existing models could be improved in a number of ways which were discussed in the workshop. Substantial benefits can be gained through improved cooperation among Chinese modeling groups and among and with international collaborators.

Plans for future collaboration to begin dealing with some of the technical issues raised in the discussions also were laid out. Future work includes a follow-on workshop, possibly to be held in the fall of 1999, where sensitivity studies will be compared for each model. Participants also will establish an electronic mail distribution network so that ideas can be shared easily between all members of the community.

US and Chinese researchers will use these new communications channels to develop and discuss a list of potential activities in addition to the follow-on workshop that includes creating a worldwide web site on energy and economic modeling, publishing a technical journal on modeling issues, and defining sensitivity scenarios which can be used to measure the critical variables in a variety of models.

Introduction

Chinese and international modeling experts have a growing history of successful collaboration.   Economists from Harvard University have worked with colleagues at the State Council and the Chinese Academy of Social Sciences for over 5 years to build a computable general equilibrium model of China's economy. Researchers at Pacific Northwest National Laboratory also have worked closely with colleagues at the Energy Research Institute to build a China module for the Second Generation Model (SGM). An updated version of this module based on newer and expanded information soon will be released. The U.S. Environmental Protection Agency (EPA) has funded much of the collaboration between the United States and China. The National Institute for Environmental Studies in Japan also has worked with Chinese experts to develop the Asian Integrated Model (AIM). Finally, researchers at the U.S. Department of Energy are collaborating with researchers at Qinghua (Tsinghua) University to begin studying the development of a Chinese version of MARKAL-MACRO.

The China Economic and Energy Modeling Workshop was held at the Beijing Friendship Hotel on 18-19 January 1999. It brought together over 70 Chinese and U.S. experts to discuss technical modeling issues and to build bridges between practitioners in both countries. During the two-day workshop, a dozen experts from China and the United States gave presentations on their modeling efforts that led to lively discussions and sharing new information. The presentations given in this workshop provide a compilation of much of the ongoing work involving US and Chinese experts. They also provide background on relationship of modeling to policy making in the US and China, and the recent developments and current state of economic and environmental -policy modeling in China and internationally.   Finally and most importantly, the discussion in this workshop produces a number of useful recommendations for further cooperation and specific priorities for future joint work.

Rapporteur Notes

The following notes summarize presentations made by Chinese and U.S. modeling experts over the course of two days.[1] Presentation material for each speaker is contained in the appendixes. Dale Jorgenson's presentation is not available in this document, but interested readers can consult one of his publications with similar information.[2]

Workshop Presentations - January 18

Zhou Dadi - *Welcoming Remarks and Comments on the Framework Convention on Climate Change (FCCC) Negotiations*

The meeting opened with an address by Zhou Dadi, Deputy Director of China's Energy Research Institute and Executive Director of the Beijing Energy Efficiency Center. Zhou began by discussing the negotiations taking place in the FCCC. He noted that the current discussions lack a spirit of cooperation. There are many reasons for this. One reason is that there is a feeling that the protocol may never enter into force and there is little point in pursuing an agreement that will never take effect.

Zhou indicated that the proposal to formally consider voluntary commitments by developing countries proved to be highly contentious in the Fourth Conference of Parties (COP-4) negotiations, but that China would have no objection if Argentina undertakes an emissions mitigation commitment voluntarily.

Zhou observed that developing nations have two goals that they wish to pursue: development and environmental quality. The highest priority is development. For developing nations to participate in emissions mitigation activities, they must be able to achieve developmental and environmental goals simultaneously, or they will not participate.

Technology may offer a mechanism to achieve both objectives. Technology transfer from developed nations to developing nations will need to be a major part of programs to reduce emissions. This is different from the Clean Development Mechanism (CDM) mentioned in the Kyoto Protocol of the FCCC. Zhou insisted that developed nations must transfer new technologies. No adequate mechanism currently exists for achieving this objective. Capital is a fundamental constraint in China. China will be unable to undertake emissions mitigation commitments unless that constraint can be relaxed.

At COP-4, little attention was paid to the question of adequacy of commitments. Most of the discussions centered on nations' perceptions of economic vulnerability to emissions

[1] For an online color version of these presentations, please visit PNNL's China E-News web page at http://www.pnl.gov/china.

[2] "Carbon Mitigation, Permit Trading, and Revenue Recycling," by Dale Jorgenson, Richard Goettle, Peter Wilcoxen and Daniel Slesnick, Dale Jorgenson and Associates, 31 August 1998 is available at http://www.ksg.harvard.edu/tep/ptep.htm.

mitigation measures. There was little consensus regarding potential gains and losses under a protocol. It will be essential to improve the state of economic analysis if there is to be any hope of developing a consensus.

Paul Schwengels - *Key Issues in U.S. Economic Modeling and Climate Change Policy*
Schwengels gave welcoming comments and responded to key issues raised by Zhou Dadi. He acknowledged the importance and difficulty of the policy and negotiation issues identified by Zhou Dadi. He stressed Zhou's final point, which is generally agreed, that many of the policy debates which are so difficult in the Framework Convention process are based in part on lack of common technical understanding. Expert groups such as that assembled for this workshop can make an extremely useful contribution by providing better technical information on which our two governments and other Parties can base their policy decisions.

In his presentation, Paul Schwengels:

1. Reviewed the U.S. experience with models and analysis in recent years. The United States made extensive use of models in the analytical process leading up to the Kyoto Protocol negotiations.
2. Identified key questions driving policy debates in the United States. Benefits of emissions mitigation, cost of emissions mitigation, and ancillary benefits to emission mitigation. The cost of emissions mitigation was shown to be sensitive to baseline emissions, technology, and policy instruments.
3. Illustrated the role economic models have played in the U.S. policy process. Where, when, and what flexibility were key features of U.S. policy. The distribution of costs among sectors, regions, and groups can be just as important as the total cost.
4. Identified areas of priority improvement in modeling and analysis. Key areas include: Technological Change (both baseline and policy induced); Consistent Treatment of Sources and Sinks/All Six Gases; Better Characterization of the Options and Costs for CDM, JI, and ET credits (e.g., Technical Options for Generating Credits in China); Institutional and other constraints to trading/CDM; and Integration of Economics, Climate, and Co-Control Benefits.
5. Discussed key policies issues, tools needed, and research priorities for China.

Paul Schwengels' presentation has been reproduced in Appendix A.

Jae Edmonds - *Climate Change and Economic Modeling*

Jae Edmonds gave an overview of modeling the economics of climate change that covered eight issues:

1. Approach: Top-down and bottom-up
2. Trade: Direct and indirect effects
3. Uncertainty and expectations
4. Non-CO_2 greenhouse gases
5. Sinks: Land-use emissions
6. Measurement of costs
7. Ancillary benefits
8. Endogenous technical progress.

He began with a discussion of different ways to approach climate modeling, which is an energy issue that depends also on agriculture, land-use, and chemical manufacture. Edmonds then went into a short summary of the different top-down and bottom-up models, describing their strengths and shortcomings. He compared results from 10 top-down models used in the Energy Modeling Forum and explained the variations in their results.

Edmonds next discussed modeling China. He pointed out that China is unique in the following ways: the economy is a hybrid mixture of market and central planning; the public sector plays a greater role in decision making; and international trade, exchange rates, and capital flows are regulated. Because of the combination of China's rapid economic growth, heavy reliance on coal, and transition from a rural to an urban society, modelers face many challenges in accurately forecasting the country's future characteristics.

He next described the effects of uncertainty on policymaking. Edmonds explained that since mitigation cost elasticities are greater than mitigation benefit elasticities, price instruments such as carbon taxes may outperform quantity instruments such as tradable permits.

Edmonds then discussed the role of non-CO_2 greenhouse gases such as N_2O, CH_4, HFCs, PFCs, and SF_6 that accounted for about 15 percent of total U.S. emissions in 1990. Most models do not have the capability to model these gases endogenously.

Edmonds then presented the following figures on emissions and stocks:

Emissions
- Land-use emissions: 1.6 Pg/yr[3]
- Fossil fuel emissions: 6.0 PgC/yr

Stocks
- Terrestrial carbon stocks: 560 PgC
- Soils: 1200 PgC
- Fossil fuels: 15,000 PgC
- Atmosphere: 750 PgC

He argued that, in the Kyoto time frame (2008-2012), sinks are an accounting issue only as there is not enough time to make major changes in aboveground stocks of carbon. Carbon sequestration in soils is not covered by the Kyoto Protocol, but it is a promising method of managing carbon if the institutional barriers can be overcome.

Edmonds next described how costs are measured in different models and described how different accounting practices can lead to significant differences in gross national product or consumption costs.

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[3] A petagram (PG) is billion tons, or $1x10^{15}$ grams.

He then described the difficulties of integrating the ancillary benefits of carbon mitigation into economic models. Not only are the societal benefits of abating carbon emissions difficult to quantify, but the secondary impacts on other pollutants are also variable. Fuel switching from coal or oil to natural gas has positive impacts on both climate and local pollutants, but other variations are not always true (sulfur control may improve local environmental conditions but increases greenhouse gas emissions).

Finally, Edmonds discussed the role of technology development and stated that, in the long run, it will play the key role in addressing the challenge of climate change. He argued that there is no magic bullet and that a portfolio of technologies needs to be developed. Scenarios using the SGM model showed how new technologies--including soil carbon sequestration, solar, biomass, and carbon sequestration from fossil fuel use--could stabilize the atmospheric concentration of carbon dioxide at 550 ppmv (parts per million by volume) within a century.

A full copy of Jae Edmonds' presentation is provided in Appendix B.

Dale Jorgenson - *The Jorgenson-Wilcoxen Model of the United States and Its Use for Policy Making*

Dale Jorgenson described the Jorgenson-Wilcoxen model of the U.S. economy, and discussed the application of similar principles to the Chinese economy. He also discussed the selection of models for the analysis of the cost of emissions mitigation. He argued that traditional "macro" models, which were originally developed to address issues of unemployment and inflation within the context of the business cycle, were unfit to assess the question of mitigation costs. He argued that only computable general equilibrium models, which simultaneously consider the interaction of all sectors of the economy, could adequately assess emissions mitigation.

Jorgenson went on to argue for the superiority of price mechanisms for the control of pollutants. He further argued for the existence of a double dividend in the United States. That is, one can simultaneously reduce emissions and increase welfare by replacing a distortionary tax, in this case the personal income tax, with an environmental tax. The economic benefits associated with improved economic efficiency would more than cover the resource costs of the environmental policy.

Dale Jorgenson concluded his presentation with four lessons:

- Modeling markets is absolutely essential—more and more environmental policy implementation uses markets.
- In order to understand the impact of carbon mitigation policies on long-term economic growth, it is important to see how markets are linked over time.
- The issues that are involved in modeling economic growth involve demography, technology, and capital accumulation. In contrast, macroeconomics involves inflation and employment.

- China must take into account the transition to a market economy to get environmental policy right.

Phillip Tseng - *The Application of MARKAL-MACRO Model in the Analysis of Reducing Carbon Emissions*

Phillip Tseng described the MARKAL-MACRO model, a generic linear programming model that can be applied to a wide range of energy- and climate change-related analytical problems.

MARKAL is a dynamic linear programming model that is run over time in 5-year intervals extending from 1995 through 2025. The objective function includes the capital costs of end-use (demand) technologies, capital costs of electricity generating technologies, fuel costs, infrastructure costs (such as pipelines), and operating and maintenance costs. The model keeps track of new investments and capital stocks between periods. It searches for a least-cost solution dynamically over the forecast period (1990-2025) to meet user-specified energy service demands. Because the model integrates both demand and supply technologies within the same modeling framework, the solution reflects the minimal cost for the energy system over the solution time period. The model's greatest strength is its ability to incorporate engineering technology detail. Model simulation results provide not only the imputed costs of reducing carbon emissions but also the sectors and technologies that are required to meet the carbon reductions.

MACRO is a macroeconomic model with an aggregated view of long-term economic growth. The basic input factors of production are capital, labor, and individual forms of energy. The economy's outputs are used for investment, consumption, and inter-industry payments for the costs of energy. The model solution is reached by nonlinear optimization, using the criterion of maximum discounted utility of consumption to select among alternative time paths for energy costs, macroeconomic consumption, and investment.

MARKAL-MACRO is an extension of the MARKAL energy system optimization model that simultaneously solves energy and economic components as a nonlinear program. MARKAL-MACRO merges the "bottom-up" engineering and "top-down" macroeconomic approaches to energy modeling. While maintaining the technological richness and flexibility of MARKAL, MARKAL-MACRO adds the price elasticity of demand for energy services and links changes in the energy system to the level of economic activity. MARKAL-MACRO solutions maximize consumer welfare over the solution period, optimize aggregate investment, and provide least-cost energy system configurations to meet the endogenously determined demands for energy services. The MARKAL technology database is used for MARKAL-MACRO.

MARKAL-MACRO can be applied to a wide range of questions associated with fuel choice, energy technology choices, and carbon emission mitigation.

Phillip Tseng's presentation has been reproduced in Appendix C.

Li Shantong - *Modeling Activities in the Development Research Center*

Li Shantong outlined the three phases of economic modeling in China: 1) the Initial Phase (1979-1988), which centered on "learning by doing"; 2) the Adjustment Phase (1988-1993), which focused on comparing and contrasting existing models; and 3) the Current Phase (1993-present) focusing on development of applied, theory-based modeling.

Representative works from the Initial Phase include "China Toward 2000" and "Planning of Energy and Heavy Chemical Industrial Base in Shanxi Province." In the Adjustment Phase, Chinese researchers and model developers took stock of global modeling resources, noting their strengths and weaknesses. As the market economy came to the fore in the 1993-94 period, modelers began developing much more sophisticated products, including econometric (Fudan University), macroeconomic (Chinese Academy of Social Sciences), and dynamic recursive computable general equilibrium (Development Research Center) models.

Li then went on to explain the model developed by his institute, a dynamic recursive CGE model. This prototype CGE was developed in the early- to mid-1990s to analyze trade and environmental issues. The model was based on an existing OECD model and modified for China's unique economy.

Main features of the model include

- 46 sectors, 10 types of households
- 5 production factors - agriculture, capital, rural labor, production work, and professional
- recursive dynamic model with vintage capital
- special treatment of foreign trade
- calibrated rather than econometric estimated.

Major policy applications of the model include

- economic growth to 2020
- growth, structural change, trade policy, and environmental impacts
- impact of tariff reduction and tax replacement on income and distribution
- impact of China's WTO accession.

Possible enhancements to the model include

- better translog production functions to replace nested CES production functions
- econometric estimation of model parameters
- more detailed description of taxation and separation of central-local government
- inter-temporal dynamic structure.

Li Shantong's presentation is provided in Appendix D.

Robert Shackleton - *The Economic Effects of International Carbon Emissions Trading Under the Kyoto Protocol: What We Have Learned From the G-Cubed Model*

Robert Shackleton described the G-Cubed model. G-Cubed is a computable general equilibrium model that has been used in the U.S. to assess emissions mitigation. The G-Cubed model is related through its data and structure to the Jorgenson-Wilcoxen model. The principal feature of the G-Cubed model is that it includes financial capital as well as physical capital. It therefore can explicitly consider balance of payments and exchange rates.

Shackleton described five scenarios that were developed for the EMF-16 analysis of the Kyoto Protocol. They reflect the wide variety of ways in which the protocol could be implemented. The breadth of ways in which the protocol could be implemented creates a wide range of potential costs and benefits that participants could experience. Marginal cost estimates for five EMF-16 cases were reported:

1. Independent compliance: U.S. $85, Japan $110, Australia $180, Other OECD $220
2. Annex I trade: $60
3. Annex I trade with China participation: $30
4. Annex I trade with LDC participation: $40
5. Full global trade: $25.

The full presentation by Robert Shackleton is located in Appendix E.

January 19, Day Two

Richard Garbaccio and Mun Ho - *A CGE Model for Analyzing CO_2 Emissions Reduction Strategies in China*

Richard Garbaccio and Mun Ho described their model of the Chinese economy. The model's structure is similar to the Jorgenson-Wilcoxen model described on the first day of the meeting by Jorgenson. They then went on to describe the transition that has occurred over the past 10 years in China. China has moved rapidly from a planned economy to a market economy. Between 1978 and 1996, the shares of products produced and sold at state controlled prices compared with products produced and sold at market prices were dramatically altered.

Shares of Production for Various Sectors at Market Prices and State Controlled Prices

1978	**Agriculture**	**Retail**	**Industry**
Market prices	6%	3%	0%
State prices	94%	97%	100%

1996	**Agriculture**	**Retail**	**Industry**
Market prices	79%	93%	81%
State prices	17%	6	14%

The situation in the investment sector is similar. The state investment budget fell from 28% of total investment to about 3% from 1981 to 1996.

It is clear that at the margin, the Chinese economy is a market economy. However, the role of state planning and state-controlled markets cannot be ignored. At present, procedures for addressing this dual nature of the economy are relatively ad hoc.

Much of the current effort in model development has focused on improving the quality of data. Data that have become the focus of current efforts include:

1. Tax data
2. Two-tier price and quantity data
3. Data by sector below the township (*xiang*) level
4. Service sector data
5. Trade data
6. Data on savings by households and enterprises
7. Investment data by source.

Garbaccio, Ho, and Jorgenson observe that their model, when used to simulate a carbon tax, produces a "double dividend" in the years after the initial periods. That is, the revenue from the carbon tax may be used to reduce capital taxes that leave enterprises with more retained earnings and hence higher potential to invest. This tax also has the effect of lowering real wages. Higher investment leads to higher GDP in subsequent years. They noted that this is an unusual result as discussed by Goulder and others in the double dividend literature. They attribute this difference in part to the fixed labor supply and the unusual nature of the existing tax system in China. Unlike other models, the lower wage here does not lead to a reduction in labor supply. The energy price elasticity results found in the model were viewed with skepticism by some attendees.

The presentation by Richard Garbaccio and Mun Ho is reproduced in Appendix F.

Jiang Kejun - *Post Kyoto: Analysis from AIM*

Jiang Kejun made a presentation on the Asian Integrated Model for Tsuneyuki Morita, of Japan's National Institute for Environmental Studies, who could not attend. Jiang began by describing the principal features of the AIM.

Energy Sectors

- Coal
- Crude oil
- Petroleum and coal products (refined)
- Natural gas
- Nuclear
- Renewable energy
- Electricity

Energy intensive products

- Agriculture, other manufactures and services
- Transport industries
- Other

Regions

1. Japan
2. Australia
3. New Zealand
4. USA
5. Canada
6. Western Europe
7. FSU (former Soviet Union)
8. Taiwan
9. Korea
10. Hong Kong
11. Singapore
12. China
13. India
14. Indonesia
15. Malaysia
16. Philippines
17. Thailand
18. Latin America
19. Middle East and N. Africa
20. Sub Saharan Africa
21. ROW (rest of world).

Jiang then described some of the results that have emerged from AIM as a consequence of the team's participation in the Stanford Energy Modeling Forum (EMF) Exercise 16 to assess the Kyoto Protocol. The EMF-16 scenarios for which results were presented include

EMF-16 Post Kyoto Scenarios

1. Modelers reference
2. No trade
3. Full Annex I trading
4. Full global trading
5. Double Bubble
6. Annex I and China and India
7. Supply Curves for Sinks and Other Gases.

The AIM uses its IPCC reference case A-1/oil&gas as its point of departure to test the consequences of policy intervention. Global emissions of carbon rise to 19.4 billion tons in this scenario. Several questions were raised regarding the AIM A-1/oil&gas scenario. Workshop participants noted that

- China does not increase emissions much after about 2020
- ROW (rest of world) becomes the largest emitter
- FSU increases continuously after 2010.

The model computed the marginal cost of emissions mitigation for the EMF scenarios. Results were as follows:

Cost of Emissions Mitigation in 2010 ($/tonne C)

Case 2: No Trade (Independent Compliance)

USA	$150
EU	$200
Japan	$240
Canada	$175
Australia	$100
NZL	$275
FSU	$0

Case 3: Annex I Trade
$65

Case 4: Full Global Trade
$38

Jiang noted that China does not sell much to the market in the AIM. China GDP declines in all cases, with the greatest losses occurring in global trading cases. It is unclear whether or not the value of the sale of permits is included in this calculation of the GDP.

Jiang Kejun's full presentation is reproduced in Appendix G.

Ron Sands and Jiang Kejun - *The China Second Generation Model*

Ron Sands and Jiang Kejun reported on recent changes in the development of the Second Generation Model. They discussed recent progress in moving from SGM97 to SGM2000. The U.S., Japan, and China modules are well advanced in their development. In the current version of SGM98, the industrial sector of the model has been disaggregated. SGM modelers are beginning to develop a separate transportation sector. The sectoral disaggregation of these two models is given below.

Sands and Jiang went on to discuss the issue of cost measures. They observed that while different models can compute the price of a tradable permit, the direct cost, and transfers associated with purchase or sale of emissions permits, approaches used to estimate gross domestic product, gross national product, consumption, and welfare varied greatly between models and were impossible to compare.

They also discussed the application of the SGM to China. They noted that the original collaboration began in 1992 and was initiated by Zhou Dadi and Jae Edmonds. The China version of the SGM differs from the U.S. version in several regards that go beyond simple differences in data and parameters. These differences include treatment of population, labor supply (wages in rural and urban areas are different), and investment.

The Energy Research Institute (ERI) has utilized the SGM for many policy analysis exercises. The SGM is the main model of the ERI. Current work on the SGM includes improving data, updating the model's base year from 1985 to 1990 and 1995, adding new sectors, and utilizing the model for domestic policy analysis and for the Global Energy Technology Strategy Project to Address Climate Change (GTSP).

The GTSP will assess technology options available in China that could reduce greenhouse gas emissions. The GTSP will also assess economic and non-economic factors that affect the deployment of these technologies.

Sands and Jiang discussed the problem of measuring economic activity in China in U.S. dollars. There was spirited discussion of this issue. There was general consensus that the market exchange rate underestimated the income level in China, but that finding an appropriate purchasing power parity (PPP) exchange rate was not easy.

Market exchange rates yield per capita income levels of approximately $800/person in China. Most participants believed this underrepresented the standard of living in China. The PPP exchange rate yields an income of about $3,000/person, which seemed too high. Participants agreed in general that an income level of $1,000 and $2,000 per capita seemed about right. This range supports the Big Mac Index provided by *The Economist*.

The full presentation by Ron Sands and Jiang Kejun can be found in Appendix H.

Ma Gang - *Impact of Carbon Tax and CO_2 Abatement on Chinese Economy: A Static CGE Analysis*

The objectives of the model used by Ma Gang at the Chinese Academy of Social Sciences (CASS) are to

- identify the sources, costs, and magnitude of potential abatement
- present the multi-dimensional view of impact of CO_2 abatement
- provide a policy package (through comparison).

Overview of the model

PRCGEM is a CGE model of the Chinese economy developed by the Institute for Quantitative and Technical Evaluation of CASS and the Center for Policy Study at Monash University in

Australia. The model can perform static analysis and comparison, as well as recursive dynamic analysis. The model was recently updated to include carbon dioxide emission equations and policy instruments such as carbon taxes.

PRCGEM is similar in structure to other CGE models. It contains 35 sectors, including 4 types of energy. The benchmark equilibrium data are the input-output data for 1992. To run policy scenarios, there are short- and long-run needs. In the short run, modelers need to set the sectoral capital stock, real wage rate, and aggregate absorption levels; in the long-run, a market-clearing assumption is adopted.

Ma presented results from a number of scenarios, including several featuring recycled carbon taxes. Ma explained that tax recycling would allow the government to replace an equivalent amount of corporate taxes with revenues gained through a carbon tax. In the short-run, without tax recycling, carbon dioxide emission reductions of 10 percent could be achieved with a carbon tax of RMB29/ton ($3.3/ton). Gross domestic product declined by almost 0.5 percent in this scenario. Recycling the taxes and reducing emissions by the same amount had a smaller impact on GDP (-0.12 percent), but a slightly higher carbon tax was required (RMB31/ton). In the long-run analysis, both the carbon tax and the impact on GDP were lessened slightly. There were questions raised whether China's economy would actually behave the way the model predicted.

A draft paper that reflects Ma Gang's presentation is provided in Appendix I.

Hu Xiulian and Jiang Kejun - *Modeling Demands for Energy and Environment in China*

Hu described modeling activities in China, with an emphasis on the work at the ERI. Chinese researchers have developed a full suite of models to address climate change. These include models of energy, climate impacts, climate, and economy. Seven models are used at the ERI:

1. AIM
2. SGM
3. Medees
4. EFOM
5. LEAP
6. MARKAL
7. Rains-ASIA

Objectives of model development at ERI are as follows:

- increase the understanding for climate change, energy, and environmental study
- enhance the ability for policymaking
- support the international negotiation process.

Research topics that are high on the ERI agenda include

- long- and medium-term emission scenarios
- GHGs emission reduction policy assessment
- cost and benefit analysis of GHG emission reduction
- technology assessment for GHG emission reduction
- local environment policy assessment
- SO_2 emission trend analysis
- local environment impact of global policies
- energy and resource development plan
- strategy assessment for sustainable development
- effects of international collaboration.

The presentation by Hu Xiulian and Jiang Kejun is reproduced in Appendix J.

Xu Deying - *Impact of Climate Change on China's Forests*

Xu Deying's presentation discussed possible tree species migration based on the temperature and precipitation changes anticipated from an increase in atmospheric concentrations of carbon dioxide. The discussion focused mainly on impacts, as opposed to modeling so details are not presented here.

Discussion of Recommendations for Future Work led by Jiang Kejun

The two days of presentations and discussion provided a common understanding of existing models and ongoing work, which allowed for an informed discussion of possibilities and priorities for future work. There was a lively discussion of future work needed to improve capabilities for analysis of linked economic, environmental, and greenhouse policy issues in China. The discussion also included the roles and potential contributions by U.S. and Chinese modelers, and key areas in which cooperation within China and internationally could be of greatest value.

Key issues

Market-based least-cost versus sustainable development – Some participants raised the concern that least-cost market choices in the current economy would not result in the best investments for long term sustainable development. This is a critical difference between modeling in developed and developing nations. Part of this problem may be addressed by policies to correct or overcome existing market distortions, but there may also be a need for government intervention, with international support, to create incentives consistent with long term sustainability. This is an area which needs to be addressed more effectively in future modeling.

How does sustainable development impact emissions mitigation? – This is related to the first discussion but recognizes the concern that there are trade-offs between sustainable development goals, such as poverty alleviation, and near term emissions mitigation. Models need to be able to identify both the "no-regrets" options which can achieve multiple goals, and the cases in which additional resources are needed to achieve these two objectives.

Understanding CGE models – Some Chinese participants expressed a great interest in future collaboration which would help expand and deepen understanding of the computable general equilibrium (CGE) models in China and the ways these models can be applied in the transition from planned to market economy.

Technology, technology deployment, and technological change in the models **–** The rate of change and deployment of technology has clearly been identified as a major determinant of the cost and feasibility of achieving environmental, sustainable development, and climate goals over long time horizons. There is a clear priority of interest in understanding and improving the treatment of technology issues in modeling and policy analysis tools.

Modeling the CDM – There was a recognition that models often treat pure emissions trading and CDM as identical. This is not the case in reality, and there is a need to understand the differences between CDM and emissions trading in practical implementation , and consider ways of modeling the two flexibility mechanisms realistically.

Introduction of MARKAL to China for climate change analysis **–** There was a sense that the MARKAL modeling approach, which includes a great deal of technology detail is a valuable addition to the Chinese capabilities for climate analysis. It is particularly useful due to the number of other countries currently using the model and creating comparable results.

Data improvement – Many participants recognized that the critical limitation for modeling economic and environmental issues in China, as in many other countries, is availability of credible and consistent data to drive the models. It was also recognized that many different modeling groups are attempting to solve very similar data problems, and that broad collaboration and pooling of efforts could be very beneficial for all participants.

Comparison of models – There was great interest in establishing a process which would encourage and support ongoing model comparisons, including methods, data, assumptions and results, to allow both developers and potential users of the models to gain understanding of the strengths, weakness and differences of particular models and identify priorities for development and improvements.

Identification of critical questions – It was agreed that clear statement of key questions in climate change policymaking that may be answered by models (2 or 3 questions) would be valuable in guiding model comparison and development work.

A modeling system for China – A goal for the collaborative efforts should be to help to design the modeling system (a set of related models and data sets, rather than a single model) for climate change policy analysis in China.

Local environmental protection and climate change – A major focus of future work should be understanding the relationships between local environmental protection and climate change modeling, exploring the measures for both environmental protection and abatement of climate change.

Involvement of the governments of China and U.S. – Participants recognized the value of participation by government officials in the workshop and express the need for government to continue to interact with the modeling community to identify the tools and methods for cooperation.

Additional Workshops

Participants recommended that at least one additional workshop be held possibly September, October, or November 1999 in Beijing. The Energy Research Institute agreed to circulate recommendations on the content, organization, and timetable of the workshop. Several participants believe that comparing results from an EMF-like modeling activity at the workshop would be useful.

Homepage and e-mail discussion group

- Jeff Logan agreed to set up a list-server courtesy of Battelle so that experts in China and the U.S. could communicate via e-mail more easily. A recommendation for publishing a technical journal on modeling issues was discussed and will be investigated further.
- Proceedings from the workshop will be published and posted on Battelle's China website (http://www.pnl.gov/china).

Conclusions of the Meeting

The collection of presentations and the discussions which ensued provided a very useful basis for future cooperation. Many of the participants were surprised at the number and quality of existing models and ongoing activities with application to China's economic and environmental policy issues. The workshop has resulted in a great deal of information exchange and detailed discussion which US and Chinese participants found extremely useful. Substantial capacity and expertise exists as represented by the experts present in the meeting, and it was clear that great progress has been made over the past few years in development of economic and environmental models. There was a clear consensus that this event should be the start of an ongoing effort to continue and expand technical cooperation of economic, environmental and climate policy modeling.

In addition to significant information exchange, which occurred in the Workshop, the group discussed a number of difficulties and limitations in modeling the Chinese economy and energy system. Even with recent progress, one of the central conclusions of the meeting was that the current models do not yet accurately capture the unique characteristics of China's domestic economy while accounting for the flow of capital, trade of carbon permits, and transfer of technology internationally. Existing models could be improved in a number of ways including incorporation of more recent input-output table data sets, improvement in the ability to model international flows of capital and carbon permits, and the ability to account for the hybrid structure of the Chinese economy. Further work by researchers in both countries is needed to improve these critical features.

Many, if not all of the critical limitations of existing models can be addressed more effectively through cooperative efforts in addition to the activities of individual modeling groups. This includes, very importantly, coordination and cooperation across the various modeling groups working in China, as well as coordination with and among US and other international experts.

The group identified research needs and developed recommendations for future technical cooperation. Recommendations include

- Continue and expand joint efforts to facilitate communication and information flow among Chinese modelers and between US and Chinese experts to address all of the issues identified in the discussion of future work and others which may be added as the process continues. Specific electronic information approaches and additional workshops were recommended as discussed above.
- A major focus of cooperation in the near term should be common efforts to address data development needs which affect all of the models
- A second major focus should be on joint efforts to develop systematic detailed documentation of models and conduct sensitivity analysis and model comparisons to improve understanding of the similarities, differences and development needs of various models.

List of Attendees

China Economic and Environmental Modeling Workshop
Friendship Hotel, Beijing, China
18-19 January 1999

Name	Organization
Sun Cuihua	Department of Region Economy Development, State Development Planning Commission of China (SDPC)
Li Liyan	Department of Region Economy Development, SDPC
Ma Aimin	Department of Region Economy Development, SDPC
Zhai Fan	Development Research Center, State Council of China
Li Shantong	Development Research Center, State Council of China
Chen Wenyin	Climate Change Research Center, Tsinghua University
Zhang anling	Clean Technology Research Center, Tsinghua University
Tan Yan	Institute of Nuclear Energy and Technology, Tsinghua University
Liu Dengqing	Institute of Nuclear Energy and Technology, Tsinghua University
Wang qiwen	Institute of Economy Management, Beijing University
Li Xue	Institute of Economy Management, Beijing University
Ma Gang	Institute of Quantitative & Technical Economics, Chinese Academy of Social Sciences (CASS)
Guo Jinlong	Institute of Quantitative & Technical Economics, CASS
Zhu Yunfa	Institute of Quantitative & Technical Economics, CASS
Chen Ping	Institute of Quantitative & Technical Economics, CASS
Yang Xinxing	Climate Impact Research Center, Chinese Academy of Environmental Sciences (CAES)
Ren Zhenhai	Climate Impact Research Center, CAES
Ma Yuqing	Institute of Technology & Economy, Tsinghua University
Zhao Xiusheng	Tsinghua University
Zhang Yanlin	Tsinghua University
Zhou Ruping	Tsinghua University
Zhang Jie	Climate Change Research Center, Tsinghua University
Su Mingshan	Institute of Technology & Economy, Tsinghua University
Liu Bin	Institute of Nuclear Energy and Technology, Tsinghua University
Liu Deguang	Climate Change Research Center, Tsinghua University
Hu Min	Environment Center, Beijing University
Hu Jianxin	Environment Center, Beijing University
Huang Tao	Institute of Economy Management, Beijing University
Lei Ming	Institute of Economy Management, Beijing University
Wang Bangzhong	State Meteorological Administration of China
Xu Yugao	Institute of 21st Century Development , Tsinghua University
Lin Erda	Agricultural Meteorological Institute, Chinese Academy of Agriculture Sciences (CAAS)
Zhang Wan	Agricultural Meteorological Institute, CAAS
Li Zehui	Commission for Integrated Survey of Natural Resources, Chinese Academy of Science (CAS)
Li Guo	Atmospheric Physics Institute, CAS
Zhou Dadi	Energy Research Institute (ERI)
Shi Yingyi	Beijing Energy Efficiency Center
Hu Xiulian	Energy and Environment Research Center, ERI
Jiang Kejun	Energy and Environment Research Center, ERI

Cui Cheng	Energy and Environment Research Center, ERI
Liu Jingru	Energy Efficiency Center, ERI
Zheng Shuang	Energy and Environment Research Center, ERI
Hu Xiaoqiang	Energy and Environment Research Center, ERI
Zhu Xiaojie	ERI
Liu Chuang	Commission for Integrated Survey of Natural Resources, CAS
Lu Xianfu	Commission for Integrated Survey of Natural Resources, CAS
Wang Wanxing	Beijing Energy Efficiency Center, ERI
Yan Lin	Institute of Quantitative & Technical Economics, CASS
Cheng Jing	Commission for Integrated Survey of Natural Resources, CAS
Zhao Yiru	Commission for Integrated Survey of Natural Resources, CAS
Xue Xinmin	ERI
Zhu Yuezhong	ERI
Geng Zhicheng	ERI
Zhang Jianming	ERI
Zhang Xiaoquan	Chinese Academy of Agriculture Science
Paul Schwengels	U.S. Environmental Protection Agency
Jae Edmonds	Pacific Northwest National Laboratory
Phillip Tseng	U.S. Department of Energy
Robert Shackleton	U.S. Environmental Protection Agency
Dale Jorgenson	Harvard University
Mun Ho	Harvard University
Jeffrey Logan	Pacific Northwest National Laboratory
Richard Garbaccio	U.S. Environmental Protection Agency
Ron Sands	Pacific Northwest National Laboratory
Chi Zhang	Stanford University
Robert Boynton	U.S. Embassy, Beijing
David Hathaway	ICF Kaiser Consulting Group

Workshop Agenda

China Economic and Environmental Modeling Workshop

Friendship Hotel, Beijing, China
18-19 January 1999

Agenda

Note: Most presentation sessions have an additional 15 minutes for questions/discussion

Monday, January 18th
8:30 - 9:00 Welcome and Opening Remarks, Zhou Dadi and Paul Schwengels

9:00-10:30
Zhou Dadi: Thoughts on climate policy (30 minutes)

Paul Schwengels: Overview of U.S. Climate Policy Modeling and Decision-Making (45 minutes)

10:30-10:45 Break

10:45-12:30
Jae Edmonds: Climate Change and Economic Modeling (45 minutes)

Dale Jorgenson: The Jorgenson-Wilcoxen Model of the U.S. and its use for Policy Making (45 minutes)

12:30-14:00 Working Lunch: Topic: Building a Collaborative Community of Economic Modelers in China

14:00 - 15:30
Phillip Tseng: The Application of MARKAL-MAKRO Model in the Analysis of Reducing Carbon Emissions (45 minutes)

Jiang Kejun: Post Kyoto: Analysis from AIM (30 minutes)

15:30-15:45 Break

15:45-17:00
Bob Shackleton: The G-cubed Model (60 minutes)

17:00-17:15
Wrap Up: Zhou Dadi

Tuesday, January 19th

9:00 - 10:45
Richard Garbaccio and Mun Ho: A CGE Model for Analyzing CO_2 Emissions Reduction Strategies in China (60 minutes)

Li Shantong: Modeling Activities in the DRC (30 minutes)

10:45-11:00 Break

11:00-12:15
Jiang Kejun and Ron Sands: The China Second Generation Model (60 minutes)

12:15-14:00 Lunch

14:00 - 15:45
Ma Gang: Impact of Carbon Tax and CO_2 Abatement on the Chinese Economy: A Static CGE Analysis (30 minutes)

Hu Xiulian: Modeling Demands for Energy and Environment in China (30 minutes)

Xu Deying: Impact of Elevated Carbon Dioxide on Chinese Forests (30 minutes)

15:45 - 16:00 Break

16:00 - 16:45 Discussion to reach consensus and conclusions

16:45 - 17:00 Wrap Up: Zhou Dadi and Paul Schwengels

Presentation Material

Presentations from each of the speakers listed below are contained in the corresponding Appendix. Full presentation material is also available on Battelle's web site at: *http://www.pnl.gov/china/*

Note: Battelle does not take responsibility for the accuracy or format of the material found in these Appendixes.

Appendix A - Paul Schwengels: Key Issues in US Economic Modeling and Climate Change Policy

Appendix B - Jae Edmonds: Climate Change and Economic Modeling

Appendix C - Phillip Tseng: The Application of MARKAL-MACRO Model in the Analysis of Reducing Carbon Emissions

Appendix D - Li Shantong: Modeling Activities in the Development Research Center

Appendix E - Robert Shackleton: The Economic Effects of International Carbon Emissions Trading Under the Kyoto Protocol: What We Have Learned From the G-Cubed Model

Appendix F - Richard Garbaccio and Mun Ho: A CGE Model for Analyzing CO_2 Emissions Reduction Strategies in China

Appendix G - Jiang Kejun: Post Kyoto: Analysis from AIM

Appendix H - Ron Sands and Jiang Kejun: *The China Second Generation Model*

Appendix I - Ma Gang: Impact of Carbon Tax and CO_2 Abatement on Chinese Economy: A Static CGE Analysis

Appendix J - Hu Xiulian and Jiang Kejun: Modeling Demands for Energy and Environment in China