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ANALYSIS OF MACROECONOMIC POLICY IN INPUT-OUTPUT ECONOMICS

—Experiences in Modelling National Economy—

Edited by

Toshiaki HASEGAWA

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Preface

This volume is the proceedings of Symposium on the Analysis and Issues of Macroeconomic Policy in Input-Output Economics : -Experiences in Modelling National Economy-held on September 4 th, 2010, Surugadai Memorial Hall, Chuo University. The program of symposium was organized by **Dr. Clopper Almon**, *INFORUM, University of Maryland* and **Toshiaki Hasegawa**, team coordinator of *CHERP, Research Unit of Asia Economic Area, Institute of Economic Research, Chuo University*. Dr. Almon with Hasegawa organized the program and served the role of chairs in the symposium.

The theme of symposium was "the Analysis and Issues of Macroeconomic Policy in Input-Output Economics : -Experiences in Modelling National Eco nomy-". The speakers for this symposium were invited from the major countries where the multisectoral macroeconomic models have been constructed and applied to their various economic issues. All paper contributors have the rich experiences in constructing the interindustry based macroeconomic models.

Also, they including Hasegawa share the common inheritance using the dynamic method of input-output analysis developed by Dr. Clopper Almon. INFORUM approach by Clopper Almon as an apprentice of the late Dr. Wassily Leontief was a solution to approach to the forecasting method in a dynamic context.

The papers presented in the symposium covers the various issues such like the indirect taxes in the multisectoral macroeconomic models, the regional economic integration, the international leakage of environment, environment in NAMEA, the scenario analysis toward the future economic development and the tax policy related to oil industry as follows :

Maurizio Grassini, *Dipartimento di Studi sullo Stato, University of Florence* :

"Indirect Taxes in Multisectoral Macroeconomic Models"

The treatment of **Indirect Taxes (IT)** in a **Multisectoral Macroeconomic Model (MMM)** described in this paper is based mainly on the data provided by the Italian Statistical Institute (ISTAT). In order to focus on the empirical basis for modeling indirect taxes in an MMM, Grassini focused on the Use table at purchasers' prices together with the excise taxes and the value added taxes matrices. He explains the table at basic prices removing (stripping off) the matrices of IT to distinguish between excise taxes (indirect taxes related to the quantities of commodities and services) and ad valorem taxes (as the Value Added tax which characterizes the fiscal system of the European Union Member States).

Grassini accentuates the difference between the impacts of excise taxes and Ad valorem taxes. The former reveals a net shifting effect. Since the 'shifting effect' of each single tax rate is no longer measurable in terms of analytical formula but only through simulation exercises, excise and ad valorem taxes should not be treated together.

Josef Richter, *University of Innsbruck, Faculty of Economics and Statistics, Department of Economics*:

"Analyzing the economic implication of joining the European Union for Austria-Lessons learned from a modelling perspective"

The prototype Austrian model built in 1971 was the first INFORUM type model outside the United States. Richter's paper reviewed the experience and the background of constructing **AUSTRIA IV model** to analyze the economic consequences of full participation of Austria in European integration. The model of AUSTRIA IV distinguished 48 industries and product groups respectively, and extended to the macroeconomic implications in a bottom up level.

The analysis carried out two alternative simulations up to the year 2000. "Full participation scenario" and the alternative "Outsider position scenario" for Austria were compared. Then, the economic implication of joining the EU for Austria was simulated for the specific aspects introduced. From the review of AUSTRIA IV's modelling project, he shows that model provided a framework to integrate all the detailed investigations into industry specific effects, and the overall effects on an industry. The model was thus able to identify winners and losers much better than the isolated studies. On the other hand it proved that all the calculations were carried out and presented in the statistical environment well-known to users.

Douglas S. Meade and Douglas E. Nyhus, *Inforum*:

"Using the Inforum LIFT and Mudan Models to Investigate the Impacts of Cap and Trade Legislation on International Leakages"

The paper by Meade and Nyhus introduced the Inforum **LIFT model** of the U. S., the **Mudan model** of China, and the Inforum Bilateral Trade Model (BTM) to examine the question of the differential impacts on U. S. trade leakages associated with the adoption of a carbon price in the U. S. The Inforum LIFT model of the U.S. economy at a detailed level of 90 industries, and the Inforum Mudan model of China at the level of 59 industries are linked along with other Inforum international models, in the Bilateral Trade Model, BTM. BTM model converts import demands of each country into the exports of bilateral trading partners. They compare the several scenarios for the U. S.; the **reference case** was developed that embodied "business as usual" assumptions for both the U.S. and China, the **second case** was developed where the U.S. adopted the major features of the Waxman-Markey legislation, but China did not adopt any similar policy, and the **third and fourth cases**, China did adopt a carbon tax, though not exactly the same as that of the U.S. **Furthermore, the** revenue recycling mechanism chosen for China was different from that assumed for the U.S.

Li Shantong, Liu Yunzhong, Xu Zhaoyuan and He Jianwu, *Development Research Center, the State Council, China*:

"Prospect of Economic Growth in China from the Twelfth Five-Year Plan Period to the Year 2030"

Reform and opening over the past 30 years in China has achieved a remarkable economic development. They adopt the scenario analysis method to analyze the economic prospects during the coming 12 th Five-Year Plan period through the next 20 years, when China will face to increasing pressure from resources and environment, as well as growing constraints as a result of the extensive and uncoordinated development mode.

For this purpose, Shantong et al. utilized a CGE model of the Chinese economy developed by the Development Research Center of the State Council of China (**DRC-CGE**). This model is recursive dynamic. It simulates the dynamic characteristics of economic development between 2008 and 2030 by solving a series of static equilibrium, at the level of 41 production sectors. The base year of the model is 2007. The model is calibrated to the 2007 Chinese Social Accounting Matrix (SAM) developed from the 2007 input/output tables.

They made simulations with three types of scenarios; Baseline, the quicker transformation of development pattern scenario and the slower transformation of development pattern scenario.

Mariusz Plich, *University of Lodz, Poland*:

"Experiences in Modelling National Economy"

NAMEA; the National Accounting Matrix including Environmental Accounts, originally developed by Statistics Netherlands in the end of the 1980 s is a framework in which economic and environmental data are consistently organized. NAMEA not only shows the integrated summary picture of economy-environment interface, also allows analytical investigations based on statistical, econometric as well as input-output approach. Polish NAMEAs developed for the period 1995-2006 by KASHUE, prepared in the form required by Eurostat have still the quality problem. For this reason, the author in his analysis introduced his own estimates of NAMEAs. In this paper, Mariusz Plich presents the design of NAMEAs for Poland and discusses the macro-economic policy and its modelling in the framework of I-O analysis.

NAMEA was used to show the strength of the pressure on global warming represented by GWP and on acidification by PAE indicator. In addition, multiplier analyses based on input-output techniques shows the different influences between energy industry and others. Based on the results of the analysis of structural changes on sectoral output and emission factors taken from the NAMEA, for the period 1993-2005, the study concluded the differences between the impact of structural change and the changes in emission factors.

A. Shirov and A. Yantovsky, *Russian Academy of Sciences, Russia*:

"Tax policy in Russian oil sector-Input-Output approach"

The current model of economic development at the Institute of Economic Forecasting of Russian Academy of Science (IEF RAS) is constructed in the framework of traditional inter-industry models. Specifically, the model characterizes the Russian economy depended on the energy sector highly. Although the Russian energy sector produces a quarter of Russian GDP, the investment budget has relatively low portions in the whole economy.

There are contradictions between government and entrepreneurs, because the former pursuit at the general macroeconomic and budgetary purpose, and the latter aim at the economic efficiency for their specific business.

This paper by A. Shirov and A. Yantovsky simulates the optimal level of investment to maintain the sustainable production. Also, the authors consider the necessary change of tax system in oil sector which is consistent to the macroeconomic context. The analysis of macroeconomic consequences of oil sector's taxes change covers the **Direct links:** effects of increase of industrial and investment activity in oil sector; **Interindustry links:** expansion of manufacturing and change of incomes in sectors connected with oil industry; and **Effects from additional incomes:** distribution of additional incomes in favor of the households, the government and fixed capital investments.

Finally, we cordially express our appreciation to the Institute of

Economic Research, Chuo University, especially to Dr. Michihiro Otonashi, Director of IER for giving the benefit to hold the symposium. In addition, PAPAIOS (Pan-Pacific Association of Input-Output Studies) and Graduate School of Economics, Chuo University, were very helpful as cosponsors of this symposium. PAPAIOS served us to send the members as the panelists and other participants. We also express our appreciation to Shuntaro Shishido, Hikaru Sakuramoto, Hiroyuki Kosaka, Satoshi Inomata, Masaaki Kuboniwa for their cooperation as the panelists.

Toshiaki Hasegawa
Professor of International Economics,
Coordinator of CHERP Team, Chuo University
E-mail : vinomac@tamacc.chuo-u.ac.jp

Contributors

as Organizers and Chairs

Clopper Almon, INFORUM & Professor Emeritus of Department of Economics, University of Maryland, U. S. A.
Toshiaki Hasegawa, Faculty of Economics, Chuo University, Japan

as Paper Contributors :

Maurizio Grassini, Dipartimento di Studi sullo Stato, University of Florence, Italy
Josef Richter, University of Innsbruck, Austria
Douglas Meade, INFORUM, University of Maryland, U. S. A.
Douglas E. Nyhus, INFORM, University of Maryland, U. S. A.
Jeff Werling, INFORM, University of Maryland, U. S. A.
Li Shantong, Development Research Center, the State Council, China
Xu Zhaoyuan, Development Research Center, the State Council, China
He Jianwu, Development Research Center, the State Council, China
Mariusz Plich, Department of Theory and Analyses of Economic Systems, University of Lodz, Poland
Alexander Shirov, Institute for Economic Forecasting, Russian Academy of Sciences, Russia
Alexey Yantovsky, Institute for Economic Forecasting, Russian Academy of Sciences, Russia

as Panelists :

Norihisa Sakurai, Central Research Institute of Electric Power Industry (CRIEPI), Japan
Shuntaro Shishido, Research Institute of World Econometric Modelling and Analysis, Japan
Hikaru Sakuramoto, Faculty of Business and Commerce, Keio University, Japan
Hiroyuki Kosaka, Faculty of Policy Management, Keio University, Japan
Satoshi Inomata, JETRO Institute of Developing Economies (IDE), Japan
Masaaki Kuboniwa, Institute of Economic Research, Hitotsubashi University, Japan

Indirect Taxes in Multisectoral Macroeconomic Models

Maurizio Grassini
Dipartimento di Studi sullo Stato, University of Florence, Italy

1. Introduction

The treatment of Indirect Taxes (IT) in a Multisectoral Macroeconomic Model (MMM) described in this paper is based mainly on the data provided by the Italian Statistical Institute (ISTAT).

At present, each European Union Member State must prepare and deliver input-output tables to EUROSTAT using the method described in "Eurostat Manual of Supply, Use and Input-Output Tables" (Eurostat, 2008)[1]. These IO tables have the same industry-commodity disaggregation so that any comparison of European Countries is direct.

Using the framework established by Eurostat, each EU Member State Statistical Bureau develops its own disaggregation in compiling input-output tables. This disaggregation may relate to the number of industries and/or commodities according to standard European classification systems (NACE Rev. 1 for industry and CPA for products)[2]. In addition to the mandatory Supply and Use tables, several other tables may be provided by a Country's Statistical Bureau. In the following paragraphs, the treatment of IT in an MMM has been developed on the basis of several supplementary tables supplied by the Italian Statistical Bureau (ISTAT).

2. The data

Indirect tax data are provided by the Ministry of Finance. The tax disaggregation is generally related to tax bases which do not exactly match the product/-industry Use table. So, Statistical Bureau researchers, who are committed to constructing Supply and Use tables, 'allocate' tax revenues among the flows of the Use table. Such a task could be done by any researcher operating in the field, but the know-how of the information and

1) European Union Member States Input-output tables are available in the 'Statistics data' on the Eurostat website (http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/)
2) For references, see Richter in this volume.

input-output table constructors is rarely found outside the National Statistical Bureau.

Intermediate and final demand flows in Use tables at purchasers' prices contain domestic and imported commodities and services and include trade margins, transport margins, indirect taxes on the product (excise and *ad valorem*) and subsidies on the product[3]. These flows, margins and taxes can be arranged in matrices to numerically establish the relationship between purchasers' prices and basic prices as described in Heiling, Richter and Richter (this Volume).

Here, in order to focus on the empirical basis for modeling indirect taxes in an MMM, the Use table at purchasers' prices together with the excise taxes and the value added taxes matrices have been considered.

3. IT in the Use table at purchasers' prices.

Let us define

q_{ij} is the real flow of input i in sector j
C_i is the amount of product i absorbed by the final demand
q_i is the total output of sector i ($\Sigma_j q_{ij}+C_i=q_i$)
p_i is the price of the product of sector i
$X_{ij}=q_{ij}*p_i$ is the nominal value of input i in sector j
$C_i=c_i*p_i$ is the nominal value of product or service of sector i absorbed by the final demand
s_{ij} is the amount of excise tax on product or service i used by sector j
s^i is the amount of excise tax on the i-th component of final demand
v_{ij} is the amount of value added tax on input i in sector j
v^i is the amount of value added tax on the i-th component of final demand

Considering the content of the excise taxes and the value added taxes matrices, the intermediate consumption flow in the Use table at purchasers' prices may be defined as $X_{ij}+s_{ij}+v_{ij}$; likewise, the i-th component of the final demand is defined as $C_i=s^i+v^i$.

Once a Use table is accompanied by matrices such as those of indirect tax yields, modeling the impact of taxation on MMM price formation requires 'stripping off' procedures and a corresponding reallocation of tax revenues. The implication of such a procedure on modeling the impact of indirect taxes

3) Here, indirect taxes and subsidies on production are not treated. These taxes are located in the value added section of the Use table.

in an MMM will be shown separately for excise taxes and *ad valorem* taxes.

Using the aforementioned notation, the excise taxes (tax as a specific amount of money per unit of quantity of a good or service) are allocated in a Use table such as the one shown in Table 1 where a sectoral detail related to 3 sectors is given as an example.

Table 1. Intermediate and final demand flows showing the excise tax burden.

	IC1	IC2	IC3	FD	TO	TO
IC1	$q_{11}^{*}p_1+s_{11}$	$q_{12}^{*}p_1+s_{12}$	$q_{13}^{*}p_1+s_{13}$	$c_1p_1+s^1$	$q_1^{*}p_1+s_{11}+s_{12}+s_{13}+s^1$	TO_1
IC2	$q_{21}^{*}p_2+s_{21}$	$q_{22}^{*}p_2+s_{22}$	$q_{23}^{*}p_2+s_{23}$	$c_2p_2+s^2$	$q_2^{*}p_2+s_{21}+s_{22}+s_{23}+s^2$	TO_2
IC3	$q_{31}^{*}p_3+s_{31}$	$q_{32}^{*}p_3+s_{32}$	$q_{33}^{*}p_3+s_{33}$	$c_3p_3+s^3$	$q_3^{*}p_3+s_{31}+s_{32}+s_{33}+s^3$	TO_3
VA	VA_1	VA_2	VA_3			
Output	$q_1^{*}p_1$	$q_2^{*}p_2$	$q_3^{*}p_3$			
excise	$s_{11}+s_{12}+s_{13}+s^1$	$s_{21}+s_{22}+s_{23}+s^2$	$s_{31}+s_{32}+s_{33}+s^3$			
TO	TO_1	TO_2	TO_3			

Key: IC=Intermediate Consumption. FD=Final Demand. TO=Total Output as row sum of the flow. Output stands for output in nominal value net of IT. Excise is the tax burden for the amount of money per unit of quantity of a good or service

In Table 2, the flows of Table 1 are re-arranged after removing the excise tax burdens from intermediate consumption and final demand. The removal of excise taxes along the rows enables us to establish the fact that the sectoral and final demand inputs are equal to the total output net of IT for each sector. But the removal of excise tax flows implies an excise tax row in the value added sector of the table.

Table 2. The table net of excise tax

	IC1	IC2	IC3	FD	TO	TO
IC1	$q_{11}^{*}p_1$	$q_{12}^{*}p_1$	$q_{13}^{*}p_1$	c_1p_1	$q_1^{*}p_1$	TO_1
IC2	$q_{21}^{*}p_2$	$q_{22}^{*}p_2$	$q_{23}^{*}p_2$	c_2p_2	$q_2^{*}p_2$	TO_2
IC3	$q_{31}^{*}p_3$	$q_{32}^{*}p_3$	$q_{33}^{*}p_3$	c_3p_3	$q_3^{*}p_3$	TO_3
VA	VA_1	VA_2	VA_3			
excise	$s_{11}+s_{21}+s_{31}$	$s_{12}+s_{22}+s_{32}$	$s_{13}+s_{23}+s_{33}$	$s^1+s^2+s^3$		
Output	$q_1^{*}p_1$	$q_2^{*}p_2$	$q_3^{*}p_3$			
TO	TO_1	TO_2	TO_3			

The removal of *ad valorem* tax burdens is very similar to the case of excise tax shown above. In Table 3, intermediate consumption and final demand include the *ad valorem* tax burden. In Table 4, *ad valorem* taxes are removed from intermediate consumption and final demand.

Table 3. Intermediate and final demand flows showing *ad valorem* taxes

	IC1	IC2	IC3	FD	TO	TO
IC1	$q_{11}{}^*p_1+v_{11}$	$q_{12}{}^*p_1+v_{12}$	$q_{13}{}^*p_1+v_{13}$	$c_1p_1+v^1$	$q_1{}^*p_1+v_{11}+v_{12}+v_{13}+v^1$	TO_1
IC2	$q_{21}{}^*p_2+v_{21}$	$q_{22}{}^*p_2+v_{22}$	$q_{23}{}^*p_2+v_{23}$	$c_2p_2+v^2$	$q_2{}^*p_2+v_{21}+v_{22}+v_{23}+v^2$	TO_2
IC3	$q_{31}{}^*p_3+v_{31}$	$q_{32}{}^*p_3+v_{32}$	$q_{33}{}^*p_3+v_{33}$	$c_3p_3+v^3$	$q_3{}^*p_3+v_{31}+v_{32}+v_{33}+v^3$	TO_3
VA	VA_1	VA_2	VA_3			
Output	$q_1{}^*p_1$	$q_2{}^*p_2$	$q_3{}^*p_3$			
vat	$s_{11}+s_{12}+s_{13}+v^1$	$s_{21}+s_{22}+s_{23}+v^2$	$s_{31}+s_{32}+s_{33}+v^3$			
TO	TO_1	TO_2	TO_3			

Table 4. The table net of *ad valorem* tax

	IC1	IC2	IC3	FD	TO	TO
IC1	$q_{11}{}^*p_1$	$q_{12}{}^*p_1$	$q_{13}{}^*p_1$	c_1p_1	$q_1{}^*p_1$	TO_1
IC2	$q_{21}{}^*p_2$	$q_{22}{}^*p_2$	$q_{23}{}^*p_2$	c_2p_2	$q_2{}^*p_2$	TO_2
IC3	$q_{31}{}^*p_3$	$q_{32}{}^*p_3$	$q_{33}{}^*p_3$	c_3p_3	$q_3{}^*p_3$	TO_3
VA	VA_1	VA_2	VA_3			
vat	$v_{11}+v_{21}+v_{31}$	$v_{11}+v_{21}+v_{31}$	$v_{11}+v_{21}+v_{31}$	$v^1+v^2+v^3$		
Output	$q_1{}^*p_1$	$q_2{}^*p_2$	$q_3{}^*p_3$			
TO	TO_1	TO_2	TO_3			

In both cases, after the removal of IT from intermediate consumption and final demand, part of IT taxes will hit final demand components; they do not therefore act as a 'cost push' factor in generating 'producers' prices'. These taxes act as a bridge between producers' prices and purchasers' prices.

4. From tax revenues to tax rates in modeling price formation

The excise taxes (or tax as a specific amount of money per unit of quantity of a good or service) are equal to a (nominal) tax rate applied to quantities (commodities or services). In Table 1, s_{ij} —the amount of excise on q_{ij} —is equal to α_{ij} times q_{ij}, where α_{ij} is the tax rate applied to the amount of q_i used in sector j.
Table 2 contains the following identities:

$$q_{11}{}^*p_1+q_{21}{}^*p_2+q_{31}{}^*p_3+q_{11}{}^*\alpha_{11}+q_{21}{}^*\alpha_{21}+q_{31}{}^*\alpha_{31}+VA_1=q_1{}^*p_1$$
$$q_{12}{}^*p_1+q_{22}{}^*p_2+q_{32}{}^*p_3+q_{12}{}^*\alpha_{12}+q_{22}{}^*\alpha_{22}+q_{32}{}^*\alpha_{32}+VA_2=q_2{}^*p_2$$
$$q_{13}{}^*p_1+q_{23}{}^*p_2+q_{33}{}^*p_3+q_{13}{}^*\alpha_{13}+q_{23}{}^*\alpha_{23}+q_{33}{}^*\alpha_{33}+VA_3=q_3{}^*p_3$$

These identities represent the basis of a Leontievian price with 'excise taxes'. Introducing the standard technical coefficient aij = qij / qj , the equation system becomes

$$a_{11}{}^*p_1+a_{21}{}^*p_2+a_{31}{}^*p_3+a_{11}{}^*\alpha_{11}+a_{21}{}^*\alpha_{21}+a_{31}{}^*\alpha_{31}+va_1=p_1$$
$$a_{12}{}^*p_1+a_{22}{}^*p_2+a_{32}{}^*p_3+a_{12}{}^*\alpha_{12}+a_{22}{}^*\alpha_{22}+a_{31}{}^*\alpha_{32}+va_2=p_2$$
$$a_{13}{}^*p_1+a_{23}{}^*p_2+a_{33}{}^*p_3+a_{13}{}^*\alpha_{13}+a_{23}{}^*\alpha_{23}+a_{31}{}^*\alpha_{33}+va_3=p_3$$

with $va_i=VA_i/q_i$ as the value added per unit of output.
In matrix notation, the price system can be written as follows:

$$\begin{bmatrix}(1-a_{11}) & -a_{21} & -a_{31}\\ -a_{12} & (1-a_{22}) & -a_{32}\\ -a_{13} & -a_{23} & (1-a_{33})\end{bmatrix}\begin{bmatrix}P_1\\P_2\\P_3\end{bmatrix}=\begin{bmatrix}a_{11}{}^*\alpha_{11}+a_{21}{}^*\alpha_{21}+a_{31}{}^*\alpha_{31}+va_1\\ a_{12}{}^*\alpha_{12}+a_{22}{}^*\alpha_{22}+a_{32}{}^*\alpha_{32}+va_2\\ a_{13}{}^*\alpha_{13}+a_{23}{}^*\alpha_{23}+a_{33}{}^*\alpha_{33}+va_3\end{bmatrix}$$

The term in right hand side is a vector which can be split into two vectors as follows:

$$\begin{bmatrix}a_{11}{}^*\alpha_{11}+a_{21}{}^*\alpha_{21}+a_{31}{}^*\alpha_{31}+va_1\\ a_{12}{}^*\alpha_{12}+a_{22}{}^*\alpha_{22}+a_{32}{}^*\alpha_{32}+va_2\\ a_{13}{}^*\alpha_{13}+a_{23}{}^*\alpha_{23}+a_{33}{}^*\alpha_{33}+va_3\end{bmatrix}=\begin{bmatrix}a_{11}{}^*\alpha_{11}+a_{21}{}^*\alpha_{21}+a_{31}{}^*\alpha_{31}\\ a_{12}{}^*\alpha_{12}+a_{22}{}^*\alpha_{22}+a_{32}{}^*\alpha_{32}\\ a_{13}{}^*\alpha_{13}+a_{23}{}^*\alpha_{23}+a_{33}{}^*\alpha_{33}\end{bmatrix}+\begin{bmatrix}va_1\\va_2\\va_3\end{bmatrix}$$

Therefore, the solution of the price equation can be seen as decomposed into two parts: one term is determined by the value added per unit of output and the other term is determined by the amount of indirect taxes on inputs. The component determined by the value added per unit of output may be named 'price net of IT'

$$\begin{bmatrix}P_1\\P_2\\P_3\end{bmatrix}_{\text{net of IT}}=\begin{bmatrix}(1-a_{11}) & -a_{21} & -a_{31}\\ -a_{12} & (1-a_{22}) & -a_{32}\\ -a_{13} & -a_{23} & (1-a_{33})\end{bmatrix}^{-1}\begin{bmatrix}va_1\\va_2\\va_3\end{bmatrix}$$

and a component due to the impact of excise taxes on price formation may be named 'tax shift'

$$\begin{bmatrix}P_1\\P_2\\P_3\end{bmatrix}_{\text{tax shift}}=\begin{bmatrix}(1-a_{11}) & -a_{21} & -a_{31}\\ -a_{12} & (1-a_{22}) & -a_{32}\\ -a_{13} & -a_{23} & (1-a_{33})\end{bmatrix}^{-1}\begin{bmatrix}a_{11}{}^*\alpha_{11}+a_{21}{}^*\alpha_{21}+a_{31}{}^*\alpha_{31}\\ a_{12}{}^*\alpha_{12}+a_{22}{}^*\alpha_{22}+a_{31}{}^*\alpha_{32}\\ a_{13}{}^*\alpha_{13}+a_{23}{}^*\alpha_{23}+a_{31}{}^*\alpha_{33}\end{bmatrix}$$

where the tax shifting effect is very clear, so that in the case of excise taxes, the price can be seen as

$$\begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix}_{\text{excise}} = \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix}_{\text{net of IT}} + \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix}_{\text{tax shift}}$$

Tables 1-4 show that the allocation of excise and *ad valorem* taxes in a Use table is similar. Modeling the impact of ad valorem taxes is very different. In a cell of intermediate consumption in Table 3, v_{ij} is the amount of *ad valorem* tax on $q_{ij}{}^*p_{i;}\beta_{ij}=v_{ij}/q_{ij}{}^*p_i$ is the tax rate which generates the tax yield v_{ij}. The flow of intermediate consumption takes the form

$$q_{ij}{}^*p_i+v_{ij}=q_{ij}{}^*p_i(1+_{;}\beta_{ij})$$

In the absence of excise taxes, the price equations with *ad valorem* taxes are

$$\begin{aligned} a_{11}{}^*p_{1^*}(1+\beta_{11})+a_{21}{}^*p_{2^*}(1+\beta_{21})+a_{31}{}^*p_{3^*}(1+\beta_{31})_++va_1=p_1 \\ a_{12}{}^*p_{1^*}(1+\beta_{12})+a_{22}{}^*p_{2^*}(1+\beta_{22})+a_{32}{}^*p_{3^*}(1+\beta_{32})_++va_2=p_2 \\ a_{13}{}^*p_{1^*}(1+\beta_{13})+a_{23}{}^*p_{2^*}(1+\beta_{23})+a_{33}{}^*p_{3^*}(1+\beta_{33})_++va_3=p_3 \end{aligned}$$

and in matrix notation

$$\begin{bmatrix} (1-a_{11}*[1+\beta_{11}]) & -a_{21}*[1+\beta_{21}] & -a_{31}*[1+\beta_{31}] \\ -a_{12}(1+\beta_{12}) & [1-a_{22}*(1+\beta_{22})] & -a_{32}*[1+\beta_{32}] \\ -a_{13}*[1+\beta_{13}] & -a_{23}*[1+\beta_{23}] & [1-a_{33}*[1+\beta_{33}]] \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} = \begin{bmatrix} va_1 \\ va_2 \\ va_3 \end{bmatrix}$$

The solution of these price equations requires the inverse of the matrix of the price coefficients. Each element of this matrix is a nonlinear function of all the above price coefficients so that a separation of the price net of IT from the shifting component due to IT, as shown above for the excise taxes, is no longer viable.

It is a matter of fact that excise and ad valorem taxes come hand-in-hand. Furthermore, *ad valorem* taxes are applied to tax bases which include the burden of excise taxes. To calculate this effect, it is more useful to look at a single price equation (out of a system of n equations) which can be written as follows

$$p_j=\Sigma_{i=1,n}(a_{ij}+\alpha_{ij})^*p_i{}^*(1+\beta_{ij})+v_j \quad j=1,n$$

The *ad valorem* tax applied to the value of intermediate consumption, which includes the excise tax, makes it impossible to separate the effects of the taxes.

The price equation becomes more intricate with the division of each intermediate consumption flow into domestic and imported: $a_{ij}=a_{ij}{}^d+a_{ij}{}^m$. The first is related to the domestic price; the second to the import price (together with the rate of exchange).

The Leontievian price equation without IT but with the distinction between domestic and imported commodities and services is

$$p_j = \Sigma_{i=1,n}\, a_{ij}^{d} * p_i + \Sigma_{i=1,n}\, a_{ij}^{m} * p_i^{m} + v_j \quad j=1, n$$

where p_i^m is the import price of input i.

Now the coefficients of the domestic prices are the 'domestic inputs per unit of output'. The solution of these equations differs from the system of equations above because of the coefficients of the domestic prices and the composition of the constant terms. Once the IT are introduced into the structure of these equations, the indirect taxes will have an effect on the constant terms as well. In fact, the constant term of each equation is composed of the value added per unit of output and by the intermediate imported input per unit of output; the latter component embodies the effect of IT as the corresponding domestic component.

5. Conclusions

The treatment of IT in an MMM has been shown within a 'stripping off' approach on the basis of data on IT (matrices) provided by the Italian Statistical Institute (ISTAT). The approach may be defined top down; it starts from the Use matrix at purchasers' prices and move towards the table at basic prices removing (stripping off) the matrices of IT. These matrices distinguish between excise taxes (indirect taxes related to the quantities of commodities and services) and *ad valorem* taxes (as the Value Added tax which characterizes the fiscal system of the European Union Member States)[4].

The impact of excise taxes reveals a net shifting effect. Ad valorem taxes generate effects which cannot be separated out in the framework of a system of price equations belonging to an MMM. Once excise and ad valorem taxes are treated together, the 'shifting effect' of each single tax rate is no longer measurable in terms of analytical formula but only through simulation exercises.

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4) European Value Added Tax (VAT) has been designed to be 'transferred' to final users; producers should be not charged this indirect tax; the application of European VAT has been subject to a number of exemptions (originally named' impurities') so that the VAT recorded on Intermediate consumption flows is the so-called non-deductible VAT. This Indirect Tax and its peculiarities related to price formation in an MMM is described in Bardazzi, Grassini, Longobardi (1991), Bardazzi, Grassini (1993) and Grassini (2001). A short and incisive description of the consequences of this IT on input-output table is in Almon (2008).

The distinction between domestic and imported inputs transfers part of the effect of IT to the constant term; of course, it is possible to measure the 'shifting effect' on the constant term of the equation system, but no relevant analytical insight is gained for evaluating the impact of IT on prices.

Not all IT are located among intermediate consumption and final demand flows. In fact, indirect taxes on production are recorded in the value added section of the Use tables. Policy simulations concerning these indirect taxes entail the design of specific value added per unit of output scenarios.

The design of scenarios concerning IT (excise and ad valorem) is an important task which follows the estimation of the price equations system. Once the estimated price equations are embodied in an MMM, the policy simulation maker must shift his attention to what is behind the construction of the IT matrices provided by the National Statistical Bureau.

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Analyzing the economic implication of joining the European Union for Austria

—Lessons learned from a modelling perspective

Josef Richter
University of Innsbruck, Austria

1. Introduction

INFORUM modelling in Austria dates back to 1969 when Clopper Almon visited Vienna. The first—very simple—prototype Austrian model was build during a visit to College Park, Maryland in summer 1972. It was the first INFORUM type model outside the United States.

Work on an input-output model for Austria was initiated as a joint effort of social partners (Trade Unions, Chamber of Labor, Economic Chamber) and the Central Bank. Later on the work was continued in the Statistical Department of the Federal Economic Chamber, an organization under public law. The different versions of the Austrian INFORUM model were used by the Economic Chamber for two purposes: To provide service to the Chamber's members and in order to carry out policy evaluation.

For two decades the Austrian INFORUM model was primarily used for corporate planning purposes by enterprises. Managers were aware that for many of their decisions they need a consistent year-by-year medium-term forecasts taking all the interdependencies between the various parts of an economy into account and providing a sufficient sectoral disaggregation. Managers were also very much interested in all kinds of sensitivity analyses in order to assess the risk of decisions with far reaching consequences.

The creation of the international family of interlinked INFORUM models was of special interest for export oriented industries. Given the size of the Austrian economy decision makers in enterprises were considerably more interested in international than in domestic markets.

The Austrian INFORUM models were also used for a number of policy related exercises. The analysis of the economic consequences (on the global as well as on the sectoral level) of joining the Single European Market was by far the most relevant application. The Single European Market in Europe became effective on January 1, 1993.

Because of a referendum (on whether Austria should join the European Union (EU) or not) it was essential to provide evidence on which industries might be the winners and which industries the losers of such a step. The results of the simulations carried out with the help of the INFORUM model were widely published and were also included in "semi-official" publications of the Austrian government (RICHTER 1993).

The referendum was held on June 12, 1994 and resulted in a clear majority in favor of joining the EU (66.6% pro with a very high participation rate of 82.5%). Austria became an EU member state on January 1, 1995.

2. Analyzing the economic implication of joining the EU

Model used

The simulations were carried out with the Austrian member of the INFORUM family of interlinked dynamic multisectoral models, called AUSTRIA IV. At this stage (1992, early 1993) the model distinguished 48 industries and product groups respectively. Like all model of this type the approach was strictly "bottom-up". All the macro variables were derived from data on the industry or product level by aggregation. Much emphasis was laid on a consistent and detailed empirical basis of the model.

The model AUSTRIA IV already consisted of a demand side and a price side model. These submodels were solved in an iterative procedure to arrive at a consistent solution for quantities and prices without relying on any calibration or scaling procedures[1)].

The demand side model was relatively detailed as regards the modelling of private consumer expenditure (distinguishing 59 consumer goods and treating consumption of Austrians in Austria separately from consumption of foreign tourists in Austria) and imports.

The price model was based on the "cost-push philosophy" treating domestically produced products and imported products separately. As regards wages and salaries a distinction was made between sheltered and non-sheltered industries. The input-output coefficients were considered variable over time and modelled separately. Because of the institutional background and the close cooperation with most of the big enterprises in Austria it became possible to make use of a lot of engineering information on future changes in technologies.

At the time the scenarios were carried out AUSTRIA IV had the status of a satellite to the INFORUM family. Austrian exports on the level of product groups were modelled as the weighted results of import demand resulting from the other models, Austria's import prices were also taken

1) For a description of the basic philosophy behind INFORUM models see among others ALMON (1991), ALMON (1995) and GRASSINI (2001).

from the INFORUM consortium and used in relation to the domestic prices to model the market shares of imported goods versus domestically produced goods on a very detailed level.

The satellite status implied that the feedback from Austria to the "Rest of the World" was neglected. In the case of such a little economy like the Austrian this seems to be an acceptable simplification (see RICHTER 1991).

AUSTRIA IV was an annual model allowing for ex -ante simulations up to 10 to 15 years paying attention to the adequate modelling of the time path.

Design of the scenarios

The analysis was done by comparing the results of two alternative simulations up to the year 2000. The first scenario was based on the assumption of joining the EU and a full participation of Austria in the process of European integration (called "Full participation scenario"). The alternative scenario ("Outsider position scenario") rested on the hypothesis that Austria has to remain in an outsider position.

For Europe and the "Rest of the World" both scenarios relied on the results of the "Europe without borders scenario" which was estimated with the interlinked system of INFORUM models other than Austria (for details see CHRISTOU, NYHUS 1994).

Main aspects covered by the "Full participation scenario"

○ Adoption of the common EU tariffs
  The changes to the common tariffs were not very big, but quite different by product groups
○ Removal of border control
  Increase in labor productivity in exporting industries and in particular in the transportation industry
○ Adoption of the common agricultural policy of the EU
  Many product specific changes as regards prices and quantities
○ Adoption of the public procurement policy
  More competition in "public markets" leading to some reduction in prices
○ More competition in trade and services
  Considerable reduction of margins, increase in labor productivity affecting prices of many products in particular on the level of retail prices
○ Reduction of the price discrimination across borders
  In particular relevant for a number of consumer durables and investment goods.
○ Deregulation of services
  More competition across borders with price effects

○ Improved conditions for tourism
○ Moderate positive effects on labor supply
○ Increase in economies of scale
More competition and reduction of monopoly power; in this respect the same assumptions were used as in the simulations by CHRISTOU and NYHUS (1994) for the Single Market.

Main aspects covered by the "Outsider position scenario"
○ "Business as usual"—none of the assumptions made for the "Full participation scenario"
○ Deterioration of Austria's position as a location for foreign direct investment in particular coming from the US and Japan
○ Moderate administrative discrimination against Austrian exporters

3. Economic implication of joining the EU for Austria —Results of the computations

Fifteen years after Austria joined the EU the few results presented in this chapter are of historical interest only. They are included in order to illustrate some of the methodological aspects of the analyses. The two tables presented were taken from RICHTER (1994).

Table 1 shows the percentage deviations of the results of the "Full participation scenario" from the results for the "Outsider position scenario". In general terms it was possible to conclude that the participation in the common market leads to a somewhat higher level of economic activity, a more pronounced division of labor across borders, a slight increase in employment and a remarkable lower price level for consumers.

Table 1. Percentage deviation of macro-results after 8 years (2000) Full-participation scenario versus Outsider scenario

Private consumer expenditure	
Austrians in Austria	5.4
Foreigners in Austria (tourism)	4.6
Government consumption	4.2
Gross capital formation	5.5
Exports	2.7
Imports	4.5
GDP	4.3
Employment	0.7
Consumer prices	−5.1

In broad terms these global findings were consistent with results obtained with the help of macro-models such as the one by BREUSS and SCHEBECK (1991).

As might be seen from Table 2 the various industries were affected in a quite different way. Joining the EU does by no simply imply additional proportional growth. The sensitivity of the output of industries with respect to "Joining" and "Not-joining" was found to be quite different and some of the findings were at least at a first glance a little bit surprising.

The most unexpected result was perhaps that consumer-oriented industries were more affected than export-oriented branches. This outcome was attributed to the important effects of liberalization on consumer prices. More competition in some of the food industries and in trade led to a lower price level for many consumer goods and had a strong positive impact on real disposable income of private households. As a consequence consumption of goods with high income/and or high price elasticities was stimulated.

Table 2 only shows the tip of the iceberg. Structural change was found to be much more pronounced on a more detailed level. This was in particular shown for consumer expenditures which were broken down by 59 consumer items.

The pattern of effects was also quite different for other variables, such as employment. Despite the overall positive effect lower employment was calculated for a number of industries in the "Full participation scenario". One of theses industries was trade, whereas output of trade was higher in the "Full participation scenario", indicating higher labor productivity in this case.

Table 2 Percentage deviation of output after 8 years (2000)
Full-participation scenario versus Outsider scenario

1 Agricultural products	2.2
2 Mining	2.8
3 Crude oil, refining	2.5
4 Non-metallic mineral products	5.4
5 Cement	5.2
6 Glass	2.6
7 Meat	1.9
8 Milling products	−0.5
9 Bakery	3.5
10 Sugar	1.5
11 Dairy products	3.7
12 Other food	5.5
13 Beverages	2.7

14 Tobacco	−1.9
15 Textiles	2.0
16 Clothing	3.1
17 Leather and shoes	3.5
18 Chemical products	4.9
19 Iron and steel	1.4
20 Machinery	2.0
21 Ships and locomotives	5.0
22 Foundries	4.5
23 Non-ferrous metals	2.0
24 Metal products	4.5
25 Precision machinery	0.9
26 Electric motors, etc.	3.3
27 Electric wires and cables	5.0
28 Other electrical products	3.9
29 Radio and TV	2.5
30 Vehicles	0.9
31 Repair	2.1
32 Sawmill products	2.0
33 Plywood	4.1
34 Furniture	3.7
35 Paper	2.5
36 Paper products	1.4
37 Printing and publishing	5.4
38 Construction	5.2
39 Installation, maintenance	4.9
40 Electricity	3.7
41 Gas, water	5.9
42 Trade	4.3
43 Transportation, communication	6.3
44 Banking, insurance	6.5
45 Hotel, restaurants	3.9
46 Other services	5.7
47 Real estate	5.3
48 Public services	4.1
Total	4.1

To have information on the different time paths (not shown here) was considered to be very interesting and relevant. According to the simulations some of the effects occurred more or less immediately after joining the EU, other effects (such as the ones induced by the implications on real disposable income) were only identified with a certain lag.

4. Lessons learned from a modelling perspective

Working on a detailed level

Most of the initial effects of participation in the EU were very industry or commodity specific.

The effects of the adoption of the common EU tariffs for example were very small on the overall level, but visible and quite different by product groups. The initial effect was on the prices of imported goods. The availability of detailed import matrices was of high importance to model these initial effects on intermediate costs and final demand prices.

The removal of border control affected only exporting industries and in particular the transportation industry. The shares of across the border activities by industries were available from the detailed input-output framework.

The switch to the common agricultural policy of the EU meant the removal of trade barriers and a number of product specific changes as regards prices and quantities. It was possible to make use of very detailed studies in the direct implications of joining the EU for agriculture and forestry (PUWEIN 1989, SCHNEIDER 1989).

The adoption of the public procurement policy only affects some very specific products and services, such as construction. More competition leads to some price reductions and to an increase of market shares of imports but also to additional export chances for the products and services involved. In this context it was assumed that the lower prices which government will face will not be used to reduce public deficit but rather be used to buy more products and services.

Based on a detailed study on trade (GUGER, POLLAN, WÜGER 1990) the hypothesis was that more competition in trade will lead to a considerable reduction of trade margins, an increase in labor productivity and to lower prices of many products in particular on the level of retail prices. Again this information to be incorporated was very industry (margins, productivity) and product specific (prices).

Joining the EU also meant that consumers and investors now can buy directly abroad with less administrative difficulties. The elimination or reduction of the price discrimination across borders was however limited to a number of consumer durables such as household appliances and cars and a few investment goods. It was assumed that because of this new possibility also the prices of these commodities on the domestic market will be lowered.

The improved conditions for tourism were directly fed into the system of consumption equations for foreign tourism in Austria. It has always been a special property of the Austrian INFORUM models that private consumer expenditures of Austrians were treated separately from private consumer expenditures of foreigners in Austria.

Very moderate changes in prices because of the deregulation of services were also introduced exogenously. In addition market shares of selected imported services on domestic markets and exports of services were slightly increased.

As these few examples illustrate it proved essential to have a very detailed framework in order to identify the commodities (often the transactions) or the industry facing the initial effect. The detailed framework (often much more detailed than the model itself) also facilitated "educated guesses" as regards the order of magnitude of the initial shock induced by joining the EU.

Taking the interdependencies into account

A number of investigations on branch specific effects of joining the EU were available when the simulations were carried out. Many of them were very rich in information and detail. On the other hand all of them concentrated on initial effects seen in an isolated way and were necessarily limited to what might be called "first round implications".

In order to study the overall and sectoral effects of these initial shocks a tool such as AUSTRIA IV capable of quantifying both the demand and the price effects in a consistent way (on the sectoral level and taking the main interdependencies in an economy into account) was needed.

As might be seen from the design of the scenarios many of the initial shocks affected the prices of imported and of domestically produced goods. The effects were either direct effects as in the case of a change in tariffs or indirect effects induced by an increase in labor productivity forwarded to the prices. If the products which are faced with initial price effects are used in the domestic production process the costs and the prices of all the domestically produced commodities will be altered according to the shares of imported and domestically produced inputs in the cost structures of these commodities.

The price side of the INFORUM model allowed calculating these effects, taking all the interdependencies in the production process into account. In addition the changes in prices of imported commodities delivered to final demand without domestic transformation had to be considered and incorporated in the calculations. They have implications for the price level of consumption and capital formation.

The price effects induced repercussions on the demand side. Private consumer expenditures (by products) for example are dependent on real income and relative prices. As a consequence a change in the relative price structure will result in a change in the level and structure of private consumer expenditures. In AUSTRIA IV the market shares of imported goods were dependent on the relation between prices of domestically produced goods and prices of imported goods. Any change in these relations thus led to an increase or decrease in import demand. Changes in prices also affected macro-variables such as real disposable income, a major driving force of consumer expenditure.

Changes in the demand structure resulted in implications on the price side. Changes in the output due to changes in the structure of final demand and to changes in the import share matrices led to different levels of employment and wages and salaries by industries, which in turn affected prices.

As this extremely simplified description of major dependencies illustrates a model which consists of a demand side and a price side and in which the price side and the demand side “interact” is required to arrive at a consistent solution.

Such a system is also indispensable for arriving at an overall picture because many of the initial effects work in different directions. Parts of agricultural production for example were influenced by the adoption of the European agricultural policy in a negative manner. On the other hand the more favorable conditions for tourism created additional demand for agricultural products in restaurants. Demand for food and agricultural products by residents was also influenced by the changes in relative prices and the increase in purchasing power.

Paying attention to the time path

Some of the initial effects and a number of the induced effects became effective within a rather short period. Other repercussions such as the effects caused by an increase in real disposable income on purchases of durables, the feedback of a reduced inflation on wages, the effects of an increase in activity levels on capital formation, were however distributed over a longer time horizon.

Because AUSTRIA IV was based on sets of econometrically estimated behavioral equations which also included lags of all kind, it was possible to model the time path of effects properly. As GRASSINI (2007) has put it: INFORUM models are explicitly dynamic, the models strictly refer to calendar time, each solution is related to a specific year.

Need for a detailed and coherent international background scenario

For a small and open economy like Austria it was of high relevance that it was possible to base the analysis on the 'Europe without borders scenario' provided by the INFORUM family of interlinked dynamic input-output models.

At the same time as Austria also Sweden and Finland became members of the EU. The effects of this "1995 enlargement" were not incorporated into the analyses, which must be seen a certain shortcoming of the exercise.

The direct implications of the accession of Sweden and Finland on the Austrian economy were probably not very important. The indirect effects of this enlargement on the economies of major trading partners such as Germany, France and Italy (and thus on the Austrian economy) might have been more relevant. BARDAZZI and GRASSINI (2004) have shown for the case of Italy and the Eastern EU enlargement that the indirect effects via major trading partner might be considerably higher than the direct effects.

The "1995 enlargement" was neglected in both of the scenarios in the Austrian exercise. The effects on the comparative analysis of the two simulations were therefore (probably) not very big.

Sound empirical basis

For assessing a problem of high political relevance it was seen essential to establish a sound empirical basis and to make use of all the relevant information available from the Austrian statistical system.

More resources were dedicated to going into all the details of National Accounts and to guarantee a coherent data basis than were devoted to very sophisticated estimation procedures.

AUSTRIA IV (as many other INFORUM models) can be characterized as "data driven" and not as "theory driven". The model relied much more on "as we know from empirical evidence" than on "as we know from literature". In the case of AUSTRIA IV this accent on data rather than on estimation techniques was even more pronounced than in the case of other models.

Identity based modelling

Closely related to the necessity to have a coherent data basis was the idea to build the model around the basic identities in both "layers" of National Accounts. AUSTRIA IV relied on the identities of total supply and total demand as included in the input-output framework as well as on the identities described in the sector accounts. In the sector accounts institutionally defined units are grouped together into five mutually exclusive institutional sectors which together make up the total economy. A model which also includes sector accounts covers the production sphere and the income, redistribution, expenditure and financing side of the economy.

In the Austrian model at least the sector “Private households” was modelled explicitly thus providing the bridge between incomes generated in the production process and disposable income of households.

Need for a software which allows flexibility in scenario writing

INFORUM models like AUSTRIA IV make use of the parameters of behavioral equations estimated on the basis of time series.

In the case of running simulations of the kind described above it was essential to incorporate the exogenous shocks which often meant that some of the equations had to be modified in a well-defined way. To introduce such kinds of information and to control the process is not an easy task.

Interdyme, the INFORUM software turned out to be ideal for this purpose. Interdyme (see for example ALMON 2008) has three types of fixes to do this job, for macro variables, for vectors and matrices, and even for industry outputs. The software offers possibilities to override the result of the equation with the value of a time series given, to add an exogenously given value to the results coming from the equation, to multiply the equation's results by a specified factor, to adjust the constant term of the equation, to define the relation of a equation's results to some other variable, just to mention a few of the options.

Meeting users’ needs

From the users’ perspective two properties of the simulations were considered as very advantageous.

On the one hand the model provided a framework to integrate all the detailed investigations into industry specific effects available[2] into a coherent framework. In quite a number of cases it turned out that the overall effects on an industry — taking all the major interdependencies into account — were quite different from the initial effects on which the industry specific studies (necessarily) were concentrating. The model was thus able to identify winners and losers much better than the isolated studies.

On the other hand it proved very important for the use in the political discussion that an INFORUM model is by no means a ‘black box model’. All the calculations were carried out and presented in the statistical environment well-known to users. All the equations were firmly rooted in the statistical

2) Among many others the studies by CZERNY (1993), GUGER, POLLAN, WÜGER (1990), KATTERL (1993), MISCHKULNIG (1993), PUWEIN (1989), SCHNEIDER (1989), SMERAL (1993), STANKOVSKY (1990), SZOPO (1990) and WÜGER (1993) belong to this group.

material available for Austria.

In order to test the robustness of results a number of sensitivity studies were carried out, the results of which were made available to decision makers. All calculations were performed in a stepwise procedure always adding an additional set of assumption to the scenario. Although the final results were not independent of the sequence chosen, this approach helped to make users familiar with the “mechanisms” of the model and to shed some light on the relative importance of the various sets of assumptions. In addition the model results were complement by a documentation showing the main sources of deviations of results between the two scenarios.

5. Conclusions

The use of a simple INFORUM type model like AUSTRIA IV for assessing the economic consequences—on a global and on a sectoral level—of the full participation of Austria in the process of European economic integration clearly showed the advantages of such a modelling approach for this type of analysis. It is not surprising that other (and often much more elaborated) INFORUM models were used for similar problems. The investigation into the effects of a Mexico-USA Free Trade Agreement (ALMON, RUIZ-MONCAYO, SANGINES 1991), on the implications of the Common Market on the Spanish economy (COLLADO 1992), on the effects of a Japan-Korea Free Trade Area (HASEGAWA, SASAI, IMAGAWA 2001) and on the effects on the Eastern enlargement of the EU on the Italian economy (BARDAZZI, GRASSINI 2004) are examples of such applications.

The use of such models is however not limited to study the effects of economic integration. Such models are mighty tools in particular for analyzing the consequences of shocks and political measures affecting only one or a few groups of commodities or one or a few industries. The implications of such shocks can be examined in a consistent manner in their effects on other goods or industries as well as on the whole economy. By disaggregating the economy in some detail and by modelling the interdependencies between the various industries and products, INFORUM models extend the analytical potential of macroeconomic models considerably.

From a user’s perspective such models are indispensable if one is not only interested in macro-totals. The sectoral disaggregation permits the detailed analysis of the outcomes of political measures and shocks of all kind.

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Using the Inforum *LIFT* and *Mudan* Models to Investigate the Impacts of Cap and Trade Legislation on International Leakages

Douglas S. Meade and Douglas E. Nyhus
Inforum, University of Maryland, U. S. A.

Background

In the last two years, various policy initiatives have been drafted with the goal of putting a system in place for reducing U. S. carbon emissions. Most of these initiatives have incorporated some form of cap and trade system, whereby a given number of emissions allowances are marketed by the government to emitters, and a market price for the emission of carbon dioxide is established. Under certain simplifying assumptions, such a cap and trade system is equivalent to the imposition of a carbon tax, but with the advantage that the market sets the value of the allowances according to the marginal cost curves of the producers who must reduce their emissions.

An interesting and politically relevant question with regard to cap and trade is the effect of the carbon price on "international leakages". These leakages are the effect of higher export prices of U. S. goods that require energy inputs that use carbon, either directly or indirectly, which will lead to a reduction of U. S. exports. Imports to the U.S. may increase due to the increased relative cost of domestic goods compared to goods produced in other countries without an emissions reduction system, such as China.

Our study uses the Inforum *LIFT* model of the U. S. Economy, the *Mudan* model of the Chinese economy, and the Inforum Bilateral trade model to assess the leakages associated with the adoption of a carbon price in the U. S. This paper begins the analysis by comparing several scenarios for the U. S. The first scenario is the base case, based on the *Annual Energy Outlook* (AEO) 2009 "Stimulus" case, produced by the Energy Information Administration (EIA). In this scenario, the reference case is also used for Mudan, which assumes no price is imposed on carbon emissions. The second scenario assumes implementation of certain key features of the Waxman-Markey (WM or HR 2454) legislation. In this scenario, we still assume that China does not price carbon emissions. In Scenario 3, we assume that China does price carbon, but does not try to establish the price at the same level as the U. S.

price[1]. The revenue obtained by the Chinese government is recycled in the form of tax relief, to keep the China scenario roughly deficit-neutral. Finally, in Scenario 4, China also prices carbon, but the revenue is distributed as a combination of tax relief and increased health care spending. This paper discusses the implementation of these scenarios and reviews the results, including the U. S. trade impacts in the different cases. This paper focuses on effects of the legislation from the U. S. perspective, but we also discuss some of the policy issues and choices from the Chinese perspective.

The Inforum *LIFT* model is ideally suited for an analysis such as this since it models the U. S. economy at a detailed level of 90 industries. Effects of carbon taxes on industry prices are explicitly modeled in the cost structure of each industry. A carbon tax raises the cost of energy inputs, such as electricity, petroleum and natural gas. Each industry can pass some portion of these costs on in the form of higher prices, which may lead to a reduction in competitiveness. *LIFT* also models imports and exports at this 90 industry level, and both import and export equations make use of the ratio between foreign and domestic prices for each commodity. *LIFT* models the U. S. economy annually, showing the dynamic response to policy and price changes, and is capable of making projections out to 2050[2].

The Inforum *Mudan* model of China is similar to the *LIFT* model, but has industry detail for 59 industries. Energy consumption detail has recently been enhanced for a study looking at energy consumption in China under various scenarios. The *Mudan* model will be adopted for the current study to analyze the price effects of carbon taxes in China.

Mudan and *LIFT* are linked, along with other Inforum international models, in the Bilateral Trade Model. This model converts import demands of each country into the exports of bilateral trading partners, using an econometrically estimated equation for each country/commodity pair that uses relative exchange rate adjusted price and relative growth in industry specific investment in each country.

We begin by summarizing the main components of the proposed Waxman-Markey legislation. We then describe the development of the base case for the U. S. *LIFT* model, which is calibrated to the *Annual Energy Outlook* (AEO) 2009 Stimulus case. The next section describes the main assumptions adopted in the modeling of the Waxman-Markey legislation, and provides an overview of results. Here we only compare the reference case

1) The price of carbon is determined so as to reduce emissions consistent wit China's stated goals, and is actually set higher than the U. S. price.
2) For calibration to the AEO, we are of course limited to the AEO forecast horizon. For the AEO 2009, this was 2030.

("Case 1") with the case where the U. S. prices carbon but China doesn't ("Case 2"). The next section discusses how the adoption of carbon pricing in China changes the results, and compares the differential effects of the two forms of revenue recycling. The final section concludes, and discusses how a similar framework could be adopted to analyze different cap and trade policies, as well as the calibration to newer versions of the AEO and the extension of the modeling horizon. The *LIFT* model, *Mudan* model and Bilateral Trade Model are described in more detail in appendices to this paper.

Summary of the Proposed Waxman-Markey Bill

There have been many proposed bills for reducing carbon emissions in the U. S. At the time this study was initiated, the Waxman-Markey bill was being considered by Congress. The Waxman-Markey legislation (H.R. 2454) is also known as the American Clean Energy and Security Act (ACESA) of 2009. This legislation has 4 major titles:

1. **Clean Energy**: This title includes stimulus for renewable power generation, carbon capture and sequestration (CCS), clean transportation, smart grid investments and nuclear power.
2. **Energy Efficiency**: This title includes incentives for improving building efficiency (lighting and appliances) and transportation efficiency.
3. **Reducing Global Warming**: This is the title that includes the cap and trade system with allowance allocation, banking of allowances and offsets.
4. **Transition Issues**: This title consists of two major provisions: A) "I nslee/Doyle Provisions" or output-based rebates to Energy-Intensive Trade Exposed (EITE) industries, and B) "Green Jobs" or worker transition assistance.

Not all elements of the proposed legislation were modeled in *LIFT*. In the next section we discuss the development of the AEO 2009 base case in *LIFT*, and the following section describes how selected elements of the Waxman-Markey legislation were incorporated into the Waxman-Markey scenario.

Development of the AEO Base Case with the LIFT Model

The *LIFT* model was calibrated to be consistent with the AEO 2009 Stimulus case. This was done in two stages. In the first stage, industry variables, macroeconomic variables, and IO coefficients were modified to produce a macroeconomic forecast consistent with the AEO. In the second stage, imports, exports, personal consumption expenditures and IO coefficients were modified to calibrate energy and carbon projections from the AEO. For this study, the *LIFT* projections were made to 2030, which is the same forecast horizon used in AEO 2009.

The following table provides an outline of the general calibration strategy, but the final version required several iterations of these steps. The general strategy is based on the goal of getting the exogenous variables

Population and labor force	Population projections are made by detailed age group in *LIFT*, and participation rates by age group can be fixed by assumption. However, total population and labor force can also be set exogenously.
Government spending	Government spending in *LIFT* is composed of many small components, which are adjusted to control to the total government spending shown in the AEO.
Exports	In this study exports were endogenous. In other words, the export equations based on forecasts of foreign demands and foreign competing export prices. However, we applied add factors to exports to bring the total in line with the AEO.
Crude oil price, natural gas price and coal price	The price in *LIFT* is specified as a nominal price index. AEO presents these prices in real terms, i.e., divided by the GDP deflator. Once the path of the GDP deflator has settled down, this assumption can be fine-tuned.
Personal consumption	The real personal consumption total can be specified exogenously to *LIFT*. However, this takes away much of the model's behavioral responses. So, while it may be helpful to fix total personal consumption at first, before we are done we need to take this assumption off, and guide personal consumption total to its target, through a combination of hitting the real disposable income target, and changing the personal savings rate.
Investment	The AEO macro table only shows the total investment figure. In *LIFT* this is the sum of equipment investment, residential structures investment and nonresidential structures investment.
Total Imports	In *LIFT*, imports are the sum of imports of about 90 commodities. Individual equations relate these imports to domestic demand for that commodity, and relative domestic to foreign import prices. Imports are calibrated to the AEO base through aggregate modifiers.
Imports of Crude Oil	Imports can also be adjusted by targeting the import share of domestic demand. This is often a useful method for calibrating imports of crude oil. Given the domestic requirements for crude oil, the import share variable specifies the share of that demand that will be imported.
Labor Productivity Growth	Aggregate labor productivity growth in *LIFT* is essentially a weighted average of productivity growth by industry. The *LIFT* labor productivity equations are time trend equations with a cyclical component to model pro-cyclical labor productivity.
Employment and Unemployment	Employment is also calculated in *LIFT* at the industry level, based on output, productivity, and average hours worked per employee. Since employment and productivity trends are integrally related, it is useful

	modifications to employment. The aggregate unemployment rate can also be calibrated by altering the multiple job adjustment, which relates industry employment to household employment.
Energy Consumption, Energy/GDP ratios	Energy consumption can be traced in the *LIFT* model at several different levels. Energy consumed in final demand includes personal consumption of gasoline, heating oil, natural gas and electricity; government purchases of fuels and electricity, and energy consumed in building residential and nonresidential structures. Energy flows in the intermediate demand part of the model include industrial consumption of energy for space heat and light, stationary power sources, transportation fuels, and electricity for many uses. These flows also include the conversion of energy from one type to another, such as the refining of crude oil into petroleum products, and the generation of electricity from coal and other fuel sources. The main objective when measuring energy use to GDP is not to double-count, but to measure only net flows of energy.
Nominal and Real Disposable Income	The AEO shows a projection for real disposable income only. Real disposable income in *LIFT* is determined by first building up personal income from its pieces (labor compensation, dividends, net interest, p roprietors' income, transfer payments, etc.) and then removing personal taxes to obtain nominal disposable income. Nominal disposable income is then divided by the aggregate consumption deflator to obtain real disposable income. To calibrate real disposable income, we need to adjust components of personal income and the personal tax rate.
GDP Price Level and Inflation	The aggregate GDP price level in *LIFT* is determined as a combination of all commodity prices, including of course exogenous prices such as those for crude oil and coal. These prices are used to calculate final demand in current prices. The sum of all final demands equals GDP, and the price level is obtained simply by dividing nominal GDP by real GDP. We define inflation in *LIFT* as the first difference in logarithms of the GDP deflator, multiplied by 100. To target, or calibrate an inflation rate such as AEO, adjustments are made to the forecasts of several categories of value added by industry.

calibrated first, and then working down into further degrees of endogeneity.

Energy consumption by sector and by source is calibrated by mapping major sectors of the NEMS/AEO framework to industries and final demands in *LIFT*. For example, the NEMS Industrial sector includes industries 1 to 58 in *LIFT*. The NEMS Commercial sector includes industries 65, 68 to 88 plus government. The Residential sector corresponds to personal consumption expenditures for electricity, natural gas and heating oil. The Transportation sector maps to *LIFT* sectors 59 to 64 for commercial transportation activities, and to personal consumption of gasoline and oil for personal consumption. Sectors 66 and 67 are electric utilities and natural gas utilities, respectively.

Energy consumption by business is represented in *LIFT* in the intermediate sales block of the model. This consumption is calibrated by adjusting IO coefficients of energy products to energy-consuming industries, so that the total energy consumption by sector in real terms grows at the same rate as the energy consumption in AEO. For the personal consumption sector, which includes household energy use, and fuel for personal vehicles, a multiplicative factor is applied to the personal consumption equation in *LIFT* to match the AEO growth rate.

The electricity generation model is calibrated by first fixing the shares or levels of electricity generation by type (coal, gas, nuclear, etc.). The model can also be adjusted to model increased efficiency of generation from fuels (electricity produced from a unit of coal). The demand for fuels and other inputs from the electric power industry is then determined as a weighted sum of the inputs from the 8 types of power generation, to determine coal, gas and petroleum requirements.

The Main Assumptions for the Modeling of Waxman-Markey

The Waxman-Markey scenario was developed by starting with the AEO 2009 calibrated baseline, and then incrementally changing existing assumptions or adding new assumptions. These assumptions are described below.

Carbon allowance price. The *LIFT* model does not solve for the equilibrium carbon price. However, an exogenously derived price can be input as an assumption, and the price effects on energy sectors and energy-intensive sectors can be determined. Table 1 shows the assumed carbon price for selected years, in real and nominal terms.[3] This assumption was supplied to us by the DOE policy office, and is the price used in a parallel exercise using the Markal model.

Table 1. Carbon Price Assumption for Waxman Markey

	2008$	Nominal
2012	10.16	10.54
2015	13.21	15.01
2020	16.86	22.01
2025	21.40	31.21
2030	27.46	44.60

Changes in energy prices.

In order to avoid double-counting, the carbon tax was assumed to apply

3) The deflator used to calculate the implied nominal rate of tax was the GDP deflator forecasted in the AEO 2009 base case. The GDP deflator actually rises by about 1.3% in the Waxman-Markey tax simulation. However, no attempt was made to iterate to obtain consistency between the GDP deflator and the nominal carbon price.

to domestic and imported natural gas, coal and refined petroleum products. It was not applied to electricity, but electricity price rises due to the higher cost of fossil fuel inputs[4]. We leave the price of crude equal to that in the AEO 2009 base case.

In the Inforum model, prices satisfy the IO price identity:

$$P_d' = P_d' A_d + P_m' A_m + v'$$

where P_d = the domestic output price vector
P_m = the import price vector
A_d = the direct requirements matrix of domestic requirements
A_m = the direct requirements matrix of import requirements
v = nominal value added per unit of real output q

The value added vector v is comprised of 13 components of value added, one of which is taxes on production and imports, or indirect taxes. Energy taxes are modeled for this exercise as a separate vector of indirect taxes. Energy taxes increase the prices of energy products directly, but also cause an increase in the prices of all other products indirectly.

The amount of carbon associated with each energy product was determined during the calibration of the *LIFT* model to the AEO 2009. Table A-18 in the *Annual Energy Outlook* shows carbon emissions by sector and source[5]. These emissions were linked to energy consumption flows in *LIFT*. *LIFT* energy flows were first calibrated to Table A-2 (“Energy Consumption by Sector and Source”) and in several other tables[6], and then carbon emission coefficients were calculated to yield the carbon emission projections in AEO.

Note that *LIFT* maintains a full and consistent accounting for the price effects of the carbon tax, as well as the revenue generated, and the status of government receipts and expenditures.

Table 2 shows the impact of the carbon taxes on selected energy price variables. Of course, the largest difference is for coal (124% by 2030), which has a high carbon content per unit of value. The increase in the natural gas price by 2030 is also significant (18%). The gasoline price increases to a lesser

4) However, we do assume a change in generation mix due to the carbon price, so the electricity price does not increase as much as it would without reducing fossil fuel use.
5) Note that these are carbon dioxide emissions only.
6) Other tables that are used to calibrate *LIFT* include: A-4 Residential sector key indicators and consumption; A-5 Commercial sector key indicators and consumption; A-6 Industrial sector key indicators and consumption; A-7 Tranportation sector key indicators and delivered energy consumption; A-8 Electricity supply, disposition, prices and emissions; A-11 Liquid fuel supply and disposition; A-14 Oil and gas supply; A-15 Coal supply, disposition and prices; and A-20 Macroeconomic indicators.

extent (6.3%), with the increase in the electricity price slightly lower than this.

Table 2. Effects of the Carbon Tax on Selected Energy Prices

	Caol $/ton			Natural gas $/thous cu ft			Gasoline $/gallon			Electricity cents/Kwh		
	Base	Carbtax	% diff	Base	Carbtax	% diff	Base	Carbtax	% diff	Base	Carbtax	% diff
2012	29.80	49.83	67.2	5.49	6.09	11.0	2.82	2.93	4.0	9.50	9.88	4.0
2015	32.02	59.11	84.6	6.41	7.25	13.1	3.71	3.86	4.1	10.36	10.87	5.0
2020	35.79	71.57	100.0	8.74	9.95	13.9	4.78	4.97	3.9	11.98	12.62	5.3
2025	40.58	87.01	114.4	9.87	11.61	17.6	5.40	5.66	4.9	13.53	14.26	5.4
2030	45.55	102.44	124.9	12.86	15.20	18.2	6.21	6.60	6.3	15.63	16.47	5.4

Changes in industrial, commercial and residential energy consumption.

In the industrial and commercial sectors of the *LIFT* model, there are no price-responsive energy consumption equations. Energy demand in the intermediate part of the model is determined by IO coefficients. However, these IO coefficients can be made to respond to price, either through an implied or estimated demand function, or through the behavior of another model or study. For this iteration of the current study, we drew parallel simulations using Markal to inform the degree of price response. These changes were imposed as changes in the time path of IO coefficients.

The residential sector does have price-responsive demand equations, but these were overridden for the current study, to agree with the results suggested by Markal. Table 3 **below shows a summary of** the aggregate demand response by sector to the carbon-induced price changes. Detail is also available by type of energy used.

Table 3. Effects of the Carbon Price on Consumption by Sector

	Industrial			Commercial			Residential		
	Base	Carbtax	% diff	Base	Carbtax	% diff	Base	Carbtax	% diff
2012	31.56	31.10	−1.4	19.98	19.90	−0.4	21.38	21.32	−0.3
2015	31.37	30.23	−3.6	20.41	20.16	−1.2	21.29	21.07	−1.0
2020	31.59	29.86	−5.5	21.48	21.08	−1.8	22.32	21.89	−1.9
2025	32.10	29.89	−6.9	22.59	22.12	−2.0	23.03	22.31	−3.1
2030	31.35	28.41	−9.4	23.78	22.67	−4.6	24.01	22.49	−6.3

Changes in electric utility generation mix.

LIFT includes a disaggregation of the electric power sector into 8 types of generation. The total input-output column for electric power has been split into 8 columns, allocating the different types of fuel requirements according to energy supplying sector (coal, gas, oil). The nuclear, wind, solar and hydro have higher capital requirements.

The change in the mix of generation by type was made based on parallel runs done using the Markal model. The *LIFT* model then uses these shares to estimate fuel and other requirements from the electric power sector. For example, the sales of coal are much reduced. The effects of the carbon price are somewhat alleviated by the switch to less carbon-intensive modes of generation.

Table 4 shows the generation by type in each scenario, in billions of kilowatt hours. Note that total power generation is lower in the HR 2454 scenario due to reductions in overall electricity demand.

Table 4. Electric Power Generation Mix (Bil Kwh)

Base									
	Coal	Gas	Petroleum	Nuclear	Hydro	Wind	Solar	Geo & Oth	Total
2012	2069.2	568.7	42.4	815.0	264.7	188.3	1.4	99.1	4048.8
2015	2058.9	546.3	41.9	831.5	277.7	189.4	2.0	121.7	4069.3
2020	2086.3	597.1	43.6	876.3	277.8	189.4	2.2	163.3	4236.0
2025	2086.7	771.0	44.0	881.6	279.0	193.4	2.5	191.2	4449.5
2030	2198.5	826.5	45.0	890.1	278.8	193.2	2.8	199.7	4634.5
Waxman-Markey									
	Coal	Gas	Petroleum	Nuclear	Hydro	Wind	Solar	Geo & Oth	Total
2012	1939.7	568.4	43.6	817.8	275.0	187.3	1.4	158.7	3991.8
2015	1807.1	543.5	42.5	831.0	299.2	211.7	2.2	244.0	3981.3
2020	1670.0	582.7	41.6	876.0	299.7	278.9	3.3	352.4	4104.4
2025	1560.6	725.2	39.1	948.0	303.2	273.1	3.6	416.7	4269.5
2030	1378.6	744.3	34.1	1103.0	309.0	263.3	3.8	428.5	4264.6

Recycling of revenue.

The revenue collected from the marketing of allowances represents a net drain on the economy. In the absence of any revenue recycling, this puts strong downward pressure on macroeconomic aggregates such as GDP, real income and personal consumption. The substance of the HR 2454 legislation provides some guide as to how this revenue recycling may likely occur. In our modeling exercise, the recycling took the form of the following set of policy instruments:

- Personal tax rebates
- Assistance to industries: electric utility, petroleum refining, agriculture
- EITE industry assistance
- International transfers

■ Household rebates and subsidies

The total revenue collected was modeled by assuming how many carbon allowances are allocated, multiplied by the allowance price. Table 5 shows the assumptions used in this study for the number of carbon allowances issued, the domestic offsets used, banking of allowances and the resulting international offsets purchased. The bottom section of the table shows the revenue implications of these assumptions and results.

Table 5. Waxman-Markey Allowances Offsets and Banking

	2012	2015	2020	2025	2030
MMT					
Total carbon emissions	5598.9	5462.5	5265.7	5233.0	4919.4
Total number of credits issued	5551.0	5361.3	4906.2	4140.9	3380.5
Total domestic offsets	125.0	188.6	286.0	414.1	500.6
Annual banking of offsets	234.5	478.9	832.7	801.7	815.3
International offsets	157.4	391.5	906.2	1479.7	1853.6
Billions of Dollars					
Allowance revenue (to be distributed)	58.5	80.5	108.0	129.2	150.8
Domestic offsets payments	1.3	2.8	6.3	12.9	22.3
International offsets payments	1.7	5.9	19.9	46.2	82.7

Modeling Alternative Chinese Response to a U. S. Cap & Trade Policy

We assume that China starts implementing a carbon tax in 2010. The tax begins at 5 yuan per ton of CO 2 (approximately $.76/ton) and gradually rises to 130 yuan in 2015 ($23.68) 230 in 2020 ($44.76) and 350 by 2030 ($72.34)[7]. We have assumed that the yuan will appreciate from 6.83 per dollar today to 5.14 per dollar in 2020, and 4.84 by 2030. Since there is a direct relationship between tons of coal and CO 2 we are able to estimate the amount of the tax and the resulting increase in the price of coal to the ultimate users. The ultimate users see the high relative prices of coal (costs) and react by reducing their purchases. The reduced usage shows up as a reduction in tons used and that in turn lowers CO 2 emissions. The exact level of the tax was calibrated so that the combination of policies used (electrical generation and the tax) were able to reduce the ratio of CO 2 emissions to real GDP by 50% from the level in 2000, by 2020.

The amount of tax revenue generated can be quite large. A critical modeling question is to decide what the government will do with the carbon

7) These prices were derived as estimates of the level of carbon price required, along with investments in nuclear and renewable energy, to enable China to meets its energy and emissions goals.

tax revenue. Simply letting the revenue accrue to government savings will serve as a Keynesian drag on the economy, and result in a decrease in household income (higher prices for energy goods), high prices of exports and lower real GDP. We have postulated two possible courses of action, which both serve to recycle the revenue generated by the tax. The first is to reduce most indirect taxes and the other is to spend the money for social needs. Nearly 70% of government income comes from indirect taxes and rest about equally divided between social security and income taxes from persons. The second is to reduce personal income taxes and then use the remaining revenue on a massive improvement of health care across the country, particularly in the west and rural areas where about 350 million people are currently without any adequate health care. We have modeled both scenarios and they lead to somewhat different outcomes. One common feature of both scenarios is the reduction in personal income taxes.

Four sets of scenarios were run, as summarized in the following table. Each case consists of a U. S. *LIFT. model run, and China Mudan* model run, and a run with the Bilateral Trade Model, to model the impacts on world trade flows, as well as Bilateral U. S. China flows. The next section describes results from the U. S. side. The following section discusses the Mudan results when adopting the tax. After this, we return to the U. S. perspective to see the differential impacts of China adopting or not adopting a tax framework.

Summary of Modeling Cases

Case	Summary	Description
1	Reference	Neither country pursues a carbon tax or cap and trade system in this reference case.
2	US yes, China no	US pursues a cap & trade policy but China doesn't enact any policy.
3	US yes, China yes, with tax cuts	China fulfills plans to move its electrical generation capacity away from coal and towards nuclear and renewable sources, and also introduces a carbon tax. It reduces other indirect taxes (except those on tobacco and alcohol) and reduces personal income taxes such that the effect on the government budget is approximately neutral.
4	US yes, China yes, tax cuts & health care	China fulfills its electrical generation plans and introduces a carbon tax (same as case 3) and provides for personal income tax reductions. However instead of lowering other indirect taxes it uses the money on a massive improvement of health care across the country particularly in the west and rural areas where about 350 million people are currently without any adequate health care.

U. S. Modeling Results

A full set of modeling results are available for China, from the *Mudan* model. However, this part of the paper focuses on the impact of the carbon pricing and any resulting trade leakages from the U. S. perspective. From the U. S. side, we will begin by examining the differences between the reference case (Case 1) and the case where only the U. S. imposes a tax (Case 2).

Carbon dioxide emissions.

The *LIFT* model calculates carbon dioxide emissions by sector and source, based on the energy consumption by type of energy product in each industry, and assumed carbon emissions ratios to energy consumption by type[8].

Table 6 shows the emissions by sector and source in 2010, and then the estimated emissions in the base case and the Waxman-Markey case in 2030.

Table 6. Carbon Dioxide emissions by Sector and Source
(Million metric tons)

		Base (Case 1)	Waxman-Markey (Case 2)
	2010	2030	2030
Residential	398	374	336
Commercial	223	233	229
Industrial	927	1004	886
Transportation	1903	2021	1928
Electric Power			
Petroleum	46	41	31
Natural Gas	317	361	302
Coal	1931	2199	1196
Other	11	11	11
Total electric power	2305	2612	1540
Total Economy	5755	6244	4919
Carbon Dioxide Emissions			
(tons per person)	18.5	16.6	13.1
(tons per million$ GDP)	500.1	324.3	256.2

8) For this study, the carbon emissions ratios used were for aggregate sectors. However, a more detailed set of emissions data and ratios is currently being developed, in conjunction with the Department of Commerce.

Note that even in the base case, although the total emissions are rising from 2010 to 2030, emissions per person have fallen, from 18.5 tons to 16.6 tons, a decline of 10.3%. Emissions to real GDP also decline, from 500 tons per millions $ GDP to 324.3 tons, a decline of 35.2%. These declines in the base case are due mainly to the following three factors:

1. Increasing energy efficiency of the industrial, commercial and transportation sectors, and a reduction in residential energy use.
2. A shift away from coal in electric power generation.
3. Sectoral shifts from energy/carbon intensive sectors to sectors that are less energy/carbon intensive[9].

In the Waxman Markey (Case 2), there is a further decline in emissions, to 13.1 tons per person (29.2% decline) and to 256.2 tons per million$ GDP (48.8% decline). These changes from the base case are also due to an intensification of the same 3 factors listed above which were already changing over time in the base. Efficiencies in response to higher energy costs have accelerated, the electric power sector has shifted even further away from fossil fuels (especially coal) than in the base case, and there have been further sectoral shifts, partially from international trade.

Macroeconomic effects: GDP, real income, GDP deflator, net exports.

Table 7 summarizes the broad picture of the macroeconomic effects of the HR 2454 ("Case 2") scenario. GDP falls significantly (−1.1%) relative to the base as the carbon price is first introduced. However, due partly to increased energy efficiencies, and partly to the positive effects of revenue recycling, the decline in GDP from the base is only -0.6% by 2020, and is −0.3% by 2030. Real exports and real imports both decline in the aggregate, but exports decline more than imports. Some of the import decline is a decline in oil imports. The impact on real disposable income is relatively larger than the impact on GDP in the early, declining by 1.2% in 2015, but about the same level as the GDP decline in the subsequent years. The effect of HR 2454 on the aggregate GDP price deflator is positive, reflecting the higher energy prices due to the carbon price. The last line of the table summarizes economy wide energy efficiency, as summarized by the ratio of Btus to real GDP. Energy efficiency increases by 5.9% by 2030.

9) As we discuss below, emissions intensive sectors such as Agricultural fertilizers and chemicals, Ferrous metals, and Stone, clay and glass experience declines in exports.

Table 7. Macroeconomic indicators

Line 1: Case 1 (Reference)
Line 2: Case 2 (US Waxman-Markey, No China response)

Alternatives are shown in percentage deviations from base.

	2012	2015	2020	2025	2030
Real Gross Domestic Product (bil 2000$)	12642.7	13500.8	15123.2	17119.0	19252.9
	−1.1	−0.9	−0.6	−0.4	−0.3
Real Exports	1623.2	2052.4	2557.1	3230.9	3938.8
	−0.9	−2.2	−2.2	−2.0	−1.8
Real Imports	2105.6	2345.3	2760.7	3213.5	3750.9
	−1.5	−1.2	−1.2	−1.1	−1.2
Real Disposable Personal Income	9648.3	10195.2	11324.2	12839.3	14430.5
	−1.3	−1.2	−0.6	−0.4	−0.2
GDP Deflator	1.3	1.4	1.6	1.8	2.0
	2.0	2.7	2.6	2.0	1.3
Energy Intensity	8.0	7.5	6.9	6.3	5.7
	0.0	−1.1	−2.6	−3.4	−5.9

Price effects on other industries.

In addition to the increased price of energy products, sectors that use energy intensively also experience price increases. Table 8 shows the top 10 sectors, ranked by the percent of price increase in 2030. We have removed from the ranking the energy extraction, petroleum refining and utilities sectors.

All industries in the list except for are either transportation or energy-intensive industrial sectors. Agricultural fertilizers (7.4%), Stone, clay and

Table 8. Top 10 Industries, Ranked by Percent of Price Increase in 2030 (Price indexes, 2000=100)

	Base (Case 1) 2020	WM (Case 2) 2020	Base (Case 1) 2030	WM (Case 2) 2030	Percent Difference 2030
1 62 Air transport	140.0	151.5	161.3	174.3	7.73
2 20 Agricultural fertilizers and chemicals	181.7	194.2	225.5	242.7	7.39
3 60 Trucking, highway passenger transit	148.8	159.4	172.0	184.5	7.00
4 31 Stone, clay & glass	150.9	160.6	175.4	186.9	6.34
5 59 Railroads	116.3	124.9	130.3	138.2	5.90
6 23 Other chemicals	175.1	185.6	214.9	226.7	5.35
7 32 Primary ferrous metals	168.6	175.7	196.5	204.6	4.03
8 61 Water transport	152.0	156.8	171.8	176.4	2.65
9 21 Plastics & synthetics	150.6	155.5	177.2	181.8	2.59
10 18 Paper	140.7	144.8	162.3	166.1	2.30

glass (6.3%), Other chemicals (5.4%), Primary ferrous metals (4.0%), Plastics and synthetics (2.6%) and Paper (2.3%) are the industrial sectors with the largest price increases, that we would expect to suffer from international trade leakages.

Changes in sectoral exports and imports.

Imports for a given commodity are determined by domestic demand of that commodity and relative domestic and import prices. With domestic prices rising in response to the carbon price, we expect imports of several sectors to rise. Table 9 shows imports between the base case and the Waxman-Markey case 2 for 2020 and 2030, ranked by the percentage difference in 2030. This table does not bear out the result that the import changes are in those sectors with the highest domestic price increase. The largest 5 sectors are investment goods, and the next several sectors are consumer goods. The increase in imports is likely related to the revenue recycling mechanism. Note that overall imports are down, which is a reflection of a slower economy, and the fact that oil imports have been reduced.

Table 10 shows the results for exports, again ranked by the percentage change. This time, we have ranked the sectors with the largest decline first. In the case of exports, the biggest losers are also sectors with large increases in domestic price, such as Agricultural fertilizers, Ferrous metals, Stone clay and glass, and Chemicals. Remember, total exports are down by 1.8% by 2030, and exports of most sectors have declined, though not nearly as much as in these sectors that have carbon intensive production techniques.

Table 9. Top 10 Industries, Ranked by Percentage Increase in Imports in 2030

			Base (Case 1) 2020	WM (Case 2) 2020	Base (Case 1) 2030	WM (Case 2) 2030	Percent Difference 2030
1	40	Computers	151839	152625	231619	233931	1.0
2	41	Office equipment	10405	10437	15036	15178	0.9
3	58	Miscellaneous manufacturing	100840	100513	131173	132341	0.9
4	38	Special industry machinery	15419	15495	23372	23579	0.9
5	37	Metalworking machinery	22575	22673	38773	39108	0.9
6	13	Alcoholic beverages	13139	13260	12132	12236	0.9
7	44	Household appliances	23077	23245	29314	29552	0.8
8	46	TV's, VCR's, radios & phonographs	81508	80988	91747	92468	0.8
9	55	Medical instruments & supplies	40253	40519	62666	63107	0.7
10	87	Education, social services, NPO	3498	3505	4192	4219	0.7

Table 10. Top 10 Industries, Ranked by Percentage Increase in Exports in 2030

			Base (Case 1) 2020	WM (Case 2) 2020	Base (Case 1) 2030	WM (Case 2) 2030	Percent Difference 2030
1	20	Agricultural fertilizers and chemicals	3812	3286	2940	2570	−12.6
2	32	Primary ferrous metals	14208	13183	18641	17265	−7.4
3	31	Stone, clay & glass	12881	12203	23299	22237	−4.6
4	23	Other chemicals	73146	70482	109483	106311	−2.9
5	26	Rubber products	15864	15377	19931	19370	−2.8
6	33	Primary nonferrous metals	20255	19871	15739	15394	−2.2
7	1	Agriculture, forestry, and fisheries	74774	72680	121405	118944	−2.0
8	27	Plastic products	14853	14514	21495	21085	−1.9
9	79	Advertising	2446	2387	4065	3999	−1.6
10	41	Office equipment	3016	2898	3258	3206	−1.6

China Modeling Results

Before turning back to the U. S. to see the effects of China adopting the tax, we will look at a few features of the China modeling results, to better understand the full model scenarios. The *Mudan* model maintains a domestic price vector, but also a vector of prices for exported goods. It is the domestic price that is directly affected by the carbon charge, and the export price is related to that price.

Table 11 compares the export prices with and without the carbon tax

Table 11. Top 10 China Industries, Ranked by Percent of Export Price Increase in 2030 Percent

		Case 2 2020	Case 3 2020	Case 2 2030	Case 3 2030	Percent Difference 2030
10	Logging and transport of timber and bamboo	212.5	240.3	313.2	371.9	18.7
48	Water transportation	146.9	164.8	158.4	174.8	10.3
9	Non-metal minerals mining and mining, n.e.c.	214.9	230.7	238.6	256.4	7.5
46	Railway transportation	158.4	169.4	167.0	178.2	6.7
47	Highway transportation	165.4	179.1	172.7	184.2	6.6
45	Construction	182.5	192.4	210.8	222.4	5.5
7	Ferrous ore mining	192.3	195.9	211.2	215.8	2.2
50	Pipeline transportation	187.8	193.5	232.1	235.8	1.6
30	Primary non-ferrous metals manufacturing	269.8	274.7	336.6	341.6	1.5
52	Commerce	130.7	134.6	135.6	137.2	1.2

(Case 2 compared with Case 3), for the 10 sectors with the largest export price increase. We have removed the energy industries from this ranking (coal, gas, petroleum and electricity). In China, logging and transport of timber and bamboo has the highest export price increase (19.7%). Four of the other top 10 industries are transportation industries. The only overlap with the high price increase sectors in the U. S. is ferrous ore mining (2.2%) and non-ferrous metals (1.5%).

Table 12 shows the differences in Chinese exports after imposing the carbon tax. The top 10 industries are shown, ranked by the largest decline in exports relative to Case 2. Only 3 of these sectors are also in table 11: Logging and transport of timber and bamboo (−6.9%), Primary non-ferrous metals manufacturing (−4.8%) and Non-ferrous ore mining (−3.9%). Forestry, with a large export decline (−6.9%), had only a small export price increase (0.1%). Aerospace, with a 4.6% decline, had only a 0.2% export price increase[10].

The Bilateral Trade Model, which determines the exports for each country, relies not just on relative prices, but also on relative investment growth. It is possible that for some reason these sectors saw relative investment declines compared to case 2. This is because case 3 also had large investments in nuclear and renewable energy, which crowded out investments in other sectors.

Table 12. China Exports
Top 10 Industries, Ranked by Percentage Difference

	Case 2 2020	Case 3 2020	Case 2 2030	Case 3 2030	Percent Difference 2030
2 Forestry	10	9	11	10	−6.9
10 Logging and transport of timber and bamboo	0	0	0	0	−6.9
30 Primary non-ferrous metals manufacturing	1932	1842	4248	4044	−4.8
36 Aerospace	185	182	397	379	−4.6
8 Non-ferrous ore mining	33	33	47	45	−3.9
13 Tobacco manufacture	43	41	239	230	−3.8
9 Non-metal minerals mining and mining, n.e.c.	427	411	704	679	−3.6
26 Rubber products	3587	3525	7045	6920	−1.8
16 Leather, fur and their products	3869	3812	6751	6647	−1.5
33 Railway Equipment	302	296	932	919	−1.4

10) The response of exports to a change in price is a weighted combination of import price elasticities of the trading partners, and price response in the Bilateral Trade model.

Table 13 shows selected variables in the macroeconomic summary for China, comparing cases 3 and 4 with case 2. Unlike in the U. S. scenarios, GDP in China after imposing the tax regime is higher than without the tax (except for 2012 in case 3). In case 3 GDP rises to be 1.1% higher than case 2 by 2030. In case 4 it is 0.7% higher. However, the mix of GDP changes is quite different between the two simulations. Case 4 of course is characterized by a large increase in "public consumption" of health care, which increases total public consumption by 12.2% by 2030, relative to case 2. Conversely, total private consumption falls in this case compared with case 2, by 2.1% by 2030, whereas private construction rises slightly (0.5% by 2030) in case 3. Total fixed investment is down in both cases. This is due to the fact that to achieve the necessary reduction in carbon emissions, there was a large investment in nuclear power. Investment funds were assumed to be diverted from other industries to achieve the targeted nuclear capacity level. In case 4, total fixed investment is down even further than in case 3 (3.8% vs. 3.4%), as the increase in health investment is crowding out some private investment.

Imports are down significantly in both cases, falling by 5.5% by 2030. This is due partly to a reduction in energy imports, particularly crude oil and natural gas. However, it is also due to a reduction in capital goods imports, driven by the reduction in fixed investment described above.

Exports are down for most years in case 3, but reach rough parity with case 2 by 2030. In case 4, exports are reduced in all years. Real disposable income is higher in most years in case 3, rising to 1% above case 2 by 2030. However, in case 4 it is reduced. Finally, in either scenario China is able to make a big cut in carbon emissions, which see a decline of about 40% by 2030.

Prices are higher with the carbon tax, as we would expect, and this shows up as a higher aggregate GDP deflator. However, in case 3, where part of the carbon tax revenue was recycled in the form of reduced other indirect taxes, the price increases are ameliorated. However, in the case where a large portion of the recycling is through health care spending, the price increases show up more strongly. In this case (case 4), the aggregate deflator is 4.7% higher than case 2 by 2030, whereas it is only 0.9% higher in case 3.

What is the logic driving these results. Contrary to many other studies that have investigated the impact of a CO_2 tax, this set of results from Mudan shows an increase in GDP, whether revenue is recycled as other taxes, or whether it is recycled as a combination of taxes and health care investment. Is it true that such revenue recycling can fully compensate for the negative impacts of a carbon tax. The differences from case 2 do not appear to be caused by the behavior of exports, which are predominantly lower than case 2 in both cases 3 and 4. Both cases see a sizeable reduction in imports, whereas we might have expected to see an *increase* in imports in response to a tax driving up domestic prices. However, as mentioned above, the import reductions are concentrated in energy imports and capital goods imports.

Table 13. China Macroeconomic Summary

Line 1: Case 2 (US Waxman-Markey, No China response)
Line 2: Case 3 (US Waxman-Markey, China carbon tax, recycle through tax)
Line 3: Case 4 (US Waxman-Markey, China carbon tax, recycle through tax and health investments)

Alternatives are shown in percentage deviations from base.

	2012	2015	2020	2025	2030
Gross Domestic Product	292984	349074	471186	631178	836652
	−0.2	0.6	0.8	1.1	1.1
	0.2	1.1	1.2	1.1	0.7
Private Consumption	105209	129617	172509	227411	302267
	−0.1	0.8	0.5	0.8	0.5
	−0.7	−0.7	−1.6	−1.6	−2.1
Public Consumption (*)	41015	49876	67461	89752	118516
	0.0	0.0	0.0	0.0	0.0
	8.5	10.5	12.4	12.1	12.2
Total Fixed Investment	131570	165705	233911	320481	429733
	0.5	0.1	−1.8	−2.3	−3.1
	0.0	−0.2	−2.2	−2.9	−3.8
Exports (*)	126006	154079	206863	278794	379886
	−1.2	−1.3	−0.8	−0.3	0.1
	−2.0	−1.9	−1.4	−1.3	−1.4
Imports	−110013.6	−151541.3	−210707.4	−285531.3	−387387.8
	−1.3	−3.0	−4.9	−5.0	−5.5
	−1.5	−2.8	−4.6	−4.9	−5.5
GDP deflator	137.3	149.6	162.8	177.5	189.4
	2.3	2.7	2.4	1.3	0.9
	3.2	4.1	4.4	4.2	4.7
Real disposable income	148450	175308	238778	327034	458571
	−0.4	0.3	0.4	1.0	1.0
	−1.0	−0.9	−1.5	−1.6	−2.2
CO 2 Emissions	7790	9072	10973	13467	16320
	−19.7	−31.8	−38.2	−40.0	−40.2
	−20.0	−31.9	−38.0	−39.7	−40.0

Comparison of U. S. Macro and Trade Impacts with China Tax

In this section, we bring in the comparison of case 3 and case 4 for the U. S. Case 2 will be used as the reference for comparison, as we are trying to establish clearly the differences due to China adopting the carbon tax.

Table 14 is the U. S. macroeconomic summary, comparing cases 3 and 4 with case 2. In case 3, where China recycles the tax through a reduction in other taxes, U. S. GDP is higher by 2030, by 0.3%. In case 4, where China uses a combination of taxes and health care investment, U. S. GDP is 0.1% lower.

Total U. S. real exports are reduced from case 2 in both cases, down 0.4% in case 3, and 0.2% in case 4. This is contrary to our expectations, which is that we would see less leakage in the form of export loss, once China also adopted a carbon pricing regime. Total U. S. real imports are higher in case 3 than in case 2, but there is no significant change in case 4.

Table 14. Macroeconomic Indicators with Comparison China Response

Line 1: Case 2 (US Waxman-Markey, No China response)
Line 2: Case 3 (US Waxman-Markey, China carbon tax, recycle through tax)
Line 3: Case 4 (US Waxman-Markey, China carbon tax, recycle through tax and health investments)

Alternatives are shown in percentage deviations from base.

	2012	2015	2020	2025	2030
Real Gross Domestic Product (bil 2000$)	12504.1	13378.5	15036.0	17047.7	19199.2
	0.0	0.0	0.1	0.3	0.3
	0.0	0.0	0.0	−0.1	−0.1
Real Exports	1607.9	2008.2	2501.4	3166.9	3867.4
	0.1	0.0	−0.1	−0.2	−0.4
	0.1	0.0	−0.1	−0.2	−0.2
Real Imports	2075.0	2316.2	2727.9	3176.9	3704.1
	0.0	0.0	0.1	0.3	0.5
	−0.1	0.0	0.0	−0.1	−0.1
Real Disposable Personal Income	9521.0	10077.8	11256.6	12789.8	14408.8
	−0.1	0.0	0.2	0.4	0.6
	−0.1	0.0	−0.1	−0.1	−0.1
GDP Deflator	1.3	1.4	1.6	1.8	2.0
	0.0	0.0	−0.3	−0.9	−1.5
	0.0	0.0	0.0	0.0	0.0
Energy Intensity	7.97	7.46	6.68	6.08	5.37
	0.0	0.0	0.1	0.3	0.5
	0.0	0.0	0.0	0.0	0.0

What of the effects of China's carbon taxes on the export sectors that had been hit the hardest by the U. S. carbon price. Table 15 is the summary of exports changes, comparing the percent difference from base in cases 2 through 4. These comparisons are for the 10 industries which lost the most in exports with the adoption of the U. S. carbon pricing scheme. We would have expected to see some mitigation of the exports leakage as China adopts an energy tax. There is a minor reduction in the loss in some sectors (Agricultural fertilizers, Rubber products, Plastic products), a stronger reduction in a few sectors (Primary nonferrous metals, Office equipment), but some sectors see a larger export loss in cases 3 and 4 (Metal mining, Agriculture, forestry and fisheries, Advertising).

On the whole, these results are inconclusive. It is possible that the mechanism for recycling the tax revenue is responsible. In the case of recycling revenue by reducing other indirect taxes, we have muddied the price response. In other words, in sectors where the increase in price from the carbon tax outweighs the reduction in other indirect taxes, the price will go up. In sectors where the reduction in indirect taxes outweighs the carbon tax, prices go down. This can have the effect of reducing any mitigation of U. S. export reductions that would have otherwise taken place without this form of revenue recycling.

Another factor at play is the assumption that increasing nuclear capacity is done at the expense of total fixed investment. This results in a reduction of imports of capital goods, which are supplied partly from the U. S.

Table 15. Effects of China Carbon Policies on U. S. Exports

	Base 2030	WM 2030	Case 3 2030	Case 4 2030	Case 2	Case 3	Case 4
					Percent Difference from Base in 2030		
20 Agricultural fertilizers and chemicals	2940	2570	2592	2593	−12.6	−11.8	−11.8
2 Metal mining	2932	2624	2550	2563	−10.5	−13.0	−12.6
32 Primary ferrous metals	18641	17265	16819	16860	−7.4	−9.8	−9.6
31 Stone, clay & glass	23299	22237	22214	22229	−4.6	−4.7	−4.6
23 Other chemicals	109483	106311	106327	106433	−2.9	−2.9	−2.8
26 Rubber products	19931	19370	19441	19430	−2.8	−2.5	−2.5
33 Primary nonferrous metals	15739	15394	15846	15806	−2.2	0.7	0.4
1 Agriculture, forestry, and fisheries	121405	118944	118438	118739	−2.0	−2.4	−2.2
27 Plastic products	21495	21085	21099	21117	−1.9	−1.8	−1.8
79 Advertising	4065	3999	3981	3992	−1.6	−2.1	−1.8
41 Office equipment	3258	3206	3224	3230	−1.6	−1.0	−0.9

Conclusions and Next Steps

This paper has illustrated the use of the Inforum *LIFT* model of the U.S., the *Mudan* model of China, and the Inforum Bilateral Trade Model (BTM) to examine the question of the differential impact on U. S. trade leakages. A reference case was first developed that embodied "business as usual" assumptions for both the U. S. and China. In the U. S. case, the base was calibrated to the Department of Energy *Annual Energy Outlook* (with simulus) for 2009. In the case of China, the Inforum base case was used. A second case was developed where the U. S. adopted the major features of the Waxman-Markey legislation, but China did not adopt any similar policy. In the third and fourth cases, China did adopt a carbon tax, though not exactly the same as that of the U. S. Furthermore, the revenue recycling mechanism chosen for China was different from that assumed for the U. S.

The results so far are inconclusive. In other words, it does not appear that the parallel adoption of carbon tax policy in China significantly reduces the trade leakage in the U. S. As we have alluded above, this could be partly due to the nature of the carbon tax revenue recycling mechanisms we have assumed. But from a broader perpective, it is also due to the fact that China is not the only trading partner of the U.S., although it is a significant one, especially with regard to U. S. imports. However, the behavior of other countries has a much larger affect on the path of U. S. exports. According to the current Census trade data, China is the third largest purchaser of U. S. exports, after Canada and Mexico. However, exports to China represent only about 7% of total U. S. exports. On the import side, China is the single largest source of U. S. imports, with Canada and Mexico not far behind. Of total U. S. imports, those from China comprise 17.7%. However, U. S. imports actually increased from case 2 to case 3, where China adopted a carbon tax but recycled other taxes. There was no significant change in imports from case 2 to case 4.

It would be helpful to check the robustness of these results by performing further simulation studies with the U. S. and China models within the BTM context.

Appendix A. The Structure of the Inforum LIFT Model

The Inforum *LIFT* (Long-term Interindustry Forecasting Tool) model is unique among large-scale models of the U. S. economy in that it is based on an input-output (IO) core, and builds up macroeconomic forecasts from the bottom up. In fact, this characteristic of *LIFT* is one of the principles that has guided the development of Inforum models from the beginning. This is in part because the understanding of industry behavior is important in its own right, but also because this parallels how the economy actually works. Investments are made in individual firms in response to market conditions in the industries in which those firms produce and compete. Aggregate investment is simply the sum of these industry investment purchases. Decisions to hire and fire workers are made jointly with investment decisions with a view to the outlook for product demand in each industry. The net result of these hiring and firing decisions across all industries determines total employment, and hence the unemployment rate. In the real world economy pricing decisions are made at the detailed product level. Modeling price changes at the commodity level certainly captures the price structure of the economy better than an aggregate price equation. In *LIFT*, prices and incomes are forced into consistency through the fundamental input-output identity, and the aggregate price level is determined as current price GDP divided by constant price GDP.

Despite its industry basis, *LIFT* is a full macroeconomic model, with more than 1200 macroeconomic variables determined either by econometric equation, exogenously or by identity. The econometric equations tend to be those where behavior is more naturally modeled in the aggregate. Many aggregates are formed as the sum of industry detail, such as total corporate profits. An equation for the effective corporate tax rate is used to determine total profits taxes, which is a source of revenue in the Federal government account. Equations for contribution rates for social insurance programs and equations for transfer payments out of these programs can be used to study the future solvency of the trust funds. Certain macrovariables provide important levers for studying effects of government policy. Examples are the monetary base and the personal tax rate. Other macrovariables, such as potential GDP and the associated GDP gap provide a framework for perceiving tightness or slack in the economy.

Since its inception, *LIFT* has continued to develop and change. We have learned much about the properties of the model through analytical studies and simulation tests. We have learned about the behavior of the general

Inforum type of model, from work with Inforum partners in other countries, including China, Japan, Germany and Italy.

In the last several years, the *LIFT* model has been extended through the incorporation of several modules that can be used to study energy demand and supply, and the implications of energy use on carbon emissions.

An Overview of the Model

We first focus on the "real side" of the model, where the expenditure components of GDP are calculated in constant prices. First personal savings are determined, which affect how much of real disposable income will result in total expenditures on consumption. Personal consumption is modeled in the PADS (consumer demand system) function to get consumption by category. PADS allows the classification of consumption goods into related expenditure groups, for example food, transportation or medical care. In PADS, motor vehicles prices affect the demand for public transportation, since motor vehicles and public transport are substitutes.

Exports by commodity may be determined outside the model, from the Inforum bilateral trade model (BTM) or by equations use information from BTM in the form of weighted foreign demands and foreign prices. The equipment investment equations are based on a Diewert cost function, that models the substitution (or complementarity) of equipment capital with labor and energy. The equations use a cost of capital measure that includes real interest rates, present value of depreciation, investment tax credit and corporate profits tax. The construction equations are for the roughly 20 categories of private construction. Though each has a different form, common variables are interest rates, disposable income and sectoral output.

Federal and state and local consumption and investment expenditures are specified exogenously in real terms, but *LIFT* allows for detailed control of these expenditures. For example, defense purchases of aircraft can be specified independently of missiles, ships or tanks.

The input-output solution solves jointly for output, imports and inventory change. Note that the IO matrix coefficients are specified to change over time, according to trends for each row. However, individual coefficients can also be fixed, to model changes in price or technology.

Labor productivity equations are used to determine the ratio of output to hours worked by industry. Average hours equations determine the average hours per employed person per year. Together, the productivity, average hours and output forecast generate employment by industry in the private sector. Adding in exogenous projections of government and domestic employment, total civilian employment is obtained. Subtracting total employment from projected labor force yields unemployment, and the unemployment rate, which is a pivotal variable in the model.

Prices in LIFT are determined as a markup over unit intermediate and labor costs. However, all components of value added are calculated first. Some are then scaled so that value added by commodity and prices are consistent. The largest component of value added is labor compensation by industry, which we call simply the "wage rate", although it also includes supplements. The "wage" equations relate the growth of the wage rate to growth in the ratio of M 2 to GDP, expected inflation, and the growth in labor productivity. Multiplying the wage rate by the total hours worked per industry gives total labor compensation per industry.

It is also important to determine the components of capital income. Such items as corporate profits, proprietors' income and capital consumption allowances are calculated in LIFT by industry. The value added relationships not only play a role in the determination of prices, but are also needed to be able to calculate corporate profits taxes, and retained earnings and capital consumption allowances are the large components of business savings, which is an important part of the savings-investment identity. Furthermore, dividends, proprietors' income, interest income and rental income all contribute to personal income.

Finally, there is a block of the model calle. "the Accountant", which is a large set of equations and identities that aggregate industry and commodity level variables up to the aggregate level, and calculate many of the main variables in the National Income and Product Accounts (NIPA). Part of the job of the accountant is to estimate all of the components of national income, personal income and disposable income. It also calculates federal and state and local government receipts and expenditures, as well as transfer payments and social insurance contributions. All of the fundamental national accounts identities are also calculated by the Accountant.

The standard solution interval for *LIFT* has recently been to 2030. For the calibration to the *2010 Annual Energy Outlook*, the solution interval will be extended to 2035. Note that we have also developed special versions of *LIFT* that forecast to 2050 (for carbon emissions modeling) or to 2085 (for long-term health care projects).

The Use of LIFT for Energy Modeling

As described above, *LIFT* is an interindustry macroeconomic (IM) model. Price and quantity calculations are grounded in the IO relationships. To a large extent, the macroeconomic forecasts are aggregates of detailed industry equations. The *LIFT* model embodies industry and interindustry detail for about 90 commodities, as well as a full set of NIPA (national accounts) variables. While not an energy model *per se*, LIFT maintains detail for the following energy industries.

3. Coal
4. Natural gas extraction
5. Crude petroleum
24. Petroleum refining
25. Fuel oil
66. Electric utilities
67. Natural gas distribution

LIFT shows constant and current price sales of these industries to all other industries and to final demand, as well as showing the purchases of these industries from other industries in the economy.
The calculation of prices in *LIFT* is also based on IO relationships. Prices are based on the prices of domestic and imported inputs, and the value added generated in production, including labor compensation, gross operating surplus and indirect taxes. Energy taxes, such as those analyzed in this study, are implemented as an indirect tax, which affects the price of the target industry directly, and the prices of all other industries indirectly.

Residential energy demand and household transportation are modeled as part of a system of personal consumption expenditure equations. These consumption equations respond to disposable income, relative prices and other variables. Industrial, commercial and non-household transportation energy demand is modeled via IO relationships. The IO relationships are not static, but may be modeled to incorporate efficiency improvements, price-induced substitution, or changes in structure due to technological change. The structure of the electric power generating industry is represented as a disaggregation into the following list of 8 separate components, based on the technology or fuel type.

Types of Electricity Generation

1. Coal
2. Natural gas
3. Petroleum
4. Nuclear
5. Hydro
6. Wind
7. Solar

8. Geothermal, biomass and other

Additional modules have been attached to *LIFT*, which perform side calculations. These modules take output, price and other variables from the model, solve, and then provide variables to feed back to the main model. Examples of modules now functioning with *LIFT* include:

- Biofuels
- Light-duty vehicles
- Building efficiency
- CCS
- Renewable power (wind and solar)
- Nuclear power
- Carbon and carbon tax calculator
- Electricity generation by type

A module such as the building efficiency or light duty vehicles calculates variables such as residential and commercial energy demand for which *LIFT* would normally use the personal consumption equations or the IO coefficients. With the addition of the module, these default calculations are either replaced or modified. Personal consumption expenditures on gasoline may then be calculated as the sum of fuels of vehicles of different types, based on MPG and vehicle miles traveled instead of the default equations which rely on income and price. Changes in commercial energy demand coming through building or vehicle efficiency are implemented as changes in IO coefficients.

Producing Sectors of the LIFT Model of the U. S. Economy

1 Agriculture, forestry, & fisheries

Mining
2 Metal mining
3 Coal mining
4 Natural gas extraction
5 Crude petroleum
6 Non-metallic mining

Construction
7 New construction
8 M & R construction

Non-Durables
9 Meat products
10 Dairy products
11 Canned & frozen foods
12 Bakery & grain mill product
13 Alcoholic beverages
14 Other food products
15 Tobacco products
16 Textiles and knitting
17 Apparel
18 Paper
19 Printing & publishing
20 Agric fertilizers & chemicals
21 Plastics & synthetics
22 Drugs
23 Other chemicals
24 Petroleum refining
25 Fuel oil
26 Rubber products
27 Plastic products
28 Shoes & leather

Durable Material & Products
29 Lumber
30 Furniture
31 Stone, clay & glass
32 Primary ferrous metals
33 Primary nonferrous metals
34 Metal products

Non-Electrical Machinery
35 Engines and turbines
36 Agr., constr., min & oil equip
37 Metalworking machinery
38 Special industry machinery
39 General & misc. industrial
40 Computers
41 Office equipment
42 Service industry machinery

Electrical Machinery
43 Elect. industry equipment
44 Household appliances
45 Elect. lighting & wiring eq
46 TV's, VCR's, radios
47 Communication equipment
48 Electronic components

Transportation Equipment
49 Motor vehicles
50 Motor vehicle parts
51 Aerospace
52 Ships & boats
53 Other transportation equip

Instruments & Miscellaneous Manufacturing
54 Search & navigation equip
55 Medical instr & supplies
56 Opthalmic goods
57 Other instruments
58 Miscellaneous manufacturing

Transportation
59 Railroads
60 Truck, highway pass transit
61 Water transport
62 Air transport
63 Pipeline
64 Transportation services

Utilities
65 Communications services
66 Electric utilities
67 Gas utilities
68 Water and sanitary services

Trade
69 Wholesale trade
70 Retail trade
71 Restaurants and bars

Finance & Real Estate
72 Finance & insurance
73 Real estate and royalties
74 Owner-occupied housing

Services
75 Hotels
76 Personal & repair services
77 Professional services
78 Computer & data processing
79 Advertising
80 Other business services
81 Automobile services
82 Movies & amusements
83 Private hospitals
84 Physicians
85 Other medical serv & dentists
86 Nursing homes
87 Education, social serv, NPO

Miscellaneous
88 Government enterprises
89 Non-competitive imports
90 Miscellaneous tiny flows
91 Scrap & used goods
92 Rest of the world industry
93 Government industry
94 Domestic servants
95 Inforum statistic discrepancy
96 NIPA statistical discrepancy
97 Chain weighting residual

Appendix B. The Inforum *Mudan* Model of China

The Inforum model of the Chinese economy is called *Mudan* (MUltisector Dynamic ANalysis). It is a 59 sector IM (Interindustry Macromodel) which has a complete set of industry accounts, household accounts and government accounts. These various industry accounts are aggregated to produce the macroeconomic accounts. The industry accounts show for each industry. output, exports, imports, personal consumption purchases, investment purchases, government purchases and changes in inventories (in nominal and real terms) and for value added wages, depreciation, indirect business taxes less subsidies and surplus (nominal values). The ratios of current to real values are the various price indices for output, exports, imports, etc. Household consumption is modeled for 24 categories of urban household spending and 10 categories of rural household spending. Investment is modeled by investing industry for some 52 industries (an aggregation of the 59). Employment is modeled for the same 52 industries. The household accounts show household income from wages, capital type income (dividends) and government transfers (social insurance) while household expenditures for goods and services, social insurance taxes, income taxes, etc. are also modeled. The resulting excess of income is household savings (currently about 30% of income). The same is done for the government accounts where the model shows government incomes from indirect taxes (a value added category), income taxes, from profits, interest, etc. The result is government savings. From the household accounts the model produces disposable income which goes back into the household consumption equations.

Through its various accounts the model is able to trace the flows of income from one sector (household, industry, government) to another. This ensures consistency. The input-output identities ensure the consistency of the industry accounts. Thus for example if China is able obtain an export market at the expense of the US because of the carbon tax in the US we can trace that flow from exports to output to increased demands for inputs to incomes (wages and profits) and back to households and the government.

The data base of *Mudan* is a set of input-output tables in current and constant prices (2002) from 1992-2007. These tables are consistent with the published national accounts in nominal terms and with published price indexes. They are not fully consistent with published constant price values for GDP. No detailed data for constant price GDP on the product side (household consumption, exports, investment, etc) exists for China. The Chinese do publish constant price estimates of value added by very broad categories (primary, secondary and tertiary). These estimates use a vast array of information found in the Chinese Statistical Yearbooks and the

Chinese Statistical Labour Yearbooks.

China Energy Use

Historical Energy Data in China

The *China Statistical Yearbook* provides chapters on energy for at least the past 15 years. Several tables in the yearbook are relevant for this study. There are balances for petroleum, coal, and electricity for the years 1992-2007. These balances are in physical units and show production, exports, imports, stock changes, and consumption. In addition, there are data on the consumption of energy by detailed sector and energy type, all in physical units. This data are available from 1995-2007. Table 1 below shows a sample break down of the data as it appears. Most of the manufacturing rows and all of the service rows have been omitted. In addition the columns for Gasoline and Kerosene have also been omitted. The data are in physical units (tons, cubic meters, kilowatt hours) and by purchasing industry and by households.

Historical data and the Input-Output Accounts

One of the useful characteristics of input-output accounting is that the physical flows in tons (or other physical unit) given in Table B-1 can be matched to input-output transactions (sales from one industry to another industry). That is, we can move the flow (in constant price monetary units) by the corresponding movement in physical units to obtain a flow in constant prices. For example from Table 1 we have Paper and Paper Products consuming 3379 units (unit=10,000 tons) of coal. The flow from the input-output table for coal into paper is 26.93 in monetary units. Using this historical data on physical flows of tons of coal consumed by paper we have a measure of the flow in constant price units which can be measured against the constant price measure of the output of paper. The resulting coefficient then represents, in effect, the number of tons needed of coal to produce a given amount of paper. If we then convert these flows to direct coefficients we can examine how, over time, the particular coefficient has moved. It is then possible to study how these coefficients might change in the future. This enables us to make a forecast of Chinese energy consumption in physical units, which is useful for determining carbon emissions.

Chinese historical data on the usage of each energy type relative to GDP establishes the following:

1. Coal consumption relative to GDP fell rapidly from 1997 to 2002 as more modern electricity generating plants were put online in the late 1990's and as households switched from using coal to other forms of

Table B-1: Consumption of Energy by Sector (2007)

Source: CSY Table 7-9

Sector	Coal Consumption (10000 tons)	Coke Consumption (10000 tons)	Crude Oil Consumption (10000 tons)	Diesel Oil Consumption (10000 tons)	Fuel Oil Consumption (10000 tons)	Natural Gas Consumption (100 million cu.m)	Electricity Consumption (100 million kwh)
Total Consumption	**258641**	**30337**	**34032**	**12493**	**4077**	**695**	**32712**
Primary Industry	**2338**	**82**		**1875**	**1**		**979**
Mining	**17660**	**217**	**1204**	**326**	**42**	**96**	**1614**
Mining and Washing of Coal	16518	75		57	6	5	609
Manufacturing	**94188**	**29826**	**32655**	**1118**	**1983**	**333**	**18106**
….other manufacturing industries							
Manufacture of Paper and Paper Products	3379	5	1	22	32	1	442
Electric Power, Gas and Water Production and Supply	**133424**	**39**	**9**	**279**	**609**	**80**	**4911**
Production and Supply of Electric Power and Heat Power	131923	7	8	267	604	71	4642
Production and Supply of Gas	1471	32	0	9	6	9	46
Production and Supply of Water	31	0	0	2	0	0	224
Construction	**565**	**17**		**434**	**16**	**2**	**309**
…other services							
Household Consumption	**8101**	**76**		**205**		**133**	**3623**

energy for heating and cooking. The surge in industrial production after China's entry into the WTO (in 2001) required vast amounts of new electricity generating capacity.

2. Substantial improvements in industrial energy efficiency in the use of refined petroleum products have occurred over the past decade. (This does not include transportation.)
3. The Chinese economy has become much more electricity intensive. This is a result of three factors.
   a. Many industries have switched to technologies that are electricity intensive as the use of electronic equipment has increased.
   b. A change in the mix of production stemming from faster growth of the electronic and electrical machinery industries compared to that of apparel and textiles.
   c. As Chinese household income has increased, more air conditioning, refrigerators, televisions and other household appliances are being used.
4. The increase in the intensity of use of natural gas has been dramatic — rising one and a half times as fast as real GDP. This increase is especially strong in the household sector.
5. The pattern of coal used to generate electricity has followed an erratic

pattern. For the period 1997-2002 there was substantial scrapping of old generating equipment and new investment to expand capacity. The new equipment was substantially more efficient and this tended to reduce coal intensity. After 2002, the pace of new investment slackened substantially and coal consumption rose again. These changes are driven both by technology and relative prices.

6. Transportation use of petroleum relative to real GDP has steadily increased over the period of our database. The dominant factor is the increasing use of trucking for inter-provincial trade. As late as 1997 a portion of trucking consisted of human powered vehicles (types of bicycles) to move food and produce from the farms into the cities.

Equations for Energy Consumption by Sector

Modeling energy use by sector in a developing economy is a particularly complex matter. New technologies may greatly enhance production capacity while at the same time being energy intensive. At the same time older inefficient technologies are being replaced. The interactions of technology coupled with a widely varying international oil price makes estimation difficult.

The equation we estimate is:

$$\ln c_{i,k,t} = b_0 + b_1 t + b_2 \ln\left(\sum_{j=0}^{j=4} (price_{i,t-j}/pgdp_{t-j})/5.\right)$$

where:

$c_{i,k,t}$ is the coefficient of fuel type i (row of the input-output table) used by sector k in year t;

The time trend t is a specially created time variable to reflect the rapid changes taking place in the first part of the estimation period as old factories were closed (values were 1995=1972; 2000=1994; 2002=1998.32; 2004=2002.64; 2007=2006.7);

$price_{i,t-j}$ is the price of domestically used energy type i in year t-j;
and

$pgdp_{t-j}$ is the gross domestic product deflator for year t-j.

These coefficient equations have been estimated individual coefficients for Refined petroleum, Coal, Natural gas and Electricity.

Measurement of CO 2 Emissions

Data on emissions by China is available from the IEA website. The emissions are by fuel type. The amount of emissions per physical unit of energy (tons, mcf, etc) is very stable. The variance for natural gas is essentially zero. The variance in the ratio for coal and oil reflect some small changes in mix of fuel. For this study we have chosen to keep the 2007 ratios of emissions to physical unit of fuel constant. This focuses on energy use by industrial sector and by households.

Electricity Generation

A crucial focus of China's energy policy is on reducing coal as a primary fuel and replacing it with hydro, nuclear and renewables. For each method of production (hydro, thermal, etc) input coefficient are calculated and projected forward by assumption. These direct coefficients are then used in *Mudan* when making a forecast. These input-output coefficents can be thought of in terms of physical units such as tons (coal and oil) or mcf (gas) per kwh.

Mudan Output Sectors

1 Farming
2 Forestry
3 Livestock
4 Fishing
5 Coal mining
6 Crude petroleum and natural gas production
7 Ferrous ore mining
8 Non-ferrous ore mining
9 Non-metal minerals, and mining n.e.c.
10 Logging and transport of timber and bamboo
11 Food processing & manufacturing
12 Beverages
13 Tobacco manufacturing
14 Textiles
15 Wearing apparel
16 Leather, fur and products
17 Sawmills and bamboo etc. products
18 Furniture
19 Paper and paper products
20 Printing industries
21 Cultural, education, sports articles
22 Petroleum refineries and coking products
23 Chemical industries
24 Medicines
25 Chemical fibres
26 Rubber products
27 Plastic products
28 Building materials and other non-metallic mineral
29 Primary iron and steel manufacturing
30 Primary non-ferrous metals manufacturing
31 Metal products
32 Machinery
33 Manufacturing and repair of railroad equipment
34 Manufacturing and repair of motor vehicles
35 Shipbuilding and repair of ships
36 Manufacturing and repair of aircraft
37 Manufacturing and repair of transportation equipment
38 Electric machinery and instrument
39 Electronic and communication equipment
40 Instrument, meters and other measuring equipment
41 Industries n.e.c
42 Electricity, steam and hot water production
43 Gas production and supply
44 Production and supply of water
45 Construction
46 Railway transportation
47 Highway transportation
48 Water transportation
49 Air transportation
50 Pipeline transportation
51 Communications
52 Commerce
53 Restaurants
54 Finance and insurance
55 Real estate and social services
56 Health care, sports and social welfare
57 Education, culture, arts, radio, film and television
58 Scientific research and polytechnical services
59 Public administration

Appendix C. Inforum International Models and the Bilateral Trade Model

The Inforum system of macroeconometric, dynamic, input-output models has been producing annual forecasts and analyses of public policy since 1979. The current system contains models for the United States, Canada, Mexico, Japan, Korea, China, Germany, France, United Kingdom, Italy, Spain, Austria, and Belgium. Models of Denmark, Holland, Poland, Hungary, Russia, South Africa, India, and Thailand are underway, but not yet a part of the linked system.

Each of the models builds from industry detail to macroeconomic totals and has its own macroeconomic properties. The models produce all of the principal results of any aggregate model, such as GDP, the price level, the unemployment rate, and so on. In addition, they produce sectoral (product) forecasts for gross output, exports, imports, consumption, price indexes, and value added. These sectoral series are internally consistent with each other and consistent with the macro results. Indeed, the macro results are, with the exception of household and government consumption, the sum of sectoral results. Thus, real GDP is the sum of final demands expressed in constant prices, nominal GDP is the sum of value added by industry, and the GDP deflator is the ratio of the two.

Each of the models has sectoral equations for private consumption expenditures, capital investment, government purchases, imports, exports (see below for the link with the bilateral trade mode), labor compensation, return to capital, profits, etc. In each of the models, these sectoral equations are an integral part of the macroeconomic results. Hence, in the case of imports, the sum of the forecasts of the sectoral imports is the figure for total imports. The macroeconomic behavior of imports is thus derived as the sum of the behaviors of individual sectoral equations. To cite another example, a change in the rate of productivity growth in the construction sector will affect the overall growth rate of productivity and hence real GDP.

Each of the models has as a basic building block an input-output table linking the various sectors of the entire economy in a consistent manner. The table is used for the calculation of product outputs and product prices for each year of the forecast. The input-output coefficients have dynamic paths of change over time, which, in some instances, are responsive to changes in relative prices. Product outputs are determined using the familiar input-output calculation where the output of any one sector is the sum of sales to each of the other sectors and of sales to final demand. Likewise, prices are derived as the sum of the costs of intermediate goods and service inputs (including the cost of imported goods and services), and the costs of primary factors (labor, capital, etc.) per unit of real output. The individual country sectoral dimensions are shown below.

Each of the models is dynamic. That is, past levels of output, together with their pattern of change over time, will influence the level of investment and employment by industry.

Each of the country models is linked to the others bilaterally, by commodity, through trade flows and prices. The links are at both the macroeconomic and sectoral level. The macroeconomic side provides the exchange rate assumptions. All other links are at the sectoral level. Thus, steel imports in the USA influence steel exports of Japan; German auto prices affect the price of auto imports to the USA; and, USA grain prices affect Canadian exports of Grain. The model that links all of the country models is the Bilateral Trade Model, or BTM.

Exchange rates are exogenous. The system emphasizes the flows of goods and services at the industry level between countries together with the price impacts of such flows.

The models are linked together with the Bilateral Trade Model (BTM). BTM, as its name implies, shows bilateral trade flows between the countries in the system for some 120 commodities. Historical data are based on Statistics Canada's World Trade Database. BTM uses country and sector specific data on prices and investment to estimate the import shares and then the importing country's imports to obtain the level of imports from each exporting country. Summing across the importers then yields the exports by country and commodity. These estimates are then used in the country models as indicators of exports. In addition, BTM gives the importing country

Summary of Individual Model Dimensions (Output Sectors, Categories, etc.)

Country	Output	Consumption	Investment	Employment
USA	97	92	55	97
Canada	94	94	40	38
Mexico	74	12	1	74
Japan	102	85	101	102
Korea	71	29	25	17
China	59	34	52	52
German	58	22	58	58
France	88	88	38	36
Italy	45	40	21	41
UK	55	39	54	55
Spain	43	43	11	43
Australia	53	59	3	19
Belgium	53	61	24	44

information on its import prices by commodity.

Every six months, both macroeconomic and microeconomic model solutions are updated. In accordance, reviews of details and analysis are also performed in six-month intervals and are available upon request. Historical and forecast databases exist as part of the standard model data banks.

The following table briefly summarizes the overall capabilities of the individual models. Documentation varies substantially between models. Two were constructed as a part of a Ph.D. thesis; some have substantial papers written concerning their properties; others have only limited documentation. All documentation can be made available upon request.

The forecast horizon is 2030. The system can be used to study the industrial and aggregate impacts of macroeconomic developments such as changes in exchange rates, trade policy, and government policy. Some specific examples of applications of the International System include:

Examination of Customs Unions, Free Trade Areas, and International Trade Issues

- The Canadian, Mexican, and USA models were used by the Canadian government (Department of External Affairs) in a study of the impacts of alternative free trade agreements between the U. S. and Canada on the Canadian economy. Later, a similar study was completed looking at the NAFTA accord.
- Using detailed microeconomic studies for several industries a comprehensive and consistent study was made of the economic effects of European economic integration.
- A study of the economic effects of China's entry into the World Trade Organization (WTO) was conducted using detailed data on tariffs and non-tariff barriers.
- A study of the possible macroeconomic and sectoral impacts of the establishment of a free trade area for China, Japan and South Korea.
- The impact on American international trade competitiveness of increased capital investment in the US was investigated.
- An extremely detailed study showing the jobs required to produce exports was done for Canada, Japan, Germany, France, Italy, the United Kingdom, and the European Union.
- Our analyses of the impact of the U. S. and Japan imposing tariffs on each other’s products showed that both countries could be very negatively affected. The drop in personal income in the U. S. could be so large that even U. S. autos would experience a drop in output,

despite a substantial drop in imports of autos from Japan.

Specialized Studies

- The Department of Commerce has used the USA, Canadian, and Japanese models to show the embodiment of R&D expenditures in exports, imports and domestic consumption.
- The impact of achieving hypersonic (5-10 times the speed of sound) commercial travel ten years earlier than expected was studied in an international environment. Cases in which the U. S. alone had the capability were studied in contrast to cases in which Japan and Europe had it as well. Detailed impacts on technology in several industries were used
- A study of the industrial and trade impacts of alternative growth paths for the Chinese and Japanese economies was conducted. The impacts on Korea and the United States also
- A study of the effects of changing world oil prices on the US, Japanese, and European economies was done for a US manufacturer of plastic resins.
- An analysis of the effect on the Japanese economy of allowing free trade in rice at international prices was conducted.
- The system is used to provide the U. S. model, *LIFT*, with forecasts of foreign prices and demands for U. S. exports by sector.

Prospect of Economic Growth in China from the Twelfth Five-Year Plan Period to the Year 2030

Li Shantong, Liu Yunzhong, Xu Zhaoyuan and He Jianwu,
Development Research Center of the State Council, China

Over the past 30 years of reform and opening, China has experienced rapid economic development, and significantly increased its economic strength. By 2008, GDP per capita was over USD 3000, and made remarkable achievements in all social areas. Reform and development in China has thereby entered a new historical stage. However, in the coming 12 th Five-year Plan (FYP) period, China will remain in a critical stage with a vital strategic opportunity, and will face many challenges. Internationally, the world economic growth slowed down since the start of the global financial crisis, the pressure on reduction of CO_2 emission increased, and China's external economic development environment changed significantly. Domestically, China is facing increasing pressure from resources and environment, as well as growing constraints as a result of the extensive and uncoordinated development mode. Therefore, it is necessary to analyze China's economic development prospect in the 12 th FYP period and beyond, so as to be better prepared, adopt more effective policy and instruments, seize opportunities, adapt to challenges, and promote better and faster economic development.

I. Opportunities and challenges for China's current economic and social development

From the 12 th FYP period to 2030, significant changes will take place in China's international and domestic development environments, which will affect various levels of its economic development systems, technologies and production factors.

1. State intervention and trade protectionism will prevail for a longer time, but in the long term, economic liberalism and globalization will remain dominant.

The global financial crisis induced by the sub-loan crisis in the US shocked the global economy, leading to economic recessions even in many developed countries. In general, the overall economic recovery is still to be seen. To achieve economic recovery, countries may introduce various state interventionist and trade protectionist measures to protect their own markets and employment. On the other hand, global climate change and relevant uncertainties may also lead to strengthened state intervention and trade protectionism. Of course, excessive state intervention and trade protectionism cannot deal with the consequences of the financial crisis, nor can they promote the global economic growth. In the long term, therefore, global economic growth will continue to be dominated by economic liberalism and globalization. However, in the short term, the resurgence of trade protectionism may harm the growth of international trade. Especially, as a big exporting country, China may face more antidumping and protectionist measures, which will harm its exports.

2. Global climate change and relevant resource and environmental issues will become the major constraint in global economic growth and the important factors to influence global society.

Global climate change threatens various aspects of human life, including rising sea level, access to water, grain production, changes in biological species, health, land use, and environment, which will significantly affect pe ople's life and wealth. Climate change is hitherto the greatest and the most extensive phenomenon of market failure[1)].

Reducing the negative impact of climate change needs coordinated international action, agreements on the long-term objectives of climate policies, effective cooperation agencies, responsible actions of some major countries, and efforts to establish trust in other parties. However, it is very difficult to reach agreements on these issues and adopt actions, both in political and in economic terms, and the relevant disputes may lead to international instability.

The variety and the mode of resource utilization may also become important factors affecting the future development environment. Due to the limited reserves of traditional fossil energy and its impact on the environment and the climate, demand for new energy in future will increase, which will change the supply pattern and geopolitics of traditional energy supply, and affect the economic development m of China in the next 20 years.

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1) See Stern Review, the Economics of Climate Change.

3. New areas of technology revolution will be new growth points of the future economy and the effect of technology diffusion should be strengthened.

In future, global technology will see a range of breakthroughs, and demonstrate new competitive characteristics, which will have significant impact on the overall national strength, social and economic structure, and people's life. The main areas of the leaping development of global technology may concentrate on the following areas: (1) life science and technology will make new strategic breakthroughs, and will thereby take new dominant position in 2010, and become the most attractive leading technology of the 21st century; (2) information technology will continue to have ample space of development in the next 20 years, with a development trend dominated by technology application and market demand, and by a continuous merge of communication, computer and other industries; (3) driven by information technology and other technologies, advanced manufacturing technology will see rapid development and extensive application, with a future development trend characterized by integration, intelligence and flexibility, and greater impact on industrial restructuring and relocation; (4) with a good development prospect, nano-technology will continue to be the hot-spot in a new round of world technology competition, with great potential of industrialization; (5) lead by nano-technology and other matter sciences, material sciences and technology will also be a most active area of modern high-tech; (6) resource, environment and space technologies will achieve greater progress, and energy saving, energy storage and new energy-related technologies will attract more attention, so as to address the increasing disparity between supply and demand; and (7) aviation and space technologies will be more mature, with greater space for activity. The Earth sciences and Ocean sciences will continue to expand human living and activity space, and help the human being to thoroughly understand the Earth they are living in.

Due to the rising status of developing countries and the impact of globalization, the trend of world technology development in future will be multipole. Driven by the effect of the continuous globalization, cross-boundary barriers to human capital, capital, technology, information and goods will continue to decline, technology resources will move around the world, the criterions and standards of technological activities will gradually converge, the R&D of transnational companies will be dispersed around the world, and international technology exchange and cooperation characterized by "grand technology" projects will be strengthened. Similar to the economic and political situation, world technology in the 21st century may also be multi-centered. The US will maintain its lead in science and technology.

There will be more integration of science and technology in the EU. There will be very strong momentum of technology development in some Asian countries, such as China, Japan, South Korea and Singapore.

4. The global supply of resource and energy commodities will be basically balanced, but due to their uneven distribution, countries will inevitably adopt global strategies for such commodities.

Resource and energy commodities are an important base of development human society, and are the life lines of national economies. In future, along with the ever increasing expansion of the global economy, global demand for such commodities will continue to grow, and their constraints to and impact on the human economic and social development will become even greater. Forecasts of the International Energy Agency and US Energy Information Administration reveal that global energy demand will increase by around 1.75% per annum during 2005-2030, developing countries will become the main source of growth of world energy demand, and energy demand of developed countries will stay at high levels. Although the global demand for resource and energy commodities will continue to grow, based on the discovered reserves or forecasted outputs of such commodities, their overall supply will be able to meet the demand.

However, despite the basic global equilibrium, the distribution of such commodities is highly uneven. Of the 40 main mineral resources, over 75% of 13 kinds of minerals concentrate in three countries, and over 75% of 23 kinds of minerals concentrate in five countries. About 57% of world oil reserves concentrate in the Middle-east, eastern Europe and the former Soviet Union; while 53% of extractable coal concentrate in the US, China and Australia. Among the nonferrous metals, over 50% of copper, lead, zinc, aluminum, gold and silver concentrate in three to give countries. Among non-metal mineral resources, about 75% of kali salt reserves spread over Canada and Russia. Due to the uneven geographical distribution of mineral resources, there is no single country in the world that can meet its economic development demand absolutely with its own resources. Therefore, a global strategy for resource and energy commodities will become an inevitable choice of all countries. Under such global strategies, countries will compete even more fiercely for resource and energy commodities to promote their economic development.

China's voice in the international community will increase accordingly.

5. The economic system reform in China will face challenges; and the adjustment of the interest distribution pattern will be even more difficult.

Due to the expansion of interest distribution gaps among different regions, among rural and urban areas, and among different production factors, income gaps among different regions, among rural and urban areas and among different social classes have also increased. The urban to rural income ratio was 2.6 times in 1990. However, it rose to 3.33 times in 2007, and may expand to 3.36 times in 2008. Regional gaps in China apparently enlarged since the 1990's. The GINI coefficients calculated with non-population-weighted GDP per capita figures rose from 0.276 in 1990 to 0.347 in 2000, and peaked to 0.35 in 2003 before it dropped slightly to 0.316 in 2007[2)]. Regional disparities will remain a major development discord in China both at present and in long time to come.

With regard to factor distribution, the share of labor income in GDP in China is small. It dropped continuously during 1990-2006, from 53% in 1990 to about 40% in 2006. International comparable data also reveal that the share of labor income in China is small[3)]. Estimates based on the average shares during 1960-2005 reveal that the share of labor income in China was 52%, lower than the 61% in America, the 56% in Japan, the 58% in Canada, and the 52% in South Korea, and same as that in Russia. The smaller share of labor income will result in greater income gap.

Income distribution gaps among urban and rural areas, among different regions and among production factors are related to China's development stage and development level, as well as to China's income distribution system, investment system, administrative system, and state asset (resource) management system. As the reforms of these hard-core areas involve more complicated interest relations, they are more difficult to accomplish, and difficult to achieve instant results.

6. Major changes will take place in the structure of production factors that has promoted China's economic growth.

Since the start of the 21^{st} century, China has entered a stage of population growth characterized by low fertility, low mortality, and slow increase. According to some research, total population in China will reach its peak around 2030, and then gradually decrease, shifting from a stage of slow

2) See Li Shantong and Xu Zhaoyuan, the Current Status and Trend of Regional Disparities in China, Issue No. 50, Reports of China Development and Research Foundation.

3) Li Daokui et al, The Evolving U-shaped Rule of Labor Shares in GDP, Economic Research, Issue No. 1, 2009.

growth onto a stage of negative growth[4]. The number of working-age population in China will start to decrease continuously after 2015. In the next 20 years, labor supply in China will therefore come to a turning point, with the ever increasing labor supply starting to shrink gradually.

The higher educational level of labor force will to some extent offset the diminishing supply of labor, or even the resulting consequences. For example, the average years of education of labor force in China was 3.9 in 1978, and 7.5 in 2007. In view of the future development of the compulsory education and vocational education, the average years of education of the labor force in China should be able to reach 10 years.

In terms of capital accumulation, the growth rate was 9.3% before the reform and opening (1952-1978), 10% during 1979-1998, and 13.5% during 1999-2007[5]. Such a high speed of capital accumulation was the result of high savings rate in China. However, the aging of the population may increase the uncertainty of domestic saving. This problem is becoming especially prominent as China has entered a process of rapid population aging. According to the UN forecast, people aged over 65 in China will reach 169 million by 2020, accounting for 11.9% of the total population; while the dependency ratio (i.e. share of elderly to working age population) will reach 17.1%[6], close to the 18.6% of OECD level in 1990, and higher than the levels of its neighboring countries. Population aging will affect the overall national savings rate, and create great pressure on economic development and the social insurance system.

Moreover, along with economic development, the low cost of labor that has been an important factor in attracting the inflow of foreign capital, has risen significantly in some areas and some sectors in China. Consequently, foreign capital may turn to India or other Asia countries, and Latin American countries, thereby further increase uncertainties in capital accumulation in China, and destabilize economic growth.

Economic growth will be increasingly constrained by the inadequate reserves of strategic resources—including water, mineral resources and energy—and the environmental capacity. With a large population and small amount of per capita resources, economic growth in China will be increas-

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4) Wang Dewen, Change of Labor Supply and Demand in Low-fertility Period and Economic Growth in China, Working Pater of the Population and Labor Research Institute of China Academy of Social Sciences.

5) Wang Xiaolu et al, Changing Economic Growth Pattern and Sustainable Growth in China, Economic Research, Issue No. 1, 2009.

6) Cai Fang, Wang Meiyan, "Becoming Old before Becoming Rich" and Labor Shortage, Working Paper of the Labor Economics Research Institute, China Academy of Social Sciences.

ingly constrained by resources and the environment, and face the difficulties of inadequate energy supply, production capacity, transportation capacity, and environmental capacity. Meanwhile, higher resource prices will increase the cost of economic development.

As China works hard to catch to advanced technologies in the world, it faces increasingly fewer late development advantages, and urgently needs more input in independent innovation and reform in the innovation systems. With smooth implementation of relevant measures, it may maintain the past speed of technology progress in future.

II. China's Economic Prospects of 12 th Five-year Plan period through 2030

According to the above analysis, the period from "12th Five-Year" through the next 20 years will be a crucial period for China to establish itself as an economic giant power. During that period China will not only face internal resource constraints and the task of deepening reform, but also a variety of international uncertainties. And there are also many opportunities and challenges. Due to all these factors, China's future economic development is also uncertain. So it's particularly important to choose a right development strategy in this complicated situation. This section uses the scenario analysis method to analyze the economic prospects during 12 th Five-year Plan (FYP) period through 2030, and reveals the major risks which impact China's economic growth as well as the possible policy options.

1. Model introduction

We utilized a CGE model of the Chinese economy developed by the Development Research Center of the State Council of China (DRC-CGE). This model is recursive dynamic. It simulates the dynamic characteristics of economic development between 2008 and 2030 by solving a series of static equilibrium.

The model includes 41 production sectors; 12 representative households by income level: 7 urban households and 5 rural households; and 5 primary production factors: agricultural labor, productive workers, professionals, capital and land. The 41 production sectors include 1 agricultural sector, 23 industrial sectors, 1 construction sector and 16 services sectors. The base year of the model is 2007. The model is calibrated to the 2007 Chinese Social Accounting Matrix (SAM) developed from the 2007 input/output tables.

2. Scenario design

This study adopts scenario simulation method to analyze China's economic growth prospects. A baseline projection scenario is first established to create China's economic development and structural features. This baseline growth scenario is based on past and current development characteristics, taking into account some most possible changes including population, factor endowments and technological progress. Two scenarios are then constructed in accordance with the major risks and policy adjustment faced by China's economic development.

1) Summary of scenario design

Since the thirty years of major economic reforms, China's growth has accelerated dramatically, but it also faces some problems. For example, the pressure of resources and environment grows, industrial structure and the proportion of investment to consumption is uncoordinated, and institutional and technological innovation has yet to be strengthened. The fundamental reason behind those problems is that the transformation of development pattern is too slow and the heavy reliance on low-cost structure to drive growth hasn't been fundamentally changed. So we design the quicker transformation of development pattern scenario and the slower transformation of development pattern scenario in order to focus on studying how the transformation of development pattern influences China's economic and social development and to lay a foundation for the direction and focus of our domestic reform. Those above scenarios are presented in Table 1 below:

Table 1 Scenario Design of China's Future Economic Prospects

	Description
Baseline Scenario (A)	***Business-as-Usual*** 1. Trend in total population exogenous, use of prediction data by UN 2. Level of urbanization and rural and urban population exogenous, 0.9 percentage points rise of urbanization from 2007 to 2020 annually, and 0.7 percentage points growth of urbanization from 2021 to 2030 annually 3. The total labor growth exogenous, and agricultural land supply exogenous 4. All domestic tax rates are fixed at their base-year level, and all transfer of payment exogenous 5. Balance of payment gradually declines to zero from 2010 to 2030 6. Growth rate of government consumption exogenous 7. Total factor productivity (TFP) growth rate exogenous, following the pattern of past 25 years, at about 2 percent[7)] 8. Technological and intermediate input rate changes exogenous
Scenario B	Quicker Transformation of Development Pattern 1. Levy on energy / carbon taxes, and improve energy efficiency. Energy utilization efficiency is 10 percent higher than the baseline in the period 2010～2015, levy carbon tax starting in 2010, gradually increase the tax rate from

7) Under the baseline scenario, the TFP growth rate of manufacturing industry is 0.5-1 percent higher than that of the service industry.

	10 yuan per ton of CO_2 to 50 yuan per ton CO_2, and average energy utilization efficiency is one percent higher than the baseline from 2010 to 2030. Carbon tax revenue is mainly used as an incentive for businesses to improve energy efficiency and high-tech industry to make innovation. 2. Increase government expenditure in education, medical and scientific research and social welfare Adjust the structure of the government's public expenditure and increase the share of education, medical and scientific research and social welfare in the expenditure. 3. Speed up the urbanization process, and gradually remove elimination of barriers to labor transfer Urbanization rate is 0.25 percentage points higher annually than the baseline from 2010 to 2030, and speed up the labor force transfer from rural to urban. 4. Adjust the income distribution system of state-owned and monopoly enterprises Gradually increase the return ratio of state-owned enterprises by 30～40 percent from 2010 to 2030, increase the government's public expenditure, and enhance the government's transfer payments for poor areas and poor people, about 10 to 15 percent higer than the baseline scenario between 2010 and 2030. 5. Improve the services regulatory reforms, and reduce tax burden of this sector Services TFP is 0.9 percentage points higher than the baseline in the period 2010～2015, and gradually reduce this sector's tax burden by 10%.
Scenario C	Risk Scenario 1. The urbanization process and labor force migration slows down Urbanization rate is 0.2 percentage points lower than the baseline between 2010 and 2030 annually, and the transfer of urban and rural labor force is also slower than that of the baseline. 2. The world economy recovers slowly, and trade protectionism rises increasingly Being different from the baseline scenario, in which export demand can be restored to normal in the short-term, international demand for exports from can only be recovered after the 12 th Five-Year; and due to the impact of factors such as the rising trade protection, export growth rate will be below the baseline scenario from 2015 to 2030. 3. International energy prices climb, energy imports are restricted, and international crude oil price returns to above $100 a barrel. 4. Technological innovation and efficiency improvement slow down. then TFP is 0.4 percentage points lower than that of the baseline.

2) Specific Description of each scenario

A: Baseline Scenario

The baseline scenario simulation results show that China's economy will continue the development trend of past period. It is assumed that agricultural labor will continue to steadily migrate to cities, human capital will accumulate gradually, more progress will be made in science and technology, and institutional reform is expected to deepen. Due to the joint influence of these factors, it will result in a more effective and fairer allocation of resources and an annual TFP growth of 2 percent from 2008 to 2030. Urbanization and industrialization will continue to move forward at an average annual pace of 0.85～0.55 percentage points, with the urbanization rate rising to slightly above 47% by the end of "11 th Five-Year", 52% by 2015 and around 65% by 2030. Considering changes in international economic environment and China's comparative advantage, in the baseline scenario, the export growth rate will gradually decrease; trade surplus will continue to exist over the long run, but scales down, basically achieving foreign trade balance through around 2030.

Other important elements of the baseline scenario which influences medium and long-term economic growth and structural change are presented in Appendix 1～4.

B: Quicker Transformation of Development Pattern Scenari.

The Report to the 17 th National Congress of the CPC pointed out: Through the unremitting efforts we have made since the founding of the Pe ople's Republic of China in 1949, particularly since the introduction of the reform and opening up policy, China has scored achievements in development that have captured world attention. But the overall productivity remains low; the capacity for independent innovation is weak; the rural areas still lag behind in development; we face an arduous task to narrow the urban-rural and interregional gaps in development and promote balanced economic and social development the longstanding structural problems and the extensive mode of growth are yet to be fundamentally addressed; we need to thoroughly apply the Scientific Development Approach, pursue comprehensive, balanced and sustainable development, build a resource-conserving and environment-friendly society that coordinates growth rate with the economic structure, quality and efficiency, and harmonizes economic growth with the population, resources and the environment, so that our people will live and work under sound ecological and environmental conditions and our economy and society will develop in a sustainable way. Accelerate transformation of the mode of economic development and promote upgrading of the industrial structure, and this is a pressing strategic task vital to the national economy as a whole. Accordingly, we designed this scenario.

The quicker transformation of development pattern scenario takes into account the situations that institutional reforms move forward smoothly, the market plays a stronger role in allocating resources, the industrial structure is upgraded, and the transformation of economic growth pattern makes progress. So this scenario assumes: ① Prices of various resources are straightened out, the allocation of resources becomes more reasonable, the external cost of economic activities is internalized through tax measures, and enterprises use energy and resource more efficiently. ② Adjust the structure of the government's public spending, and enhance more investment on education, health care, scientific research and social welfare. Many studies have found that less government expenditure on public services is the main reason why households are less willing to spend. Therefore, government spending restructuring helps promote the household consumption and coordinate consumption with the investment structure. ③ Government puts more efforts to further eliminate barriers in the transfer of labor and speed up the urbanization process. Urbanization is an important driving force that promotes optimal resource allocation, economic growth and industrial restructuring. The Central Economic Work Conference in December 2009 took employment and settlement of the rural people, who meet related conditions, in urban areas as an important task to promote urbanization, and decided to ease restrictions on household registration system in small and medium-sized cities and towns. ④ Adjust state-owned enterprises and monopoly enterprises' income distribution systems. In recent years, China's household saving rate has been on the rise. An important reason is that corporate savings rate keeps rising, which is a main cause that economic structure is not optimal. Higher corporate savings rate relates to unreasonable income distribution systems of state-owned enterprises and monopoly enterprises. The model assumes that the higher return ratio of state-owned enterprises is, the more reasonable the national economy structure becomes. ⑤ Give more support to the service industry, further prompting the industrial upgrading. China's service industry has develops slowly, which relates to China's current stage of development as well as many institutional restraints. Market access restrictions mainly exist in basic and monopolistic services, such as finance, railway, highway, aviation, telecommunications, electricity and urban water supply. In this model, higher TFP growth rates and lower tax burden indicate that the service sector speeds up development.

C: Ris. Scenari.

In the future, China will face various difficulties and challenges from both at home and abroad. Particularly, China will face an arduous task to transform domestic growth mode and adjust industrial structure, the pressure on resources and environmental has been very high, and the current economic growth mode is difficult to sustain. So if adjustment and transition don't move forward smoothly, it will lead to huge risks for the economic development. Accordingly, we design the slower transformation of development pattern scenario, which corresponds with the quicker transformation of development pattern scenario. This scenario assumes the following aspects: ① The pace of urbanization is slow. A slower pace of urbanization not only restricts the effective transfer of labor, but also limits urban agglomeration effects and the upgrading of consumption structure and industrial structure optimization. So it doesn't help achieve good and steady economic growth. ② The world economy recovers slowly, trade protection is escalating, and export growth is slow. Export is an important driving force that promotes economic growth. China's export has increased at a rate of above 20 percent annually since 2000, with its share in GDP rising gradually. In 2000, export accounted for 23.3% of GDP (including goods and services). In 2008, it reached 36.9%, a rise of 13.6% during 8 years. As the world economy recovers slowly and trade protection is escalating, the export growth rate may further slow down, which will have a huge negative impact on our economic growth, employment and people's income. Under the case of wide economic growth slowdown, it will be more difficult to adjust and optimize industrial structure. ③ International energy price climbs, and energy imports are restricted. With the rapid development of China's economy in recent years, the level of international reliance on some resources rises continuously. Particularly, China's reliance on imports of crude oil and iron ore is already very high. In 2007, China produced 186 million tons of crude oil and imported 211 million tons of crude oil, with imported crude oil exceeding domestic production. As to other resources, there is a strong demand on iron ore. In 1990, China imported 14.19 million tons of iron ore, increasing to 444.13 million tons by 2008. China's consumption of iron ore increased to 1090.4 million tons from 193.5 from 1990 to 2007. In 2008 China's reliance on imported iron ore reached a record level of 49.5%. Therefore, if the international energy price climbs and energy import becomes restricted, it will be very difficult to develop our economy. ④ Technology innovation and efficiency improvement become slow. Since the reform and opening up, China's production efficiency improved noticeably, greatly promoting economic growth. That is mainly thanks to various reasons, of which two reasons are very important. One is that our technology and management fall short of that of the international, so we can narrow the gap with developed countries by learning new technical skills; the other reason is that with the state-owned enterprise reform and economic development, business management efficiency has been greatly enhanced. However, we can still greatly improve efficiency through institutional reform during the "12th Five-Year" or even over a longer period of time, but it's increasingly difficult for us to achieve more advancements. Accordingly, the technological gap between our enterprises and that of the developed countries are also getting smaller and smaller. Further innovation relies more on the capacity for independent innovation. So if innovation in management doesn't improve, efficiency improvement, development pattern transformation and growth will be slow. As clearly indicated in models, TFP is 0.4 percent lower than the baseline.

3. Simulation results

Based on the previous analysis and assumptions, we design China's economic growth prospects under the above scenarios by DRCCGE.

A) Baseline Scenario

Under the Baseline Scenario assumption, China will maintain its rapid economic growth. According to the current economic growth trend, during the "11th Five-Year" period the average economic growth rate is expected to reach 10 percent. GDP growth rate will be about 7.9 percent during the "12th Five-Year" period, reaching 7.0 percent and 6.2 percent, respectively, for the 2016-2020 and 2021-2030 periods.

Table 2 Projected Economic Growth and Sources under the Baseline Scenario, 2008-2030 (%)

	2008～2010	2011～2015	2016～2020	2020～2025	2026～2030
GDP Growth Rate	8.7	7.9	7.0	6.6	5.9
Including:					
Labor growth rate	0.4	0.5	0.0	0.0	−0.3
Capital growth rate	12.6	9.4	8.4	7.8	6.7
TFP growth rat	0.9	2.0	2.0	1.9	2.0
Source of growth					
Labor	0.2	0.2	0.0	0.0	−0.1
Capital	7.6	5.7	5.0	4.0	4.7
TFP	0.9	2.0	2.0	1.9	2.0

Source : DRC-CGE model results[8)]

The main force driving economic growth from "12th Five-Year" to 2030 is projected to continue to be rapid capital accumulation. The contribution of capital to GDP growth will exceed 65 percent. During the "12th Five-Year" plan period, of an average 7.9% GDP growth, the contribution of capital to GDP will be 5.7 percent, accounting for 71.6% of overall GDP growth. Investment will drive economic growth by 5.0 percentage points from 2016 to 2020, and by 2030 about 4.0 percentage points. In comparison with capital, the contribution arising from the growth of labor supply will be very small. From the period 11 th Five-Year and 12th Five-Year, labor growth will

8) Data in the following tables are all from DRC-CGE model results, if not particularly mentioned.

continue to increase by 0.5 to 0.6 percent annually. In the period 2026-2030, as labor growth declines, its contribution to GDP growth will be close to zero[9].

As to the contribution of factors to economic growth, the contribution arising from the growth of labor supply and capital accumulation will gradually decrease starting from the "12th Five-Year" period, while the share of contribution arising from TFP will increase from 25.6% to 34% or so by 2030.

During the simulation period, the economic growth rate tends to decrease gradually. In addition to the change in labor, capital and TFP, another important reason is that the labor force growth rate grows much more slowly than the rate of capital accumulation. Therefore, if the production efficiency has not been improved significantly in a large-scale economy, the economic growth rate will slow down due to the law of diminishing marginal product and diminishing marginal product of capital investment.

As viewed from the economic scale, at 2008 constant prices, the aggregate GDP will reach 51.86 trillion yuan ($7.46 trillion) by the end of the "12th Five-Year" period. By 2020, GDP will be about 72.83 trillion yuan ($10.48 trillion), reaching 133.69 trillion yuan ($19.2 trillion) by 2030. In 2007, America and Japan's GDP is respectively 13.75 and 4.38 trillion U. S. dollars.

As to per capita GDP, China's per capita GDP will reach $5,000 in 2014, over $5,000 ($5,371) in 2015 and $7,000 in 2020, close to $10,000 in 2025 and $12,300 in 2030.

Table 3 Economic scale and the per capita GDP under the Baseline Scenario (%)

Index	2008	2010	2015	2020	2025	2030
GDP (trillion yuan)	30.07	35.44	51.86	72.84	100.21	133.69
GDP per capita(10 thousand yuan)	2.27	2.63	3.74	5.12	6.94	9.19
GDP(trillion dollar)	4.33	5.10	7.46	10.48	14.42	19.24
GDP per capita(US dollar)	3263	3784	5371	7358	9971	13217

Note: All data is calculated at 2008 constant prices, and the exchange rate between the RMB and U. S. dollar stands at 1 U. S. dollar=6.956 yuan in 2008.

In view of demand, the baseline scenario assumes that as international trade is brought into balance and investment rates decline, the share of household consumption of GDP will rise. In 2008, household and government consumptions' share of GDP was 35.3% and 13.3% respectively, totaling

9) It should be pointed out that the contribution arising from the growth of labor refers only to the labor supply, and the contribution arising from improvements in human capital is reflected in the growth of TFP.

48.6%. By 2015, household consumption's share of GDP will grow to 47.5%, an increase of 12.2 percentage points than that of 2008. By 2020 it will increase to 48.3%, slightly higher than that of 2015, and further to 49.8% by 2030. Higher household consumption ratio serves as an important indication that urban and rural households' living conditions improve. Here are three main factors which promotes household consumption: the household consumption propensity increase; the share of personal income in the distribution of national income rise gradually; non-salary income of households rise. The model assumes that the share of property income of income sources has seen a gradual increase, which is in line with the current regulations proposed by the Central Committee. Another important reason is that with more rapid aging of the population the number of people who has strong ability to save decreases, lowering the overall household savings rate.

Table 4 Structure of GDP by expenditure under the Baseline Scenario, 2007-2030 (%)

	2007	2010	2015	2020	2025	2030
Structure of GDP by expenditure approach						
Household consumption	36.1	40.3	47.5	48.3	49.9	49.8
Government consumption	13.2	13.7	15.0	16.3	17.9	19.7
Gross *capital* formation	42.2	41.3	35.5	34.1	31.2	29.6
Net export	8.6	4.8	2.0	1.3	1.0	0.8

Under the baseline scenario, primary and secondary sectors' shares in the economy will decline, while the tertiary sector will constantly rise, as seen in Table 5. At the slow stage of economic development, it's a universal law that the ratio of the primary sector steadily sinks down, which is the same as other countries around the world. And China's primary sector's share in the economy is expected to decline somewhat, to about 7.8% by 2020 and futher to 5.7 percent,

Table 5 Industrial structure under the Baseline Scenario, 2007-2030, (%)

	2007	2010	2015	2020	2025	2030
Primary sector	11.3	10.4	7.8	5.7	4.5	3.5
Secondary sector	50.0	48.8	47.3	47.1	46.2	45.6
Tertiary sector	38.7	40.8	44.9	47.2	49.3	50.9

The simulation results show that the tertiary sector's share in the economy will gradually rise. In 2007, its ratio was 38.7%, much lower than other countries at the same economic development level. It will grow to 44.9% by 2015, increase by 4.1 percentage points during the "12 th Five-Year" period and 2.3% during the period 2015-2020, and reach 51 percent by 2030. However, comparied with other countries, where the average ratio is about 63%, the ratio is still very low, with per capita GDP staying around $10,000.

According to other countries' economic growth experience, it's a universal law that as the economy develops, nonagricultural sectors' share in the economy, particulary the tertiary sector, will gradually increase. The main driving forces that promote tertiary sector's share to rise are change in household consumption, increased proportion of the tertiary industry, the use of intermediate inputs from other sectors' higher demand for services as well as increased government consumption. Moreover, slower export growth also has a strong influence on the structure of the primary, secondary and tertiary sectors, because China's export goods are mainly manufactured product. Therefore, as other conditions remain unchanged, if export grows fast, it is bound to increase the proportion of the secondary industry.

In view of the change in disaggregrated sectoral structure, within the primary, secondary and tertiary sectors, especially the secondary and tertiary sectors, each sector's share in the economy will change, as seen in Table 6.

First of all, as the technology advances, energy utilization enhances, energy consumption gradually decrease, and energy reliance on other countries rise, the mining sector's share of GDP will decline steadily. By 2015, the added value of mining industry accounts for 4.88% of GDP, 0.38 percentage points lower than the 2007 level and an estimated 0.11 percentage points lower than the 2010 level. Through 2020, the share will be 4.81%, further lower than the 2015 level.

Secondly, within the secondary industry, consumption products and intermediate products's share in the economy will both decline markedly, while the capital products' decline is small. However, compared with the proportion of consumption products, capital products increase significantly. In 2007, capital products' share of GDP within the secondary industry was 13.68%, higher than that of the consumption products (9.07%). As the economy develops continously, the proportion of capital products will decrease slightly, while the proportions of consumption products and intermediate products'decrease significantly. According to standards proposed by Hoffman, by 2030 the proportion of China's capital products will be much higher than consumption products, basically achieving the industrialization process[10].

Table 6 Change in Sectoral Structure of China under the Baseline Scenario, 2007-2030)

proportion of GDP	2007	2010	2015	2020	2030
Primary industry	**11.29**	**10.35**	**7.81**	**5.69**	**3.53**
Secondary industry	**49.96**	**48.83**	**47.27**	**47.09**	**45.58**
Mining	**5.26**	**4.99**	**4.88**	**4.81**	**4.64**
Coal	1.72	1.51	1.47	1.42	1.26
Crude oil and natural gas	2.15	2.09	2.10	2.10	2.11
Metal ore mining	0.83	0.83	0.79	0.78	0.79
Nonferrous mineral mining	0.55	0.55	0.52	0.51	0.48
Manufacturing	**39.36**	**38.19**	**37.08**	**36.66**	**35.32**
Consumer goods	**9.07**	**8.96**	**8.58**	**8.25**	**7.76**
Food	3.52	3.47	3.34	3.19	2.95
Textile	1.79	1.65	1.45	1.31	1.14
Apparel	1.49	1.54	1.57	1.56	1.56
Sawmills and furniture	0.96	0.97	0.90	0.87	0.81
Paper, printing and related	1.31	1.32	1.32	1.32	1.30
Intermediate goods	**16.61**	**15.57**	**15.10**	**14.89**	**14.13**
Petroleum	1.35	1.23	1.23	1.22	1.16
Chemicals	4.77	4.57	4.29	4.05	3.64
Nonmetal mineral products	2.27	2.21	1.99	1.95	1.76
Metals smelting and pressing	4.36	4.00	3.69	3.57	3.26
Electricity, gas and water	3.87	3.56	3.90	4.10	4.31
Capital goods	**13.68**	**13.66**	**13.40**	**13.52**	**13.43**
Metal products	1.40	1.32	1.26	1.26	1.20
Machinery and equipment	3.34	3.38	3.22	3.27	3.31
Transport equipment	2.32	2.50	2.53	2.67	2.94
Electric equipment and machinery	1.72	1.73	1.72	1.72	1.62
Electronic, telecommunications equipment	2.54	2.50	2.52	2.54	2.51
Instruments	0.40	0.38	0.39	0.40	0.38
Other manufacturing	1.96	1.86	1.76	1.67	1.47
Construction	5.34	5.65	5.31	5.61	5.61
Tertiary industry	**38.75**	**40.82**	**44.91**	**47.23**	**50.89**
Transport, post and telecommunication, Finance and insurance	12.88	12.84	13.79	14.38	15.14
Other services	25.86	27.98	31.12	32.85	35.75

10) German economist Hoffman summed up the changes within the secondary industry and found that any country will go through four stages during the process of industrialization, which is called as the Hoffman Four-stage industrialization experience in the economic field. The four stages are: (1) the consumer goods industry is dominant; (2) the capital goods industry increases faster than the consumer goods industry, reaching around 50 percent of the net output of consumer goods industry; (3) the capital goods industry continues to grow rapidly, keeping balance with the consumer goods industry; (4) the capital goods industry dominates. The proportion of capital goods output to consumer goods output can be used to study the stage where a country or region's industrialization stays, and this proportion is also known as Hoffman ratio.

As the industrial structure is being adjusted, the proportion of high energy-consuming industry within the manufacturing will drop. For a long time, a major problem faced by China's economy is that the mode of growth is yet to be fundamentally addressed and high energy-consuming industry's share is very big. However, since the "11th Five-Year", the central government has paid more attention to energy and environmental conservation, setting a binding target of cutting energy consumption per unit of GDP by 20%. From "12th Five-Year" to 2020, the central government set a new target of greenhouse gases reducing emissions, which makes it necessary to adjust the industrial structure and reduce the proportion of high energy-consuming industry. Under the baseline scenario, compared with 2007, the proportion of high energy-consuming industry will see a drop of 1% in 2015. And compared with 2015, it will remain generally stable in 2020, as seen in Table 7.

Table 7 Change in industrial structure by energy consumption under the Baseline Scenario, 2007-2030 (%, share in the value added in manufacturing industry)[11)]

	2007	2010	2015	2020	2030
High energy-consuming industry	45.54	44.21	44.29	44.20	43.67
Low energy-consuming industry	54.46	55.79	55.71	55.80	56.33

As the industrial structure changes, the structure of employment will also undergo dramatic adjustments. The movement of labor out of agriculture and other primary industries will be fairly rapid through 2030. The proportion of employment in the primary sector is projected to drop to 38.4% by 2010, to 33.8% by 2015, and further to 20.6% by 2030. Correspondingly,

11) Energy consumption levels are divided by the total energy consumption of various disaggregated manufacturing industries and the energy consumption per unit output conducted by total output value released by the National Bureau of statistics of China (2007). Low energy-consuming sectors include: processed food from agricultural products, tobacco, textiles and garments, shoes, hat manufacturing, leather, fur, feathers (velvet) and its products, furniture, printing and record medium reproduction, social articles and sporting goods, general equipment, transport equipment, electric equipment and machinery, communication equipment, computers and electronic equipment, instruments, and cultural and office appliances; medium energy-consuming sectors include: nonferrous mineral mining, food, beverage, textiles, sawmills, *bamboo*, cane, palm and straw products, medicine, chemical fibers, rubber, plastics, metal products, special equipment, crafts and other manufacturing industries; high energy-consuming sectors include: coal mining, crude oil and natural gas, ferrous ore mining, nonmetal mineral products, other mining, papermaking and *paper* products, petroleum processing, coking and *nuclear* fuel processing, raw *chemical* materials and *chemical* products, nonmetal mineral products, metals smelting and pressing, nonferrous mineral smelting and pressing, production and distribution of gas and *water*.

urbanization will continue to move forward. But to a large extent, the pace of urbanization depends on the policy support. The model assumes that about 3.5 to 6 percent of the transferred labor will become rural people each year. If this growth rate continues, urbanization rate is projected to be 51.1% by 2015, and increase by 4.5% during the "12 th-Five-Year", reaching 56.5% by 2020. During the period "13th-Five-Year", it will rise about 5.4% and reach around 64% by 2030, about 16 percentage points higher than the 2010 level. From 2010 to 2030, the average annual urbanization rate will be about 0.8 percent.

Table 8 Change in Employment Structure under the Baseline Scenario, 2007-2030 (%)

Year	2007	2010	2015	2020	2025	2030
Primary industry	40.8	38.4	33.8	28.9	24.9	20.6
Secondary industry	26.8	27.1	27.4	28.9	29.8	31.0
Tertiary industry	32.4	34.5	38.8	42.2	45.3	48.4

As the economy grows fast, incomes will also gradually rise. In the baseline scenario, per capita income in urban areas will be 33,500 yuan by the end of the "12th-Five-Year", nearly 70% higher than the 2007 level. And the average net income of rural households will reach above 7,200 yuan per person, about 60% higher than the 2007 level. But the urban-rural income gap is widening. The income ratio of urban and rural residents will rise from 4.29 to 4.61 between 2015 and 2020, further to about 4.9. That shows as the current growth mode continues, the urban-rural gap is likely to continue to expand, and the economic development is still not balanced.

Table 9 Change in Urban and Rural Household Income under the Baseline Scenario (yuan)

	2007	2010	2015	2020	2025	2030
Baseline Scenario						
Urban	19821	24547	33496	44227	57743	73836
Rural	4602	5723	7268	9010	11564	14675
Urban/Rural	4.31	4.29	4.61	4.91	4.99	5.03

Note: Data were calculated at 2007 prices.

Finally, in the baseline scenario, China's energy consumption will have a vigorous growth. The proportion of China's industry in the economy is still comparatively high for quite a long time, and the economy grows fast. Therefore, although there is great potential for improving the energy utilization effciency, the per unit of GDP energy consumption will decline from 1.23 tons of standard coal equivalent per 10,000 *yuan* output value in 2005 to 0.95 and 0.89 in 2015 and 2020. But the total energy consumption will rise to 41.25 million tons in 2015 and 54 million tons in 2020 from 26.56 million tons in 2007. During the period "12th-Five-Year", the total energy consumption is expected to increase by around 36.6%, and the estimated total energy consumption in 2010 is 30.2 million tons. Correspondantly, the total energy emissions will also continue to increase from 66.24 million tons in 2007 to 96.20 million tons in 2015 and further to 123 million tons by 2020—about 26 millions tons higher than the 2015 level, reaching 182.6 million tons by 2030. According to the baseline scenario assumption, the greenhouse gases emissions per unit of GDP is projected to be reduced from 3.07 tons for each 10,000 yuan in 2005 to 2.01 tons for each 10,000 yuan in 2020, cutting the emission intensity by 34.5%. This also indicates that if the current economic trend continues, China's total energy demand will increase, and pollution emission is also projected to substantially exceed the carrying capacity of our resources and environment. So this kind of growth will definitely be of poor quality and unsustainable.

Table 10 Energy Consumption and Greenhouse Gases Emissions (Baseline Scenario)

	2005	2007	2010	2015	2020	2025	2030
Greenhouse gas (CO_2)							
Emission (million ton)	5625.6	6623.9	7242.3	9620.9	12270.3	15170.3	18205.6
Emission intensity (ton per 10,000 yuan GDP)	3.07	2.86	2.44	2.22	2.01	1.81	1.63
Energy							
Consumption (10,000 tons of standard coal equivalent)	224682	265583	301995	412496	539889	686634	842121
Emission intensity (ton of standard coal equivalent per 10,000 yuan GDP)	1.23	1.15	1.02	0.95	0.89	0.82	0.75

Note: GDP calculated at 2005 prices.

B) Quicker Transformation of Development Pattern Scenario

The quicker transformation of development pattern scenario is quite different from the baseline scenario in many aspects, such as the growth rate, the sources of growth and industrial structure.

Table 11 shows that under the quicker transformation of development pattern scenario, China can still maintain a high growth rate, "Shier Wu"

Table 11 GDP Growth Rate (Scenario B: Quicker Transformation of Development Pattern) (%)

	2008～2010	2011～2015	2016～2020	2021～2025	2026～2030
GDP Growth Rate:	8.7	8.4	7.2	6.6	5.8
Including:					
Labor growth rate	0.4	0.5	0.0	0.0	−0.3
Capital Growth Rate	12.6	9.2	7.5	6.8	5.5
TFP growth rate	0.9	2.7	2.7	2.6	2.6
Source of growth					
Labor	0.2	0.2	0.0	0.0	−0.1
Capital	7.6	5.5	4.5	4.1	3.3
TFP	0.9	2.7	2.7	2.6	2.6

period than the baseline scenario growth rate of about 0.5 percentage points year period 2010-2030 the overall growth rate is slightly higher in the baseline scenario. Rapid changes in the development of hair scenarios, according to 2008 prices by 2015, GDP reached 53 trillion yuan (7.63 trillion U.S. dollars) in 2020 was 75.0 trillion yuan (10.79 trillion U.S. dollars) in 2030 reached RMB 137 trillion (19.71 trillion U.S. dollars), respectively, higher than the baseline scenario 1.18,2.14, and 3.28 trillion yuan).

Also you can see that rapid changes in mode of development scenarios GDP growth started to occur in the basic nature of the source of change from relying solely on the past, driven by high investment into investment-led and technology and efficiency improvements simultaneously, and increasing the contribution of technological improvements. This is in the requirements of sustainable development, but also change the mode of development of an important feature. Simulation results show that by 2030 half of the GDP growth will come from total factor productivity improvements. Improvements in total factor productivity comprehensive reflection of the technological innovation, productivity improvement, efficient use of energy resources and human capital upgrading and other factors.

Table 12 Structure of the Three Strata of Industry under the Optimistic Scenario (%)

Year	2007	2010	2015	2020	2025	2030
Primary industry	11.3	10.4	8.2	6.1	4.9	3.9
Secondary industry	50.0	48.8	45.0	43.1	40.7	38.7
Tertiary industry	38.7	40.8	46.8	50.8	54.4	57.4
Total	100	100	100	100	100	100

Compared with the baseline scenario, the ratio of the service industry is higher under the quicker transformation of development pattern scenario. For example, the ratio will reach 46.8% and 50.8% by the end of the 12th Five Year and 2020, 1.9 percentage points and 3.6 percentage points higher than under the baseline scenario, respectively. The above conclusion reflect the key characteristic of the transformation of China's development pattern, i.e. the industrial structure will be gradually optimized with the transformation of relying on rapid development of the manufacturing into the coordinated development of the manufacturing and service industry. With the structural change in the three strata of industry, the employment strucuture changes accordingly. Compared with the baseline scenario, the ratios of the service industry employment in 2015 and 2020 are 2 and 4 percentage points higher, respectively. The rapid development of the service industry provides lots of employment opportunities for rural labor, and thus accelerates the process of rural-urban migration and significantly promotes the urbanization level.

At the same time, under the quicker transformation of development pattern scenario, the industrial structure within the manufacturing sector is more optimized, with the decrease in the proportion of high energy consumption industries and the increase in the proportion of low energy consumption industries. The manufacturing industry has become a high value-added one relying on technology and innovation, rather than on low cost and low added value in the past, and gotten rid of the heavy reliance on resources and the accelerated destruction of the environment. Its position in the global industrial chain has also been upgraded.

Table 13 Industrial Structure within the Manufacturing Industry under the Quicker Transformation of Development Pattern Scenario

	2007	2010	2015	2020	2030
High energy-consuming industry	45.5	44.2	44.0	43.6	42.4
Lowe energy-consuming industry	54.5	55.8	56.0	56.4	57.6

Under the quicker transformation of development pattern scenario, the structure of investment, consumption, import & export are more balanced. As indicated by Table 14, the ratio of household consumption will reach 49.7% in 2015 and 51.9% in 2020, 3 and 11.8 percentage points higher than under the baseline scenario. The proportion of investment will decrease from 42.2% in 2007 to 33.3% in 2015 and 31.4% in 2020, 3.4 and 5.5 percentage points lower than under the baseline scenario. Under the quicker transformation of development pattern scenario , the role of consumption in driving the economic growth will be significantly enforced, the proportions of the three demands are more balanced, and households can benefit more from the economic growth. The above results reflect another important characteristic of the transformation of development pattern: the investment and export-driven mode in the past has been transformed into the coordinated mode driven by consumption, investment and export, and especially the role of consumption has become more and more important.

Table 14 Structure of GDP by Expenditure under the Baseline Scenario, 2007-2030 (%)

	2007	2010	2015	2020	2025	2030
Household consumption	36.1	40.1	49.7	51.9	54.5	55.6
Government consumption	13.2	13.7	14.8	15.8	17.0	18.2
Gross capital formation	42.2	41.4	33.3	31.4	27.8	25.7
Net export	8.6	4.8	2.3	1.0	0.7	0.6

The transformation of development pattern also requires that the widening trend of urban-rural gap should be stopped and even be reduced. As shown by Table 15, the rural household income has risen more rapidly under the quicker transformation of development pattern scenario. The urban-rural household income ratio has increased from 4.31 in 2007 to 4.39 in 2015 and 4.45 in 2020, but dropped to 4.04 in 2030, much lower than the ratio of 5.03 under the baseline scenario.

Table 15 Urban and Rural Households Incomes under the Quicker Transformation of Development Pattern Scenario

	2007	2010	2015	2020	2025	2030
Urban	19821	24547	35145	46776	61223	78010
Rural	4602	5723	8011	10519	14273	19318
Urban/Rural	4.31	4.29	4.39	4.45	4.29	4.04

Under the quicker transformation of development pattern scenario , the energy consumption are more frugal and the problem of environmental protection are less serious, due to the optimized adjustment of industrial structure and the improvement of production efficiency. This reflects one key characteristic of the transformation of development pattern: the solely emphasis on economic development has been shifted to the coordinated development of economy, resources and environment. The total energy consumption will reach 3.55, 4.04 and 5.11 billion tons of standard coal equivalent by the end of 2015, 2020 and 2030, 0.57, 1.36 and 3.31 billion tons less than under the baseline scenario, respectively. The emission intensity of greenhouse gas will decrease to 1.36 tons per 10,000 yuan in 2020, 55.7% lower than in 2005. Therefore, if the pace of transforming the development mode is accelerated, we can reduce the harm of economic developemnt to the resources and environment to the greatest extent, and better protect our earth.

Table 16 Energy Consumption and Greenhouse Gases Emission under the Quicker Transformation of Development Pattern Scenario

	2005	2007	2010	2015	2020	2025	2030
Greenhouse gases (CO_2)							
Emission (million tons)	5625.6	6623.9	7242.3	7815.1	8286.8	8899.8	9628.5
Emission intensity (ton per 10,000 yuan GDP)	3.07	2.86	2.44	1.80	1.36	1.06	0.86
Energy							
Consumption (10,000 tons of standard coal equivalent)	224682	265583	301995	355235	403889	458489	510692
Emission intensity (ton of standard coal equivalent per 10,000 yuan GDP)	1.23	1.15	1.02	0.82	0.66	0.55	0.46

Note: Energy intensity and emission intensity are both calculated at 2005 price level.

In all, our simulation results suggest that if the Scientific Outlook on Development can be really applied and the development mode can be transformed, the economy will grow steadily at a rapid rate, the driving force of sustainable economic development will be much stronger, the industrial structure will be more optimized, the proportions of consumption and investment will be more balanced, the urban-rural development will be more coordinated, and the relationship between economic development and resources and environment will be more harmonious.

C) Scenario C: Risk Scenario

Table 17 shows the economic growth under the slower transformation of development pattern scenario , starting from the "12th-Five-Year" period the economic growth rate will decline significantly, with an average annual decrease of about 0.9, 1.3 and 1.5 to 1.6 percent during the periods 2011-2015, 2016-2020 and 2020-2030. This is mainly due to the decline of TFP and investment rates.

Table 17 GDP Growth Rate under the Scenario C

	2008～2010	2011～2015	2016～2020	2021～2025	2026～2030
GDP Growth Rate	8.7	7.0	5.7	5.1	4.3
Including:					
Labor growth rate	0.4	0.5	0.0	0.0	−0.3
Capital growth rate	12.6	9.2	6.9	6.1	4.9
TFP growth rate	0.9	1.3	1.6	1.4	1.5
Sources of growth:					
Labor	0.2	0.2	0.0	0.0	−0.1
Capital	7.6	5.5	4.1	3.7	2.9
TFP	0.9	1.3	1.6	1.4	1.5

Under the slower transformation of development pattern scenario , the ratios of the primary, secondary, and tertiary sectors will be 8.1:46.2:45.7 in 2015, which is different from the baseline scenario, in which the ratios is projected to be 7.8 : 47.3 : 44.9. Therefore, the proportion of agriculture is higher while that of the service industry is lower under this scenario.

Except for the structural change in the three strata of industry, the structural adjustment within the manufacturing industry is also much slower. The share of high energy consumption sectors in the manufacturing industry is 45.21% in 2015 and 45.12% in 2020, 0.92 and 0.9 percentage points higher than under the baseline scenario.

Table 18 Industrial Structure within the Manufacturing Industry under the Risk Scenario (%, share in gross output value of manufacturing industry)

	2007	2010	2015	2020	2030
High energy-consuming industry	45.54	44.26	45.21	45.12	44.81
Low energy-consuming industry	54.46	55.74	54.79	54.88	55.19

Finally, although the economic growth rate is slower under the slower transformation of development pattern scenario, the total energy consumption will grow rapidly due to the low energy utilization efficiency. On the other hand, the energy intensity under the slower transformation of development pattern scenario is also significantly higher than under the optimistic one. The energy intensity is 0.92 tons of standard coal equivalent per 10,000 yuan under the slower transformation of development pattern scenario, 0.1 tons higher than under the quicker transformation of development pattern scenario.

Table 19 Energy Consumption and Greenhouse Gases Emission

	2005	2007	2010	2015	2020	2025	2030
Greenhouse gases (CO_2)							
Emission (million tons)	5625.6	6623.9	7244.1	9299.7	11073.8	12652.6	13880.0
Emission intensity(ton per 10,000 yuan GDP)	3.07	2.86	2.44	2.14	1.82	1.51	1.24
Energy							
Consumption (10,000 tons of standard coal equivalent)	224682	265583	301867	400025	488702	574140	644187
Emission intensity (ton of standard coal equivalent per 10,000 yuan GDP)	1.23	1.15	1.02	0.92	0.80	0.68	0.58

III Major Conclusion and recommendations

With over 30 years of rapid development after reform and opening, the aggregate size of the Chinese economy has become the third largest in the world. China's GDP per capita has amounted to US$3000, the proportion of its non-agriculture industries has reached a high level, its industrialization and urbanization have developed remarkably, its products have become competitive to certain extent in the world, and its various infrastructures have been developed and improved. It has, thereby, laid a solid foundation for future development. At present, economic growth in China has entered a new stage. By using the DRCCGE model, this article tried to simulate and analyze the economic development scenarios and key issues during 2009-2030, and has come to some major conclusions and recommendations as stated below.

1. The Chinese economy still has the potential to maintain rapid growth in the mid- and long-term.

Although the international financial crisis in 2008 brought about negative impact on economic development in China, the main impetus leading to continuous and fast economic growth still remain. During the 12th FYP period, the rate of economy growth is expected to reach 7.9%, which is close to 8%. The rate of growth is expected to stay at around 7.0% per annum during 2016-2020, and around 6% till in 2030. Based on constant prices of 2008, the total amount of GDP in China will reach USD 7.46-7.63 trillion by 2015; hence becoming the second largest in the world. GDP per capita will be over USD 5000 by 2015, over USD 7000 by 2020, and around USD 10000 by 2025. Comparisons reveal that total GDP in the US reached USD 14.20 trillion in 2008, while total GDP in China was 23.8% of that of the US. If the US maintains an annual growth rate of around 2.8%[12], this proportion will rise to 43.3%, 53.0% and 73.8% by 2015, 2020 and 2030, respectively (without taking account of changes in exchange rates).

2. In the mid- and long-term, the main constraints to economic growth include ever growing pressures from resources and the environment, and weak coordination in economic development.

Even if China cannot quickly change its development pattern, with the current development trend, it may still achieve rapid economic growth in the mid- and long-term. However, its total energy consumption will continue to grow, as well as its emissions of greenhouse gases and environmental pollutants. In the baseline scenario, total energy consumption in China will exceed 4 billion tons of standard coal in 2015, a growth of more than 50% over 2007. It will reach 5.4 billion tons of standard coal in 2020 and 8.4 billion tons of standard coal in 2030, which is more than three times of that in 2007. The resulting emission of various pollutants — such as SO_2, powder dusts and soot — will further increase, creating more pressure on the environment in China. On the other hand, the ever increasing energy consumption, especially oil consumption, will also create pressure on resource supply; hence increase threat to economic security.

Based on the current growth trend, industrial restructuring will upgrade slowly, consumption and investment restructuring will also be slow, the gap between urban and rural incomes will continue to expand, and economic growth will suffer from lack of coordination. The weak coordination is reflected mainly in the following areas: the key impetus of economic growth still come from investment in fixed asset; due to low resource prices, efficiency in resource utilization increases slowly; as government expenditure on public services remain insufficient, household savings stay high, and consumption level increases only slowly, hence unable to push economic growth; many obstacles affecting labor movement and farmers' migration to cities will remain, and urbanization speed will be slow, restricting cities to play their role in promoting economic growth. The lack of coordination is reflected in many ways, but the root is in the current extensive economic development mode. Therefore, in the mid- and long-term, substantial change in the development pattern is the key to achieve better and faster economic development.

Adopting various comprehensive measures to quickly change the

12) The forecasts by Deutsche Bank (2006) and the World Bank (2006) was 3.1%, the forecast by Sandra Poncert (2006) was 2.8%, and the forecast by John Hawksworth (2006) was 2.4%.

development mode will promote economic growth, as well as strengthen development coordination, better optimize industrial structures, minimize gaps between urban and rural areas, and significantly reduce resource consumption and pollutant emission. In contrast, if the development mode changes slowly, it will not only affect economic growth, but also its quality and coordination.

3. Further deepening the reform and promoting the change of the development pattern are key to achieve better and faster development.

From the long-term point of view, to prevent various internal and external negative and risk factors, the most important measures include further deepening the reform, promoting substantial changes in economic development pattern, and establishing a new development pattern which is highly energy-saving and efficient, so as to reduce pressure on resources and the environment from economic and social development.

First of all, it is necessary to adopt various measures, especially taxation and price adjustment measures, to increase resource efficiency. China is a very populous country with insufficient resources per capita and limited environmental capacity. Therefore, it is especially important to continuously improve energy and resource efficiency. To increase energy efficiency, it is necessary to take coordinated efforts in various areas, including reducing backward production capacity, optimizing industrial structure, and promoting public awareness, especially using taxation and price instruments, such as levying carbon taxes and adjusting pollution charges. It is necessary to use prices to guide enterprises and households to save energy and reduce consumption of energy, and promote research and marketing of relevant innovative technologies. It is necessary to further rationalize and perfect the pricing system of major resources, and let price mechanism play its guiding role in adjusting resource development and utilization by adjusting the prices of major resources, especially the scarce resources. It is also necessary to establish a legislation and policy supporting system that promotes the development of a recycling economy, so as to increase resource efficiency.

Secondly, it is necessary to adjust the structure of government expenditure, increase the proportion of government spending on public services such as education, medical-care and public health, complete the social security system, and increase the level of social security. Increasing the level of social security can directly increase the level of services related to households, and reduce their sense of uncertainty for the future, hence reduce savings rate and increase consumption, enhance the quality of people's life, and promote coordinated development of consumption and investment.

Moreover, it is necessary to enhance the quality of urbanization, and appropriately accelerate the speed of urbanization. Over many years of development, the number of rural excessive labor in China has continued to drop, labor relocation has become increasingly difficult, and the role played by labor relocation and optimization as well as urbanization in promoting economic growth has diminished. However, as the quality of urbanization in China is relatively low, there is still a great number of rural excessive labor in absolute terms. Therefore, it is necessary to speed up the transition of migrant workers to city dwellers and enhance the quality of urbanization. Further reducing the barriers to labor relocation and promoting job creation will enhance the quality of life of citizens, and promote continued economic development as well.

Furthermore, it is necessary to deepen the reform of state-owned enterprises (SOEs) and monopoly sectors, and adjust the irrational income distribution system. In recent years, one of the major reasons of the continuous increase in saving in China is that although the profitability of enterprises, especially that of the SOEs, has increased, they have only handed over very few to the government. As a result, a large amount of incomes from state assets that should be used by the whole people or the government was held up and used by the SOEs themselves, thus disproportionally increased enterprise savings rate. Therefore, it is necessary to increase the proportion of hand-over profits by SOEs, reduce enterprise savings, and promote economic restructuring.

Finally, it is necessary to further perfect the reform of the service industries, strengthen support to the service industries, and promote the rapid development of the service industries. The development of the service industries can help optimize the economic restructure, promote employment and reduce resource consumption. In the area of market entry, it is necessary to allow private capital and social capital to enter the basic and monopolized sectors such as the finance, railway, road, aviation, telecommunication, power and urban water supply. In the areas of public finance and taxation, it is necessary to further reduce various irrational fees, promote tax system reform, and reduce the taxation burden of the service industry. It is necessary to accelerate the reform and development of productive service sectors, such as the finance, the telecommunications and the logistics sectors, and it is necessary to actively undertake the transfer of international service industries and promote the export of the service industries.

Experiences in Modelling National Economy

Mariusz Plich
University of Lodz, Poland

Abstract

The acronym NAMEA means National Accounting Matrix including Environmental Accounts. NAMEA was originally developed by Statistics Netherlands in the end of the 1980 s. It is a framework in which economic and environmental data, which normally are separate parts of statistical system, are consistently organized. NAMEA not only provides integrated summary picture of economy-environment interface, but also allows analytical investigations based on statistical, econometric as well as input-output approach. In this paper we present the design of NAMEAs for Poland, constructed by the author. The matrices have been used to carry out sectoral studies of environmental pressure in the Polish economy as well as to assess the directions and strength of structural changes resulting in the reduction of air emissions. The results of these studies are also presented in this paper.

1. Introduction

NAMEA (National Accounting Matrix including Environmental Accounts) has been developed by Statistics Netherlands at the end of the 1980 s (Haan et.al. 1994, Keuning S.J. & Steenge 1999). It is a framework in which economic, energy and environmental (E 3) data, which normally are separate parts of statistical system, is consistently organized. The core of the framework are tables containing economic data from national accounts, presented in a matrix form and expressed in money terms. The environmental accounts consists of tables with data which are usually expressed in physical units. The hybrid structure cause, that there are no limits on kind of energy and environmental data being put to NAMEA. In particular, all kinds of data on emissions (to air, to water and soil), supply and use of energy as well as environmental assets, like subsoil assets or forests, can also be included.

The consistency of E 3 data in NAMEA allows for calculating different indicators. For example, the Netherlands has a system of Environmental Policy Performance Indicators within 7 themes and goals set for each of these. The themes are: climate change, stratospheric ozone depletion, acidification, eutrophication, dispersion of toxic subs, disposal of solid waste, disturbance of local environments, but the most advanced area of compilation of environmental part of NAMEA concerns air emissions.

A database including such accounts — with substances measured in physical units — make it possible to investigate interactions between economy and environment. NAMEA not only provides integrated summary picture of economy-environment interface, but also allows analytical investigations based on statistical, econometric as well as io models. Time paths of the NAMEAs indicators can be helpful in assessing the results of the environmental policy aimed at reducing human pressure on the environment, which is now at the center of international interest. Input — output techniques are widely used in economic-ecological models because of their smplicity and clarity of depiction of links between elements in complex systems. The possibility of dividing economy as well as environment into many sectors is the most important however.

The high usefulness of NAMEAs to analyze the impact of economic policies on the environment, which is one of the focal points of EU policies, caused that now all EU Members States are involved in the compilation of air emissions for NAMEA and reporting it to Eurostat. The original Dutch NAMEA is based on matrices that cover production and distribution issues, but Eurostat recommends a simplified approach based on supply-use or input-output tables for this purpose (see Eurostat 2009). In the data reported to Eurostat using standard tables, time series covering from half to almost all the 1990 s for 8 of the most common atmospheric pollutants, including 3 greenhouse gases, 3 acid rain precursors are available. In table 1 the full list is presented.

Table 1. Air emissions reported to Eurostat

Symbol	Name of pollution
CO2	Carbon dioxide
CO2_BIO	Carbon dioxide from biomass used as a fuel
N2O	Nitrous oxide
CH4	Methane
SOX	Sulphur oxides
NOx	Nitrogen oxides
NH3	Ammonia

Symbo	Name of pollution
NMVOC	Non-methane volatile organic compounds
CO	Carbon monoxide
PFC	Perfluorocarbons (CO 2 equivalent)
SF6	Sulphur hexafluoride
HFC	Hydrofluorocarbons (CO 2 equivalent)
PM10	Particulates < 10 μm

Efforts by Eurostat, in order to systematically collect data in the form of NAMEAs are still in the initial phase and some of EU Member States have very little experiences in compilation of the matrices. This cause, that "Data quality depends on the reporting country. Especially the 'big' member states such as DE, IT, FR, UK, or ES deliver data of high quality. In other cases, such as PL, the quality leaves a lot to be desired[1)]."

In Poland, the institution responsible for drawing up the NAMEA is the administrator of the National Emissions Trading Scheme (Polish acronym of that name sounds KASHUE). In 2009, this institution has developed Polish NAMEAs for the period 1995-2006, prepared in the form required by Eurostat. But they are not released to the public in Poland, although they are available on request. NAMEAs are not yet available on Eurostat's website (this applies to all EU countries). Although we received Polish NAMEAs directly from KASHUE, however due to the above-mentioned problems of quality in this study, we decided to use our own estimates of NAMEAs, covering the years 1993-2005.

The next section of the paper presents the construction of NAMEAs, used in our study, while the last two sections have been devoted to the presentation of these studies.

2. NAMEAs for Poland

The first NAMEA for Poland has been presented during the Montreal IIOA conference in 2002 and then published (Plich 2003). It has concerned the year of 1995. Later, time series of NAMEAs from 1993 to 2005 has been built. Principles of their construction have been presented in Plich 2008. In this chapter an idea of NAMEAs is shown and NAMEA for 1995 is used as an example.

In order to compile NAMEAs three different sources of data were used, i.e. economic, energy and environmental data. Polish NAMEA has been based on the Danish solution (Jensen & Pedresen, 1998) which is close to Eurostat recommendations. This particularly means that it is centered around the input-output table. The matrix is extended by adding rows and columns to show nonrenewable domestic energy resources, energy use and air emissions caused by it. Due to the different systems of classification and levels of aggregation used in the source data, sectoral classification of the NAMEA

1) Citation form Eurostat website on the EDCNRP database - Environmental Data Centre on National Resources and Products from August 10, 2010: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/EDCNRP_-_Eurostat_-_NAMEA_Air#Spatial_coverage

had to be limited to 19 production sectors plus households (see appendix), 7 types of air emissions, 21 energy carriers and 4 types of nonrenewable energy resources: hard and brown coal, crude oil and natural gas.

Emissions represented in the Polish NAMEAs concern the following 7 gases : carbon dioxide, nitrous oxide, methane, sulphur dioxide, nitrogen oxides, ammonia and non methane volatile oxygen compounds. Within NAMEAs different types of emissions are transformed into two indicators called Global Warming Potential (GWP) and Potential Acid Equivalents (PAE), which represent two environmental themes, i.e. the greenhouse effect and acidification. For GWP and PAE calculations, the same weighting factors as in Denmark are used - see table 2.

Table 2. GWP and PAE weighting factors[2)]

Theme	Greenhouse gases			Acid gases		
	CO 2	N 2 O	CH 4	SO 2	NOx	NH 3
GWP	1	310	21	•	•	•
PAE	•	•	•	1/32	1/46	1/17

Source : Jensen and Pedersen 1998.

Data on nonrenewable energy resources given in statistical yearbooks in natural units has been converted into energy units (PJ) using power values used in energy balances (see table 3).

Table 3. Heating values of prime energy carriers applied to NAMEA.p 1[3)]

Type of carrier	Heating value	Unit
Hard coal	22	$PJ/10^6$ t
Brown coal	9	$PJ/10^6$ t
Natural gas	30	PJ/km^3
Crude oil	42	$PJ/10^6$ t

Source: Energy statistics 1997.

Table 5 shows NAMEA'95. In the table economy is aggregated to 8 sectors shown in the table 4. The use of most of the energy carriers have been aggregated in the matrix as well - only the carriers corresponding to the nonrenewable energy resources are retained in the original form - their

2) More information on this subject, presented in a broader context than here, can be found in OECD 2004.

3) The average heating values change over time (see for example Energy Statistics 2008: 25). The values used in Polish NAMEAs base on numbers given in Energy Statistics 1997.

shares in the energy balance for Poland are high. Wood and Waste make up the group called "Renewable". All secondary energy carriers create one group called "Secondary".

Table 4. Classification of sectors in NAMEA'95 applied for presentation

No.	Sectors of NAMEA(8)	
	Abbreviation	Contents (sectors of NAMEA(19))
1	Agriculture	Agriculture
2	Mining	Coal, OilGas, NEnMining
3	RafChMin	CokeRaf, Chemicals, Mineral
4	Metals	Metals
5	OthIndust	Machinery, TransEquip, Wood, Paper, Textile, Food, OtherManuf
6	Energy	ElWatGas
7	Transport	Transport
8	OthSectors	BuildInd, OthSectors

NAMEA for Poland includes several blocks of data. In the upper left corner of the matrix is a block of data from input-output table, containing all the standard elements, ie intermediate and final demand flows as well as added value. The next section is devoted to energy resources (columns) and energy consumption (rows). Behind the energy block, a data on air pollution can be found. The last block contains aggregated information on environmental themes, which was previously mentioned — amounts of emissions have been recalculated using weights (PAE and GWP), and then summed.

Analyzing the size shown in the table on environmental issues, note that in the case of Polish for the greenhouse effect nearly 100 percent of carbon dioxide equivalent emissions, while the other is a trace gas (less than 2 million tones in the case of nitrous oxide and a little more than 4 million tons in the case of methane to more than 355 million tones of carbon dioxide). As regards acidification indicator, we find that about three-quarters of values of PAE is related to sulfur dioxide emissions and a quarter comes from nitrogen oxides. Let us also note, that the presented matrix does not contain information on emissions of ammonia, which also contributes to acidification. This is due to the unavailability of data on ammonia emissions at the sectoral disaggregation[4].

4) In the most recent data, this information is already available.

Table 5. NAMEA 1995 for Poland

	Output (mln z.)								FinalUse					
	Agriculture	Mining	RafChMin	Metals	OthIndust	Energy	Transport	OthSectors	PCE	Eksports	Other	**Imports**	**OthSupply**	**Total**
OpenStock														
Agriculture	12 789	10	70	0	17 900	2	1	3 795	15 935	1 652	1 263	−3 433	−5 784	**44 199**
Mining	732	2 595	5 136	1 672	1 237	6 217	536	2 979	1 734	3 668	62	−6 386	−1 936	**18 246**
RafChMin	3 650	561	11 339	2 654	10 837	2 442	2 711	15 157	12 610	10 265	2 183	−13 128	−21 949	**39 332**
Metals	63	154	412	7 805	8 257	442	238	1 773	6	6 919	202	−2 771	−1 794	**21 705**
OthIndust	5 755	3 148	3 943	2 945	66 640	1 964	2 986	31 854	81 488	35 895	27 746	−36 942	−58 018	**169 404**
Energy	792	989	1 148	1 012	3 564	2 810	748	7 507	7 015	249	1	−21	−472	**25 341**
Transport	257	394	1 511	416	2 593	660	3 270	5 740	5 134	5 556	3	−2 508	−121	**22 903**
OthSectors	1 696	1 438	6 778	1 272	13 959	2 315	3 270	52 638	60 856	13 968	82 847	−5 746	50 259	**285 550**
Households														
ValueAdded	18 464	8 957	8 996	3 929	44 417	8 490	9 143	164 108						
Total	**44 199**	**18 246**	**39 332**	**21 705**	**169 404**	**25 341**	**22 903**	**285 550**	**184 776**	**78 172**	**114 306**	**−70 935**	**−39 815**	**626 681**
HardCoal	61	77	536	140	202	1 106	9	17	317	837		−44		**3 257**
BrownCoal	1	2	1	0	1	528	0	0	4					**538**
CrudeOil			560									−540		**20**
NaturalGas	0	6	114	30	15	49	0	9	160			−244		**140**
Secondary	120	51	361	289	137	129	399	113	403					**2 001**
Renewable	19		5	0	24	1	0	11	105					**165**
OthChanges													7	
Corrections														
TotEnergy	**200**	**136**	**1 577**	**459**	**378**	**1 814**	**408**	**151**	**988**	**837**				**6 948**
CO 2														
SO 2														
NOx														
CO														
N 2 O														
CH 4														
NMVOC														
TotalEm*														
CloseStock														
ReservChang														
EnvThemes														

* Emissions marked by italics are not included in theme calculations.

(aggregated to 8 sectors and 6 energy carriers)

Reserves				Emission (1000 tons)							EnvThemes			
HardCoal	BrownCoal	CrudeOil	NaturalGas	CO2	SO2	NOx	CO	N2O	CH4	NMVOC	GreenhEf	Acidific	**TotalEm**	
1 324 026	**127 332**	**189**	**4 380**											**OpenStock**
				14 743	49	115	384	0,43	24,8	36	15 398	4		Agriculture
				7 472	41	24	17	0,12	0,6	3	7 520	2		Mining
				24 886	130	66	57	0,33	5,6	8	25 107	6		RafChMin
				25 937	64	56	217	0,21	0,9	2	26 020	3		Metals
				19 630	115	58	179	0,36	1,7	29	19 778	5		OthIndust
				178 065	1 450	443	103	2,49	4,2	19	178 924	55		Energy
				24 290	20	281	1 071	0,92	8,7	249	24 759	7		Transport
				8 804	34	11	247	0,16	16,2	16	9 195	1		OthSectors
				51 710	177	40	1 597	0,92	129,1	98	54 708	6		Households
														ValueAdded
														Total
−3 257														HardCoal
−538														BrownCoal
		−20												CrudeOil
			−140											NaturalGas
														Secondary
														Renewable
														OthChanges
−13	−2	8	7											Corrections
−3 271	**−540**	**−12**	**−133**											**TotEnergy**
											355 538		355 538	CO2
												65	2 080	SO2
												24	1 094	NOx
													3 870	CO
											1 844		6	N2O
											4 025		192	CH4
													459	NMVOC
				355 538	**2 080**	**1 094**	3 870	**6**	**192**	**459**				**TotalEm***
1 320 755	**126 793**	**177**	**4 247**											**CloseStock**
3 271	540	12	133											ReservChang
											361 407	**89**		**EnvThemes**

3. Analysis of the sectoral pressure on the environment

In this section NAMEA is used do identify sectors of economy contributing the most to global warming and acidification. The strength of the pressure on global warming is represented by GWP and on acidification by PAE indicator. The results are presented in the table 6 and graph 1.

Table 6. Sectors' shares in environmental themes and GDP

Sector	Greenhouse effect			
	shares* (%)			multipliers type I
	direct impact	total impact	GDP	
ElWatGas	**58.3**	**11.9**	4.0	1.3
Matals	**8.5**	**4.8**	3.5	3.1
Transport	**8.1**	**4.7**	3.7	2.3
Agriculture	5.0	4.6	7.1	3.9
Matals	**3.6**	1.5	1.6	2.5
OthSectors	2.8	16.9	37.7	22.0
Chemicals	2.7	**4.8**	3.0	4.0
Food	2.7	**15.6**	9.3	9.8
CokeRaf	**1.9**	**4.0**	1.6	5.7
Coal	1.8	1.3	2.3	4.0
Paper	1.1	1.4	2.2	5.8
Machinery	1.0	**8.8**	6.3	21.5
Textile	0.7	**3.2**	2.5	8.7
NEnMining	0.5	0.3	0.6	5.8
Wood	0.5	0.8	1.2	7.2
TransEquip	0.4	**4.7**	2.3	20.8
BuildInd	0.2	7.5	7.9	73.6
OilGas	**0.1**	**0.0**	0.0	1.4
OtherManuf	0.0	3.0	3.2	234.0

Sector	Acidification			
	shares* (%)			multipliers type I
	direct impact	total impact	GDP	
ElWatGas	**66.7**	**14.0**	4.0	1.3
Transport	**8.1**	**4.9**	3.7	2.2
Agriculture	4.9	4.7	7.1	3.9
Matals	**3.9**	**3.6**	3.5	4.9
Chemicals	2.8	**5.1**	3.0	3.9
Food	2.7	**16.2**	9.3	9.5
Mineral	**2.0**	1.2	1.6	3.3
CokeRaf	**1.8**	**3.2**	1.6	4.5
Coal	1.7	1.3	2.3	4.2
OthSectors	1.3	17.2	37.7	44.4
Paper	0.9	1.4	2.2	7.1
Machinery	0.8	**8.1**	6.3	21.7
Textile	0.7	**3.4**	2.5	8.6
NEnMining	0.5	0.3	0.6	5.9
Wood	0.4	0.8	1.2	8.7
TransEquip	0.4	**4.5**	2.3	19.9
BuildInd	0.3	6.9	7.9	58.8
OilGas	**0.0**	0.0	0.0	1.8
OtherManuf	0.0	3.0	3.2	180.4

* Sectors which shares in the given theme is grater than its GDP share are indicated with bold font.

The table shows both direct and total sectoral impact on GWP and PAE. A direct impact means that an emission is a result of the given sector production. Total impact takes into account cooperative linkages between sectors and thus, for example, emissions of the energy sector are distributed among all other sectors using energy products.

The table consists of two parts (two sets of columns) for greenhouse effect and acidification. Column 1 in the set contains the names of sectors and the column 2 - shares of sectors in a specific environmental theme, i.e. shares in the GWP and PAE indicators. Columns 3 and 4 present direct and total effects and sectors are shown in descending order with regard to the direct ones.

The column 4 shows shares of sectors in creation of GDP and column 5 - multipliers of type I defined as the quotient of total and direct effects.

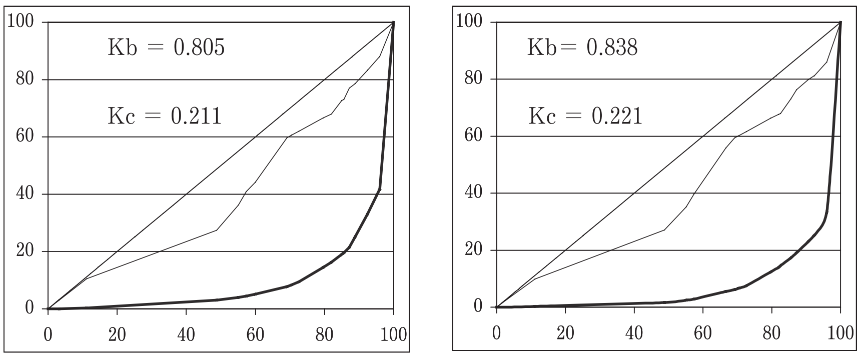
Analyses of direct impacts of air emission prove high concentration in a few sectors, both in the case of greenhouse effects and acidification (Energy, Transport, Metals, Agriculture) especially when these are compared with the shares of the sectors in GDP creation. The energy sector has the highest shares in GWP and PAE indicators being 58.3 and 66.7%. Transport's share is around 8% (in the two cases) and Metal share in GWP is 8.5%. For acidification the share of Agriculture is also significant - almost 5%.

When total effects are considered the domination of the above sectors is not so strong. The responsibility for environmental pressures is distributed more smoothly among sectors. Energy accounts for about 12% of GWP and 14% of PAE and shares of other two sectors are higher. These are Food and Other representing shares between 15—17%. In case of the Other (which concentrates most services) it is still much less then its share in GDP which amounts to 37.7%. It is also worth mentioning that the shares for most of sectors in total effects exceed 4%, whereas regarding direct effects these are lower then 2% for most of sectors.

The differences between shares of a given sector in direct and total impact on the greenhouse effect and acidification are also reflected in the values of multipliers presented in table 6, that are considerably diversified. If they were computed for a single pollutant they would show changes in its emission (in all sectors) as a result of unit increase in the emission in the given sector caused by corresponding change in the final use of this sector's products. Multipliers for GWP and PAE show changes in the pressure on the environment caused by several types of emissions: for example, if the final use of Food products increase causing a unit increase in GWP, then the total pressure will increase almost ten times as much, but for Building the increase equals to 73.6. The highest values of multipliers are observed for OtherIndustries (234 for GWP and 180 for PAE). There are some sectors with multiplier values ranging from 10 to 73, which can be described as high (OtherSectors, Machinery, Vehicles and Building.) On the other hand there are some sectors being energy suppliers, like Energy and OilGas, with multipliers less then 2. One should note however that the importance of the second one for the GDP creation is very low (0.0% shown in the table means that the share in GDP is below 0.05%)

A smoother distribution of total effects compared with direct ones can be seen also in graph 1, that shows Lorenz curves for both cases and the coefficients of concentration. It should be noted that the use of Lorenz approach to the concentration analysis is used here in a nonstandard way.

Graph 1 Lorenz curves and concentration coefficients for GWP and PAE



Usually the Lorenz curve and concentration coefficient are used to assess concentration for a single variable. Here we have a sectoral distribution of the two variables: environmental pressure measured by GWP (or PAE) and GDP. Graph 1 shows cumulated values of GDP shares (horizontally) and cumulated values of GWP (left chart) or PAE (right chart). Lorenz curves for direct impacts are marked with thicker line and for total with thinner ones. Both for GWP and PAE thinner curves lie much closer to the diagonal line. This means that concentration of GWP and PAE is much lower if intermediate effects are taken into account.

Of course Lorenz concentration coefficients confirm this conclusion (Kb stands for direct and Kc for indirect effect. For direct impact the coefficients are high (over 0.8 — this means that strong concentration exists whereas coefficients for total influence are much more lower - less then 0.23. Coefficients for greenhouse effect are slightly higher in comparison with coefficients for acidification

4. Structural changes in Poland and air emissions

Changes in output

In this part of the paper structural changes in the gross output and unit emissions as well as their influence on the emissions of 7 types of air pollutants is considered.

To estimate the impact of structural changes on output the following model was used:

$$\hat{X}_t = (I - A_0)^{-1} B_0 Y_t^{(C)} \qquad (1)$$

where $\hat{X}_t$ theoretical output for the year t, A_0 - matrix of direct input coefficients for the year 0, $Y_t^{(C)}$ - final demand by categories, and B_0 - conversion matrix for the year 0.

Data on final demand categories for the period 1990-2006 was used, and A as well as B matrices for 1995. Thus $\hat{X}_t$ shows theoretical output computed under the assumption of constant technology and final users' preferences. If parameters of the model do not change much over time the computed output is a good approximation of the historical output, but if parameters do change significantly over time, large deviations between historical and theoretical output can be expected. Theoretical outputs answer the question: what the output in year t could be if the parameters in that year were like those as in year 0.

The deviations $d_{it} = \hat{X}_t - X_{it}$ can be interpreted as results of structural changes.

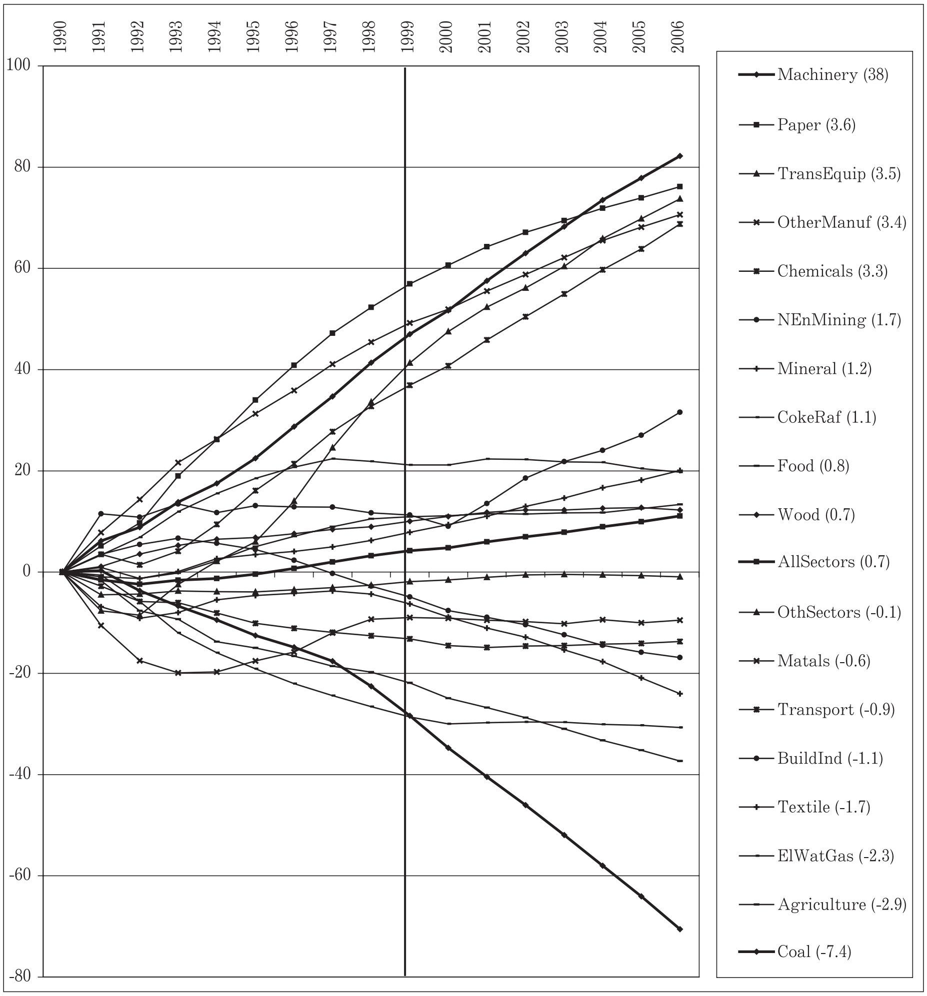
Computations were made for 54 sectors and then the results were aggregated to the level of classification, for which data on emissions was available (19 sectors). To capture the long term trends of the discussed deviations (i.e. between the theoretical and empirical output) cumulated percentage deviations normalized for 1990 were also computed. Formulas for these deviations can be written as follows:

$$d_{it}^{C} = \frac{\sum_{j<t} d_{it}^{1990}}{\sum_{j \le t} X_{ij}} 100 \qquad (2)$$

where $d_{it}^{1990} = d_{i1990} - d_{it}$. The deviations d_{it}^{C} show an average impact of structural changes on sectoral output within a year starting from 1990 or (in another words) average yearly deviation in the period 1990 to the year t. The vertical line

Graph 2 shows these percentage cumulated deviations d_{it}^{C} in the period 1990-2006. In the legend, sectors are presented in descending order (for the deviations of 2006) with the average change given in the parentheses.

Graph 2 Cumulated deviations (% of cumulated output)



The vertical thick line in the middle of the chart indicates the year 1999 as a reference point. Was distinguished by the fact that 1999 was last year in the previous, analogous study - see Plich 20039

The graph allows to compare changes in distances between sectors over time. For example, sector Paper — leader in 1999 — was not so good in 1991 as three other sectors: NEnMining, OtherManuf and Machinery. In consecutive years the last one however won and lost alternately. Looking to the other side of the graph, two sectors draw our attention: ElWatGas and Coal. The first one lost the most at the beginning of the 1990 s (particularly in 1992 and 1993). This was probably a consequence of the adjustment processes in Polish economy to market conditions which caused that energy and water started to be used more efficiently. The sector Coal started to lose already in 1991 but not so rapidly as ElWatGas and some other sectors. In 1998 and 1999 this process accelerated visibly which may be due to restructuring of the coal industry started in 1998. The shape of the line for Metals is also interesting — generally the sector lost at the beginning of the transition period. It was a winner between 1993 and 1998 and in 1999 this trend was stopped.

The sector Building draw attention — for this sector the cumulated average deviations are lower and lower from 1994. Also the upward trend in CokeRaf sector reversed in 1998. The trend of TranspEquip reversed too but in the other direction — the average deviations were lower and lower at the beginning of the 1990 s and then started to rise rapidly.

In 2006 the winners of structural changes in the period 1990-2006 in the Polish economy are the following sectors: Machinery (82.2), Paper (76.2) TranspEquip (73.7), OthManuf (70.6), Chemicals (68.7). Their cumulated outputs are much higher in 2006 than in case economic structures were as in 1990 (percentage changes are given in parentheses). For instance, in the period 1990-2006, cumulated output of Machinery industry is 82% higher compared with 1990, which gives 3.8% on average per year. The biggest looser is Coal industry, which lost 70.5% of output in the period under consideration, i.e. 7.5% per year.

Changes in emissions

The simplest model for any emission can be written as:

$$E = eX \tag{8}$$

where e is a vector of emission coefficients by sectors defined as an amount of emission per unit of output in a given sector. If the theoretical output is taken from formula (3), the above equation for year t takes the following form:

$$\hat{E}_t = e_t \hat{X}_t \tag{9}$$

Theoretical amounts of emission $\hat{E}_t$ answer the question what emission would be like if no structural changes took place.

Let us consider another modification of model (8), assuming that emission coefficients are constant (taken from year "0"):

$$\hat{E}_t^0 = e_0 \hat{X}_t \tag{10}$$

Differences between $\hat{E}_t^0$ and $\hat{E}_t$ show how changes in an emission coefficient contribute to changes in emission amounts.

Models (9) and (10) were used for simulation analyses of emission amounts in the Polish economy in the period 1993—2005. In the simulations the year 1995 was used as a base year (year "0"). Scenario given by equation (9) is called "changes in output" (because results help capture changes in output caused by structural changes) and the other scenario given by equation (10) is called "c onstant coefficients" (which means that emission coefficients are taken from year 0).

Results for 7 air pollutants are shown in table 2. In the table three rows are reserved for each pollutant. The first shows empirical amounts of emission and two other contain simulation results as deviations from empirical amounts (percentage of empirical amount). For "changes in output" scenario the deviations were computed using the following formulas:

$$d_{zt} = \sum_{j}^{19} (\hat{E}_{zjt} - E_{zjt})$$

$$d_{zt}^{0/0} = \frac{d_{zt}}{E_{zt}} 100 \qquad (11)$$

Where d_{zt} is the level of deviation, $d_{zt}^{0/0}$ — percentage deviation and E_{zt} is an amount of pollutant of type z emitted in year t by all sectors, that is

$$E_{zt} = \sum_{j=1}^{19} E_{zjt}.$$

Deviations in the scenario "constant coefficients" were computed in the same way, but theoretical amounts of emissions $\hat{E}_{zjt}^0$ were taken instead of $\hat{E}_{zjt}$.

Analyses of the results for the scenario "changes in output" presented in the table 7 lead to the conclusion that in 2005 amounts of emissions, computed under the assumption of constant parameters, were greater than empirical emissions (signs of deviations of all pollutants are positive). This means that structural changes (changes in technologies as well as changes in final users' preferences) contributed to the decrease in air emissions. This effect is the highest for SO 2 (9.7%), the lowest for CO (0,9%).

Table 7. Air emissions (empirical) and percentage deviations of their hypothetical values in the period 1993-2005n

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO 2	298 671	294 408	303 828	321 135	312 073	293 111	283 375	262 515	268 372	258 626	268 070	266 426	263 990
chnges in output	−1.05	−0.92	0.00	1.29	−0.38	2.06	4.63	−1.53	0.83	8.19	13.41	14.07	25.65
constant coefficients	−7.40	−0.90	0.00	−1.75	5.39	16.12	24.55	40.30	48.29	67.15	73.23	82.98	95.10
CO	1 972 215	1 902 077	2 273 204	2 508 163	2 262 999	1 931 095	2 067 591	1 471 979	1 458 075	1 362 209	1 348 438	1 414 820	1 504 680
chnges in output	−7.04	−0.42	0.00	−1.48	−2.05	−2.23	0.92	2.33	9.56	13.79	17.52	13.06	22.50
constant coefficients	1.57	11.61	0.00	−5.95	11.40	38.97	36.44	102.60	122.20	159.01	181.13	181.49	179.34
CH4	51 744	39 483	62 533	72 939	42 810	39 352	40 213	35 130	37 517	36 715	37 379	38 043	40 225
chnges in output	−3.34	2.21	0.00	0.19	−0.79	0.24	2.05	−5.05	−1.44	6.74	11.76	7.44	31.51
constant coefficients	10.10	52.70	0.00	−10.42	61.36	84.38	88.04	124.57	124.87	147.48	159.39	166.95	165.29
N2O	4 705	4 650	5 027	5 118	5 406	5 113	5 098	4 741	4 705	4 511	4 723	4 935	5 253
chnges in output	−3.23	−1.49	0.00	1.24	1.14	3.43	6.46	7.13	9.98	16.80	21.89	22.85	25.68
constant coefficients	−3.02	3.22	0.00	2.45	2.20	13.06	18.27	33.34	45.06	64.08	68.07	68.94	67.48
NMVOC	323 402	294 055	361 131	384 882	385 196	297 959	332 657	242 442	228 398	232 418	232 664	243 296	255 402
chnges in output	−10.02	−2.91	0.00	−1.46	−0.35	0.76	2.91	5.40	9.91	12.47	15.30	12.16	17.69
constant coefficients	−3.24	12.75	0.00	−2.47	5.66	48.02	39.75	103.24	134.97	151.92	170.641	72.01	173.55
NOx	1 012 971	1 002 782	1 053 950	1 006 515	1 035 373	936 389	923 976	756 698	730 243	720 494	757 874	779 133	813 432
chnges in output	−4.39	−1.29	0.00	0.59	0.10	1.74	4.35	2.23	5.12	11.27	15.73	14.13	23.81
constant coefficients	−6.72	−0.26	0.00	8.91	11.79	29.93	37.18	75.50	96.81	116.86	121.46	126.15	128.73
SO2	2 030 086	1 992 663	1 903 221	1 888 420	1 767 369	1 593 825	1 429 269	1 206 418	1 287 879	1 200 835	1 109 368	980 157	972 927
chnges in output	−1.31	−1.75	0.00	2.86	2.82	6.52	9.67	7.44	7.78	16.48	22.86	27.71	30.20
constant coefficients	−13.56	−7.74	0.00	5.31	17.48	34.68	56.10	93.07	94.47	125.57	161.50	210.82	230.25

First line of each pollutant shows amounts of emissions in thousands of tones (CO2 in millions)
Second and third line show deviations of simulations as percentages of empirical amounts

Let us remind that the scenario ”constant coefficients” reflects the total effect of assuming nonexistence of structural changes (as in the scenario ”c hanges in output”) and constant sectoral emission coefficients at the 1995 level. Therefore, comparing the outcomes of both scenarios allows to estimate the impact of changes in sectoral emission coefficients on the amount of emission.

It turns out that changes in the sectoral emission coefficients considerably contributed to reduced emissions of pollutants in 2005 compared with the base year, which is proved by positive signs and large differences between results of both simulations. If the 1999 emission coefficients were like those in 1995 (with at the same time “frozen” technologies and preferences of the final users), then the emission of methane would be almost 90% larger than actual. The smallest deviation in this scenario is 18% and it concerns N_20.

The deviations can be presented in a graphical form. Comparisons of time paths as well as scale of deviations between pollutants will be easier if the deviations are “normalized” for 1993. This is done here by computing “dista nce” between percentage deviation for a given year and deviation observed in 1993:

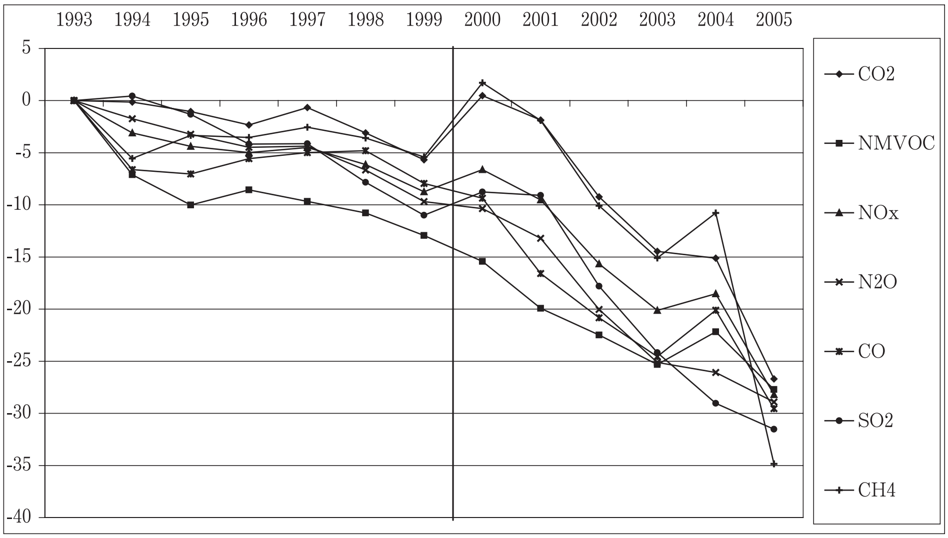
$$o_{zt} = d_{z1993}^{0/0} - d_{zt}^{0/0} \qquad (5)$$

Results for the scenario “changes in output” are shown in Graph 3 and the scenario „constant coefficients” in Graph 4.

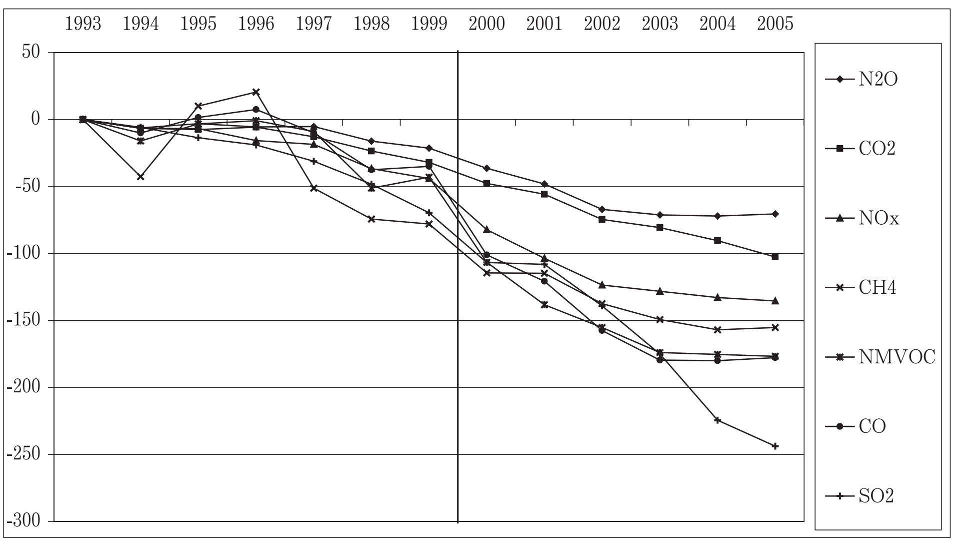
Calculation results in Graph 3 show that in the case of all analyzed pollutants structural changes that occurred in the years 1993—2005 contributed to a lower level of emissions. The impact of the changes on the amount of emission measured by the distance between deviations in the years 1993 and 2005 ranges from ca. 5 points (in the case of methane and carbon dioxide) to 13 points (NMVOC). Even though the results show an explicitly positive impact of the structural changes on reduced emissions, the observed time paths are not stabilized — the directions of impact vary. This is especially evident in the case of the carbon oxides emissions — after the deep drop in 1994 the next three years an upward trend can be observed. It seems positive that in the years 1998 and 1999 the analyzed values clearly drop for all pollutants (an exception is carbon dioxide in 1998).

Percentage deviations of the scenario “constant coefficients” analyzed in terms of the distance from deviations in 1993 (graph 4) are characterized by a considerable spread (from 20 to 80 points), which proves varying rates of changes in the emission coefficients of various types of pollutants. Particularly interesting is the methane curve that shows a rapid growth in 1995 and even stronger drop in 1997. These dramatic changes can be due to the modified methodology of making inventories of pollutants emissions, which should make us cautious about the presented results.

Graph 3. Deviations normalized for 1990.: scenario "changes in output"



Graph 4. Deviations normalized for 1990: scenario "constant coefficients"



Results of scenario "constant coefficients" include the total changes in emission level, i.e. caused by both changes in output and changes in emission coefficients. This total effect can be decomposed. For example, the following formula shows the average share of changes in output in the total change for the period from 1993 to the year t.

$$s_{zt}^{C}=\frac{\sum_{j<t} d_{z1993}-d_{zj}}{\sum_{j\leq t}(d_{z1993}^{0}-d_{zj}^{0}}$$

Impact of emission coefficients can be calculated as $100-s_{zt}^{C}$. Results of such decomposition are shown in Table 8. Generally, shares of changes in emission coefficients are higher. This is rather surprising because no special measures were undertaken in Poland to decrease emission of some pollutants, like CO2 before 2005. This can be interpreted as a “by-product” of high fees paid by enterprises for emission of other gases, like SO2. The highest share (36.5%) of output can be observed in the case of nitrous oxide.

Table 8. Decomposition of air emission changes (decrease) in the period 1993-2005 (%)

	Result of changes in	
	output	emission coefficients
CO2	14.8	85.2
CO	18.3	81.7
CH4	11.2	88.8
N2O	36.5	63.5
NMVOC	21.4	78.6
NOx	17.0	83.0
SO2	12.4	87.6

Because of relatively strong influence of emission coefficients onto emissions amounts in the considered period, it would be interesting to make a decomposition of these effects. Here, emission coefficients means the amount of emission per unit of output of a given sector. This is a very general definition and as such, it is not very convenient for a detailed analyses. Having in mind that most of air emissions are the result of fuel combustion for energy production, it is possible to decompose emission coefficients to energy intensity of output and emission intensity of energy. This will be the subject of further research

Conclusions

NAMEAs are a framework in which economic, energy and environmental data is consistently organized. Their hybrid structure cause, that there are no limits on kind of energy and environmental data being put to them NAMEA and the consistency of E 3 data in NAMEA allows for calculating different indicators both at national and sectoral level. They can be also used as data source for economic-ecological models which are more and more often used to analyze the impact of economic policies on the environment.

Time series of NAMEAs have been constructed for Poland for the period 1993-2005. They allow calculation of the two important environmental indicators: GWP and PAE. The Polish NAMEAs have used to present exemplary analyses of the impact of economic sectors on the environment.

Multiplier analyses based on input-output techniques proved that some sectors, which have meaningless direct impact on emissions, like building or transport equipment industry, indirectly, have a very strong impact on the environment. And conversely, the energy industry, which accounts for well over half of the direct emissions, in terms of analyzing indirect effects, gives way to the food industry, which direct impact is less then 3%.

Other example of the analyses concerned structural changes. Differentiation of the impact of structural change on economic activity of the sectors is very high. The average annual growth rate of output between 1990 and 2006, resulting from structural changes clearly exceeds 3% per year for the "winners", while the biggest "loser" (coal industry) had to reduced output by more than 7% per year.

Based on the results of the analysis of structural changes on sectoral output and emission factors taken from the NAMEA, decomposition of changes in emissions has been carried out for the period 1993-2005. The study has shown that this period, both structural changes and changes in factors contribute to the emission reductions for all considered pollutants. However, the influence of factors is greater than the impact of structural change, accounting for 80 percent or more reduction for most pollutants.

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Appendix

Table. Aggregation codes from 57 sectors classification to NAMEA(19) and NAMEA(8)

No.	NACE division	Sectors	NAMEA(19)		NAMEA(8)	
			Codes	Sector name	Kody	Sector name
1	1	AgrHunt	17	Agriculture	1	Agriculture
2	2	Foresrty	19	OthSectors	8	OthSectors
3	5	Fishing	19	OthSectors	8	OthSectors
4	10	CoalPeat	1	Coal	2	Mining
5	11	OilGas	2	OilGas	2	Mining
6	13	MetalOres	7	NEnMining	2	Mining
7	14	OthMining	7	NEnMining	2	Mining
8	15	FoodBever	14	Food	5	OthIndust
9	16	Tabacco	14	Food	5	OthIndust
10	17	Textiles	13	Textile	5	OthIndust
11	18	WearAppFurs	13	Textile	5	OthIndust
12	19	Leather	13	Textile	5	OthIndust
13	20	Wood	11	Wood	5	OthIndust
14	21	Paper	12	Paper	5	OthIndust
15	22	Printed	12	Paper	5	OthIndust
16	23	CokeRefPetr	4	CokeRaf	3	RafChMin
17	24	Chemicals	9	Chemicals	3	RafChMin
18	25	RubberPlastic	15	OtherManuf	5	OthIndust
19	26	OtherMineral	10	Mineral	3	RafChMin
20	27	Metals	5	Matals	4	Metals
21	28	MetalProd	6	Machinery	5	OthIndust
22	29	MachEquip	6	Machinery	5	OthIndust
23	30	OffMachComp	6	Machinery	5	OthIndust
24	31	ElectricalMach	6	Machinery	5	OthIndust
25	32	RadioTVcomm	6	Machinery	5	OthIndust
26	33	MedicalOptical	15	OtherManuf	5	OthIndust
27	34	MotorVehicles	8	TransEquip	5	OthIndust
28	35	OthTrans	8	TransEquip	5	OthIndust
29	36	FurnitOthManuf	15	OtherManuf	5	OthIndust
30	37	RecovSecRaw	15	OtherManuf	5	OthIndust
31	40	ElHwatSteGas	3	ElWatGas	6	Energy
32	41	ColdWat	3	ElWatGas	6	Energy
33	45	Construction	16	BuildInd	8	OthSectors
34	50	VehSaleRepairs	19	OthSectors	8	OthSectors
35	51	Wholesale	19	OthSectors	8	OthSectors
36	52	Retail	19	OthSectors	8	OthSectors
37	55	HotelRest	19	OthSectors	8	OthSectors
38	60	TranspLand	18	Transport	7	Transport
39	61	TranspWater	18	Transport	7	Transport
40	62	TranspAir	18	Transport	7	Transport
41	63	Tourism	19	OthSectors	8	OthSectors
42	64	PostTelecom	19	OthSectors	8	OthSectors
43	65	FinanciaInterm	19	OthSectors	8	OthSectors
44	66	InsurPensFund	19	OthSectors	8	OthSectors
45	67	FinanAux	19	OthSectors	8	OthSectors
46	70	RealEstate	19	OthSectors	8	OthSectors
47	71	RentMach	19	OthSectors	8	OthSectors
48	72	CompServ	19	OthSectors	8	OthSectors
49	73	ResDev	19	OthSectors	8	OthSectors
50	74	OthBusServ	19	OthSectors	8	OthSectors
51	75	PublicAdm	19	OthSectors	8	OthSectors
52	80	Education	19	OthSectors	8	OthSectors
53	85	Health	19	OthSectors	8	OthSectors
54	90	SewageServ	19	OthSectors	8	OthSectors
55	91	Membership	19	OthSectors	8	OthSectors
56	92	RecrCultSport	19	OthSectors	8	OthSectors
57	93	OthServ	19	OthSectors	8	OthSectors

Tax policy in Russian oil sector —Input-Output approach

A. Shirov and A. Yantovsky
Institute for Economic Forecasting, Russian Academy of Sciences, Russia

One of economic policy problems is the most rational distribution of tax burden between different sectors of national economy. The adoption of the most important strategic decisions is almost always accompanied by relevant discussions both on the level of governmental structures and the dialogue between the business sector and the state.

Based on the fact that all resources in the country are at the disposal of the state, the business sector, and the population, and their most optimal distribution ensures the stable development of the national economy, it becomes clear that the adoption of balanced decisions is almost impossible without mutual consideration of the interests of the largest economic agents.

Decisions in the field of a tax policy require qualitative calculations. These calculations should analyze consequences from policy change at level of macroeconomic, the budget, and activity of the different companies. The decision of this problem requires working out of difficult techniques and models.

Institute of Economic Forecasting of Russian Academy of Science (IEF RAS) has conducted researches connected with expansion of possibilities of traditional inter-industry models for many years. One of the problems of inter-industry models facing to developers is connected with necessity of more detailed analysis of an economic situation in different sectors. The decision of this problem demands working out of difficult techniques and models.

For example, we made many researches on development of the Russian energy sector for many years. This topic was connected with the structure of Russian economy. The current model of economic development in our country is based on high dependency from energy sector.

If we look at the energy sector in details, we'll see that the oil industry share in Russian GDP is about 20%, while the gas industry produces only 5%. Thus the Russian energy sector produced more a quarter of Russian GDP, and the oil sector is the major component of the Russian energy sector.

The share of oil sector in budget incomes is about 40%, and which

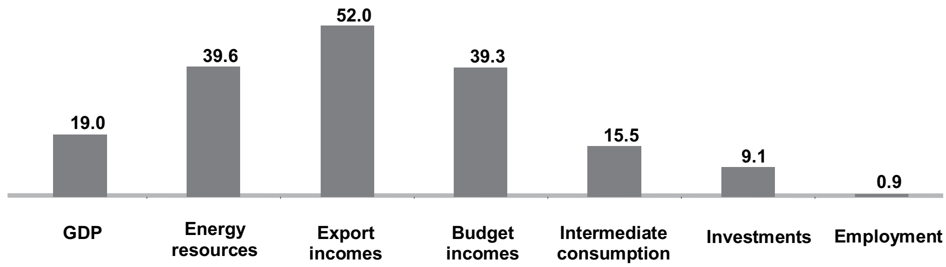


Fig. 1. Oil sector in Russian economy

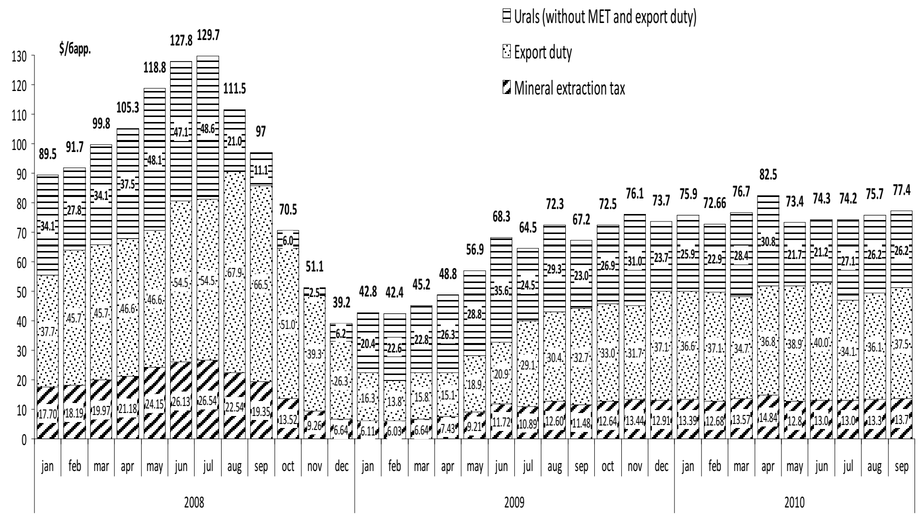


Fig. 2. Structure of oil prices for Russian companies

contributes to about 52% of export revenues. At the same time the oil sector provides only 9% of total investment and here works only 1% of employees.

The analysis shows that tax burden on oil sector exceeds it on other sectors of Russian economy (except for the gas industry). As a result investment possibilities in oil sector essentially concede to all sectors of Russian industry. Actually, it allows to speak about the absence of conditions for a normal mode of reproduction in Russian oil industry.

The problem occurs from the fact that the sector characterized by the greatest efficiency, providing a huge part of budget incomes and possessing rather significant resources for development, does not develop adequately with its possibilities.

We try to show the situation with cash flows in oil sector in Fig. 2. We can observe that the companies share in oil price (orange sector) is too low. For example in the late 2008 it was very low close to zero.

Thus the resources for investment are decreasing while extraction conditions and capital intensity need more and more financing. At this moment Russian oil companies are developing oil fields in East Siberia where capital intensity is significantly higher than in the traditional provinces.

The key problem consists that in current conditions the oil companies have no necessary financial resources for maintenance of high levels of oil extraction. Their investment appeal the presence and possibility to finance projects at the expense of extra means is reduced.

In our point of view the situation can be resolved with help of changing the tax system in oil sector.

The evident contradiction between the interests of business and the state (as economic agents) consists in the difference of the tactical tasks facing them. While the state adopts the decision on the basis of the general macroeconomic and budgetary considerations, entrepreneurs, primarily, are interested in the economic efficiency of the adopted measures for a specific business. This contradiction is fundamental and it should be always kept in mind, but, at the same time, it is necessary to consider the fact that if we put aside specific details, then the substance of the interrelations of the business sector and the state in the modern market economy consists in finding a reasonable balance between the interests of counteragents, in order to improve the general quality of life in the country.

The analysis of change in oil sector's taxes on macroeconomic consequences should include at least three basic chains of interactions:

- ***Direct links:*** effects from increase of industrial and investment activity in oil sector;
- ***Interindustry links***: expansion of manufacture and change of incomes in sectors connected with oil industry (metallurgy, the chemical industry, power generation, transport etc.);
- ***Effects from additional incomes***: distribution of additional incomes in favor of the households, the government and fixed capital investments.

At the same time, in macroeconomic studies, the problem of the interaction of the parameters in the development of the economy as a whole and separate types of economic activity is very acute and urgent.

The character of the development of the Russian economy assumes significant structural changes in the mid- and long term. In this respect, the analysis of the prospects of its development becomes almost impossible without the use of structurally varied toolkit, taking into consideration of the dynamical and structural characteristics of the economy's development in a single package. Traditionally, structural analysis is connected with the use of instruments based on interindustry balance. The use of such instruments is one of the main conditions of the elaboration of a generally consistent forecast of the economy's development in the medium and long-term perspectives. However, as experience shows, even such a structurally rich instrument as the model of interindustry balance is often insufficient in the researches for some sectors.

In the interindustry balance, the sectors (types of economic activity) are represented by quite a large assemblies. Moreover, developers of forecasts on this basis face to the problem of the arrangement of branch subjects and the interpretation of the obtained results. Even in the single commodity branches (oil, gas, and metal production), there are some large manufacturers with different strategies of business development. Therefore, it is impossible to describe the prospective dynamics of a sector's development figures adequately, without taking into consideration of the implementation of the large investment plans by such companies. For example, it is difficult to forecast the development of the power industry, and therefore requirements of the economy of the key primary resources, without a clear view of the investment plans by the power generating companies. What can be the approach composed of in the development of a model complex, including the main indices of operation of the large business units? First of all, such an instrument should be multilevel; moreover, each level of calculation should be responsible for solving certain tasks in the general ideology of the model complex.

If we consider some economic and production complex (company), then the aggregate of companies forms the branch (type of the economic activity). Thus, the consideration of some companies as the key elements forming a sector makes it possible to form units, permitting one to pass on from the level of separate holdings to a calculation on the macroeconomic level.

The general view of the scheme of calculations in this complex can be represented as follows: on the upper level of the model complex, the macroeconomic forecast is formed on the basis of scenario conditions. On the lower level, the aggregative branch forecast is formed, which in its turn is based on the results of the calculations of the financial-economic indices of some companies of the sector. If a high level of detail is necessary, as well as, in the case of the presence of a large number of holding companies in the industry, the lower level of calculation can be disaggregated to the level of some business units. The general scheme of the model complex is set forth in Fig. 3.

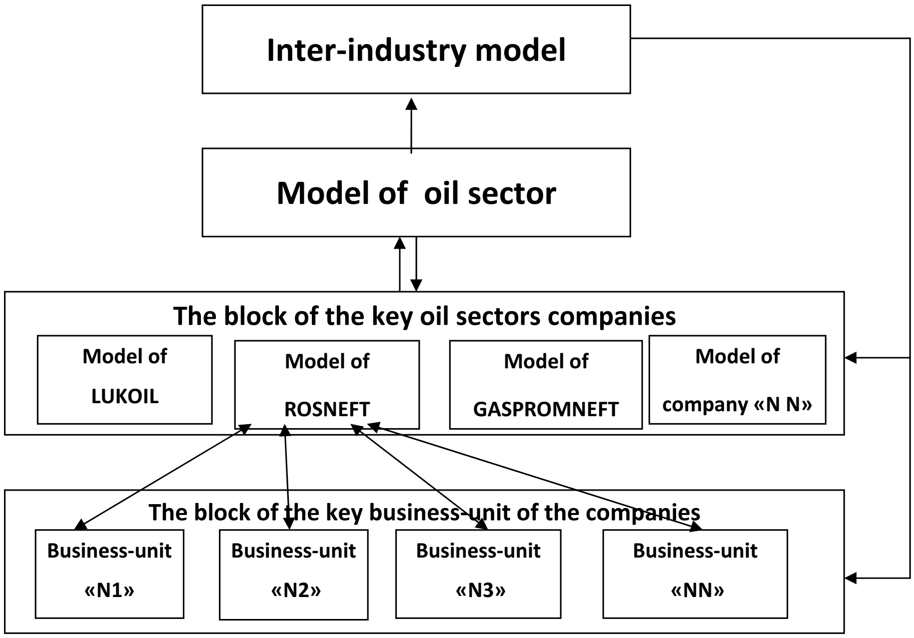


Fig. 3. Principal diagram of the forecast complex.

For this type of calculation it is necessary to understand the system of I-O links for oil. Usage of I-O tables assumes the analysis of interindustrial links in economy. For this purpose, it is necessary to analyze industry concerned, both it's production structure of expenses incomes.

In available at our disposal I-O tables, the oil sector is divided into the extraction of crude oil and the oil refining. It is necessary to consider that in our I-O tables cost units are considered. For the analysis of dynamics of natural indicators, it is necessary to use the additional information. The power balance can serve in a case with oil branch such source of the information. For the purposes of industry's development analysis under different tax burden conditions modeling of indicators both in constant and current prices, as a rule, is carried out. Such calculations allow us to take in account as changes in physical volumes of output and consumption, as price dynamics.

If we take into account the structure of consumption of production in oil extracting and oil refining it is possible to note the following features:

Table 1. Structure of oil consumption

Sector	Share in physical volumes	Share in cost volumes
Oil extraction	1.0%	0.9%
Oil refining	48.0%	26%
Export	50.0%	72%
Other sectors	1.0%	1.1%

Thus, all volume of extracted oil is distributed between export and oil refining, about one percent makes consumption in oil extraction (basically losses), all other sectors consume nearby 1% of the produced crude oil.

In case of oil refining the situation differs. Among all sectors its production is consumed by the majority in Russian economy sectors.

Table 2. Structure of petroleum consumption

Sector	Share in physical volumes	Share in cost volumes
Power generation	8.4%	3.4%
Chemical industry	6.7%	7%
Transportation	20.8%	33.8%
Agriculture	2.9%	3%
Use in energy sectors	6%	4.9%
Manufacture sectors	4.7%	5.6%
Export	48.0%	41.8%
Other sectors	2.5%	0.5%

The main consumers of petroleum products are transport, chemical industry, electric power and heat generation, internal consumption of oil refining. About 50% of production is delivered for export.

The cited data about consumption of oil sector's production is contained in I-O tables. It is possible to note that they substantially coincide with the data about product distribution which can be gathered from power balance or the analysis of companies' statistic. Similarly it is possible to consider the data of other economy sectors whose product distribution is presented in I-O table.

Thus, the I-O table allows considering rather in the precise structure of product consumption of separate sectors, and at construction on its basis of forecast toolkit to analyze dynamics of demand both in natural and cost units.

Other important part of the I-O analysis is research of structure of expenses in separate sectors of economy. In the scheme of I-O table the structure of expenses (representing a production technology) is presented in the form of cost streams of other sector's products consumption in the course of manufacture. Besides this the columns of I-O table contain the information on the sector's value added. Thus, there is a possibility of the analysis of structure of the price by the form activity as a whole.

Table 3. Structure of costs

	Share in crude oil costs	Share in oil refining costs	Share in oil sector costs
Oil extraction	0.9%	52.7%	28.0%
Oil refining	2.3%	0.8%	1.5%
Chemical industry	1.1%	0.2%	0.6%
Metallurgy	1.1%	0.1%	0.5%
Machinery and Equipment	1.2%	0.2%	0.7%
Power generation	2.6%	1.2%	1.9%
Trade	11.2%	13.2%	11.9%
Transportation	5.9%	3.0%	3.7%
Finance and insurance	1.5%	3.7%	2.6%
Construction	2.3%	2.9%	2.6%
Taxes	50.1%	14%	32.5%
Wages	5.4%	1.3%	3.2%
Profits	11%	5.6%	8.4%
Other	2.3%	1.1%	1.9%

The analysis of existing practice of work of the large Russian companies shows that at the moment practically modeling is used almost everywhere in business processes. It allows asserting that the technology of the analysis and planning in corporate sector is developed at the acceptable level.

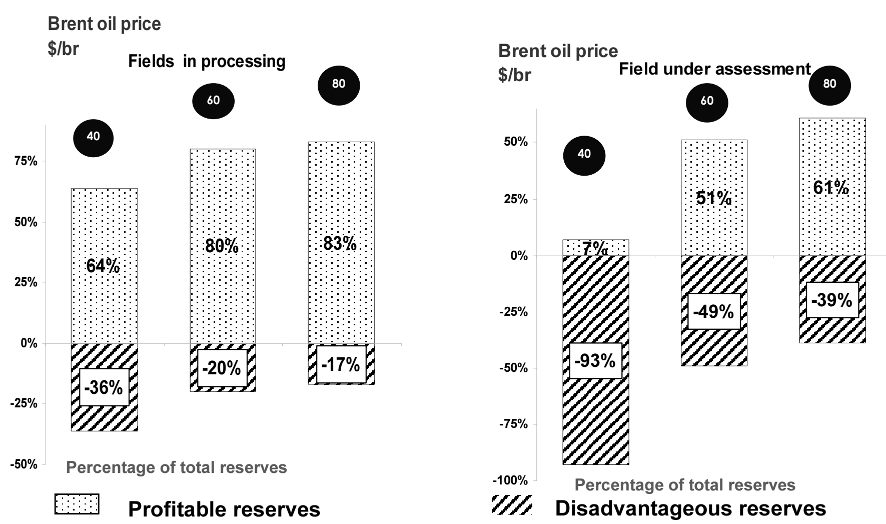
The methodological problem consists of necessity of integration of the microlevel with the macroeconomic level. It can be achieved by creating of model complex, which includes models operating at the different levels.

Advantages of the given approach are clear. First, it allows to coordinate the forecast on at level of corporations and at macroeconomic level. Secondly, this complex forms estimations of influence of sector development on macroeconomic and sectors indicators. There is a possibility to track all chain of the existing interactions in economy.

The system of the analysis and monitoring of the existing information should be a basis of a model complex. From our point of view the system of monitoring, the analysis and forecasting should be based on various information sources.

In a general view the scheme of calculations can be presented in a following kind: at the top level the macroeconomic forecast is formed on the basis of scenario conditions, at the next level the aggregated sector's forecast, which in turn is based on calculations of separate companies' economy, is formed. In case of high degree of detailed elaboration and presence in sector we can separate company for business units. The general scheme of a model complex is shown in Fig. 3.

Before beginning of main I-O calculations we have to make some special estimation about different problems in oil sector. For example, we need to estimate amount of available and more important profitable reserves of oil in dependency with on oil price values. For example in range of $ 40-80 per barrel most field in processing remain profitable but for new fields the situation rather different. At $ 40 per barrel almost all of them became unprofitable under current tax regime, and for higher price values only about half of them can attract developers.



**Data provided by Ministry of Energy of the Russian Federation*

Fig 4. Profitability of Russian oil fields

So the determination of the optimal level of tax burden in Russian oil sector became a significant problem. We tried to make such estimations with help of static model, including model of oil sector and I-O model of Russian economy. In our opinion the criteria of optimal tax system is a maximization of budget incomes. Thus, it is obvious that the government should be interested in maximization of incomes not for one year, but enough to the extended enough interval of time.

The calculations carried out at IEF RAS testify that the current level of tax burden is rather far from the optimal, including from the point of view of formulated above criteria. Bringing the tax burden level to optimal values means now a significant decrease in tax burden on oil and petroleum industry. Thus decrease in tax burden will mean, according to our calculations, increase in integrated incomes of the budget, due to prevention of production fall.

At the same time an obvious fact is that in process of the further decrease of tax burden level, the increment of the integrated incomes at first sharply decreases, and then passes in negative area owing to decreasing elasticity of output by investments. Thereby objective existence of an optimum level of the taxation in petroleum industry is proved.

Results of model calculations, which were carried out at IEF RAS, testify that the present tax burden level, which is about 60% to revenues, is excessive and inefficient from the point of view of maximization of budget incomes received directly from oil and petroleum industries.

From the given criteria, a tax burden level of 50% of revenues is optimal. As calculations testify, decrease in tax burden from 60% to 50% provides on time interval 2011-2030 increase of budget incomes directly from oil and petroleum industry equal to 110 billion dollars in the prices of year 2010. Considering that production growth in oil sector due to system of interindustry links causes increase of output in other sectors of economy, there is a question as this increase in production will affect tax receipts from other sectors. I-O calculations with use of Leontivian model allow to estimate influence of production increase in one sector on dynamics of outputs in others and, accordingly, on volumes of additional tax revenues from other sectors of economy.

As a result, the curve of cumulative integrated incomes of the budget connected with functioning of oil and petroleum industry takes a bit different form, than a curve of incomes of the budget coming directly from oil sector. In following graph we put tax burden level on abscissa and on ordinate axis— total incomes of the budget for the 20-year-old period settles down. As can be seen in Fig. 4 the maximum aggregate effect is reached at decrease of tax burden level on oil and petroleum industry to value of 40% of revenues.

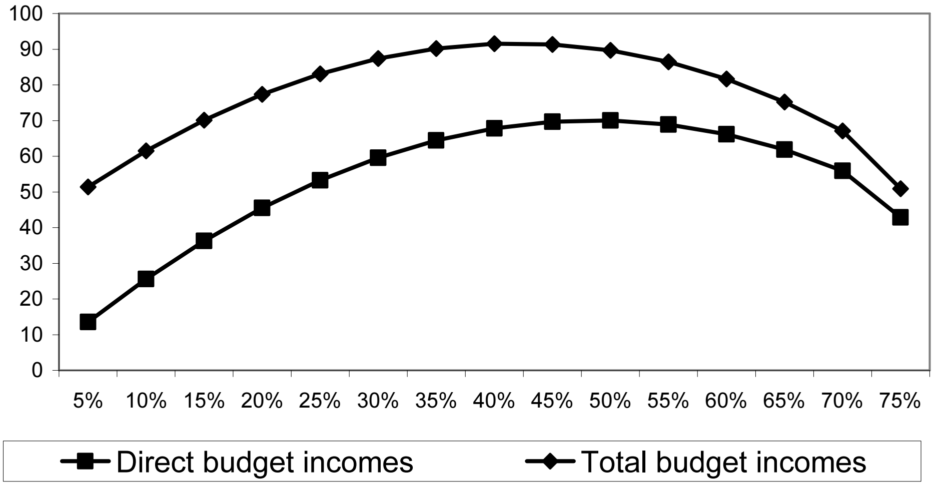


Fig.4. Direct and full budget incomes on period 2012-2030 depending on tax burden level

For carrying out I-O calculations we need to have main macroeconomic scenario. The key parameters of this scenario is shown in Fig. 5.

Capital intensity (in constant prices) increases in all scenarios from 45 $/t. in current period to 63-75 $/t. at the end of forecast period. In model capital intensity is forecasted with help of function depending on cumulative values of extracted oil. This function describes processes of depletion of fields in processing and necessity to develop new fields, which have harder geographical and technical characteristics and high capital expenses. The parameters were estimated on data about volumes, structure and characteristics of known oil reserves. Known amounts of oil reserves and extraction cost for each category and assumed that cheaper deposits will be developed prior to expensive ones, we could estimate the increase of costs with depletion of cheaper deposits and transition to more expensive oil deposits. This dependence could be presented in a form of mathematical equation and later used for estimation of required amounts of investment.

We have made calculations on three variants of possible oil extraction dynamics on the period till 2030. Two boundary variants can be considered as scenarios of maximum possible an. minimum possible crude oil production under given conditions of oil prices and technical characteristics of oil sector.

In the first scenario (preservation of a tax mode) rates of mineral extraction tax and export duties remained at present level. Within the limits of the given variant the oil-extracting industry already in short-term prospect faces deficit of financial assets to provide necessary capital investments even for supporting the existing level of production. It leads to essential decrease of investments into oil extraction and actually the termination of development of new deposits in intermediate and long-term prospect due to insufficient return of invested capital. In turn, the lack of capital investments involves considerable reductions of volumes of extraction to 2030 which makes about 50 % from current level of extraction. Thus amounts of oil extraction to 2030 falls down to 261.0 mln. tons, and exports falls down to 99.0, which means the corresponding decrease in budget incomes.

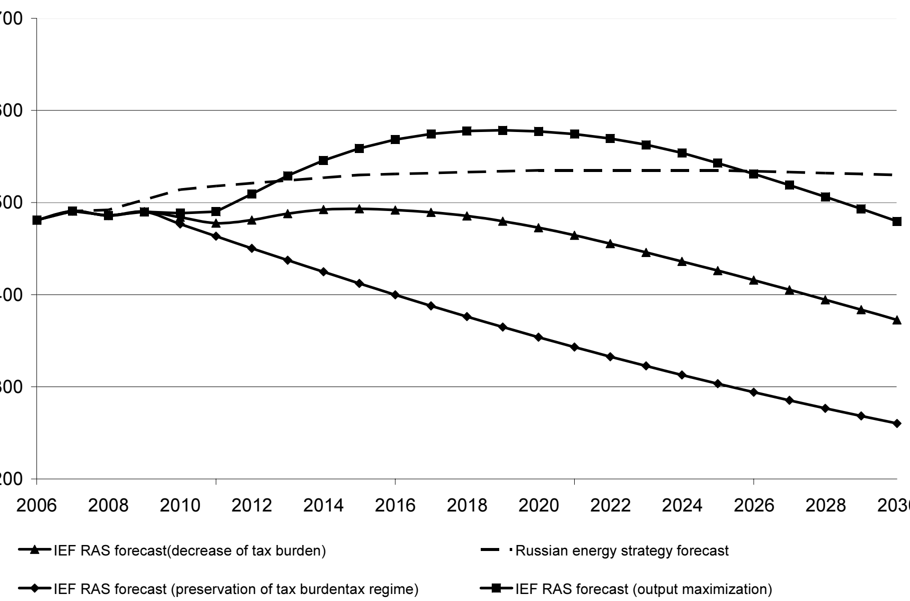


Fig. 5. Forecast of oil extraction, mln. tonn.

In the second scenario tax burden was decrease by approximately 15% of revenues. Also distribution between turnover taxes (mineral extraction tax and export duties) and corporate and windfall taxes was changed from ratio 95/5 to 50/50. These parameters of tax regime provide attainment of oil sector IRR on forecast period no less than 14%.

As calculations have shown, on long-term prospect even essential change of tax burden appeared insufficient for maintenance of required profitability level. At the end of forecast period in this scenario reduction of capital investments in oil extraction and as consequence fall of production also was observed. However as a whole, curtailment of production appeared much smaller, rather than in the first scenario. Oil extraction in 2030 reaches the level of 380.7 mln. tons, providing 197.8 mln. tons available for export.

In the third variant possibility of a maximum level of oil extraction under conditions of practically full removal of tax burden was estimated. In this variant, at the disposal of the oil-extracting industry, there are considerable financial resources that allows it to increase in the beginning, and subsequently to support extraction volumes at higher level. Maximum output for oil extraction was estimated to be about 585 mln tons. At the end of forecast period in this scenario amounts of oil extraction reaches 480 mln tons, and oil export makes up to 215 mln. tons.

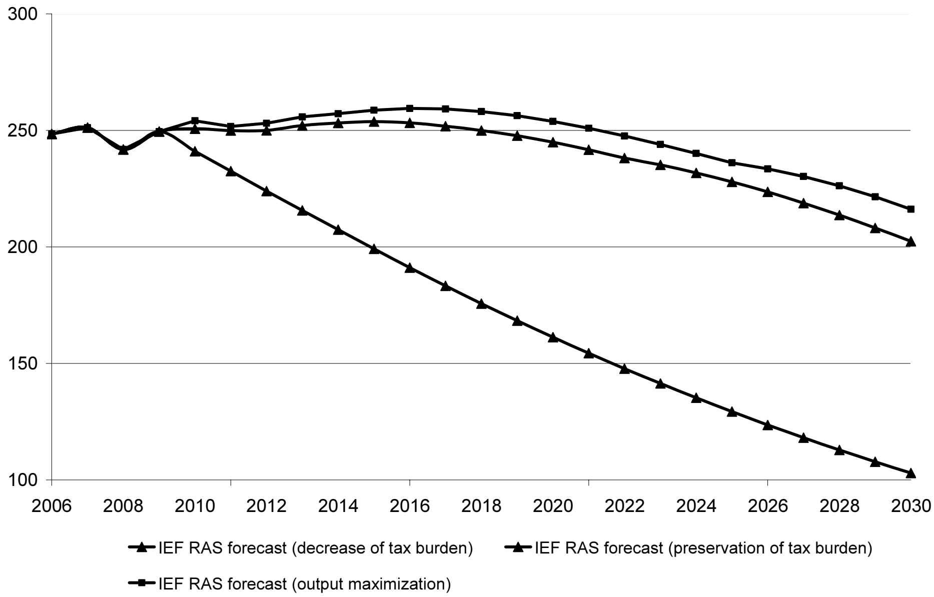


Fig 6. Forecast of oil export, mln. tonn.

Final aspect of the analysis was an estimation of macroeconomic differences between scenarios. The foul in budget incomes continues for the 4-5 years. But this is compensated by GDP growth.

In short-term prospect budget incomes in scenario of existing tax burden are more than in scenario of decreased tax burden. The foul in budget incomes continues for the 4-5 years, but later it is compensated by oil extraction and GDP growth. The difference between variants in oil extraction is about 100 mln. tons in year 2030. If we speak about the result on period then benefit from the new system is obvious.

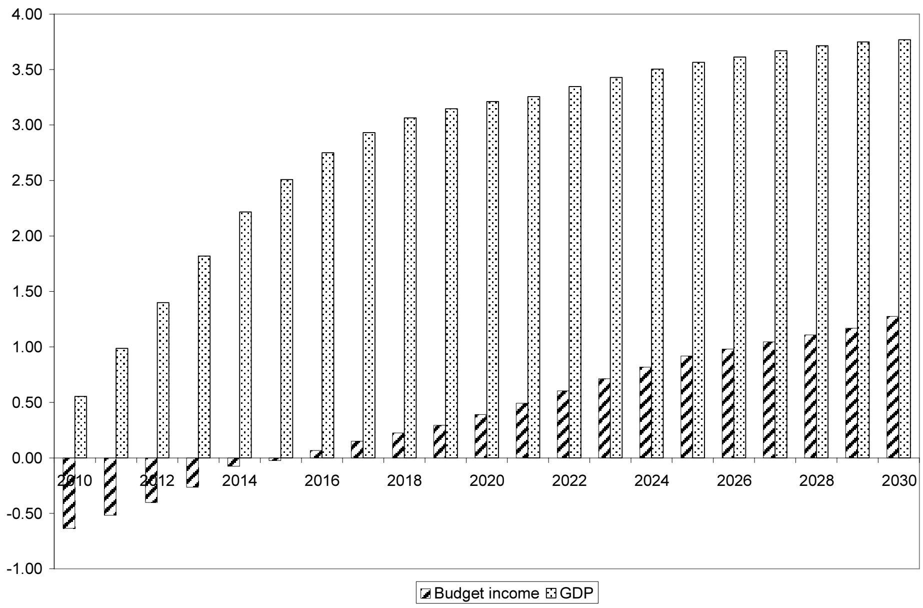


Fig 7. Differences between scenarios of preservation and decrease of tax burden, trln. roubles (1 USD=30 roubles).

A measure of possible changes in budget incomes have been received under given macroeconomic scenario. Thus an essential element of scenario calculations was the hypothesis of interaction of decreasing tax revenues and the state consumption.

Growth of investments and outputs in oil extraction and refining cause increase of demand on other sector's products and thus stimulate the growth of production in economy and partially compensate in that way of decrease of budget income.

Also an important feature of the Russian budgetary system consists in existence of reserve fund where payments from export duties and mineral extraction tax on oil and gas come. Current taking in reserve fund directly don't influence on the government expenditure. Expenditure as the operational can be financed from the means saved up earlier. During too time long decrease in incomes of oil and gas can expenses reduction of the budget incomes (in the middle of 2010 volume of oil and gas funds was about US$ 130 bln.).

Therefore, there are different possibilities of how decrease in oil sector tax payments will affect state expenditures. It may only result in lower amounts of reserves without reducing current governmental consumption.

The worst scenario consists that all decrease in tax revenues is subtracted from the state expenditure. Under conditions of this scenario initial decrease in state consumption and GDP will be completely compensated only outside of 2015

According to results, the calculations spent by 2016 of loss of the budget from decrease in taxes in oil sector are compensated for the account of increase in tax revenues in the conditions of the bigger incomes of economy. So the GDP in 2016 measured in the current prices, in the scenario of change of tax loading exceeds a similar indicator of the scenario of preservation of tax loading on 2,8 trln. roubles (US$ 91 bln.), and budget incomes on 66 bln. roubles (US$ 2.2 blm). By 2030 distinction between variants in terms of gross national product in the current prices will reach 3,8 bln. roubles (US$ 125 bln.), and under the incomes of the budget of 1,3 trln. Roubles (US$ 45 bln.).

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Tax Policy in Russian Oil Sector - Input-Output Approach
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Shuntaro Shishido, Research Institute of World Econometric Modelling and Analysis
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