A CGE Model for Analyzing CO_2 Emissions Reduction Strategies in China

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Overview

1) A brief description of DE^3 model
2) Data used, data improvements
3) Some modeling issues, differences with other models
4) Detailed equations of model
5) Projections of exogenous variables

Time permitting:

6) GAMS code; How to use results

See these three documents for background information:

1) "Controlling Carbon Emissions in China"
   Reports the use of a carbon tax to reduce carbon emissions, with carbon revenues used to reduce other taxes.

2) "A Dynamic Economy-Energy-Environment Model of China. Version 1"
   A detailed description of the equations and data construction of the model.

3) "Modeling Trade Policies and U.S. Growth: Some methodological issues"
   (in "The Economic Implications of Liberalizing APEC Tariff and Nontariff Barriers to Trade," U.S. International Trade Commission Publication 3101 April 1998)

Available on our web site at: http://www.ksg.harvard.edu/tep/

Major Features of the Model

- **Dynamic Solow Growth Model**
- **30-40 Year Simulation Period**
- **29 Sectors: Agriculture, 21 Industrial Sectors, Construction, and 6 Service Sectors**
- **Energy Related Sectors: Crude Petroleum, Coal, Refined Petroleum, Electric Power**

- **Markets for Goods and Factors of Production**
- **Factors of Production: Capital, Labor, Energy, and Materials; (Also Land for Agriculture and Crude Petroleum Sectors)**
- **Assumption of Profit and Utility Maximization, Subject to Constraints**
- **Imports are Imperfect Substitutes for Domestic Goods (Armington Assumption)**
- **Major Actors: Enterprises, Households, Investors, Government, and ROW**
- **Full Specification of Taxes and Transfers**
- **Two-Tier Plan/Market System in Goods Markets**
- **Capital Market Imperfections**

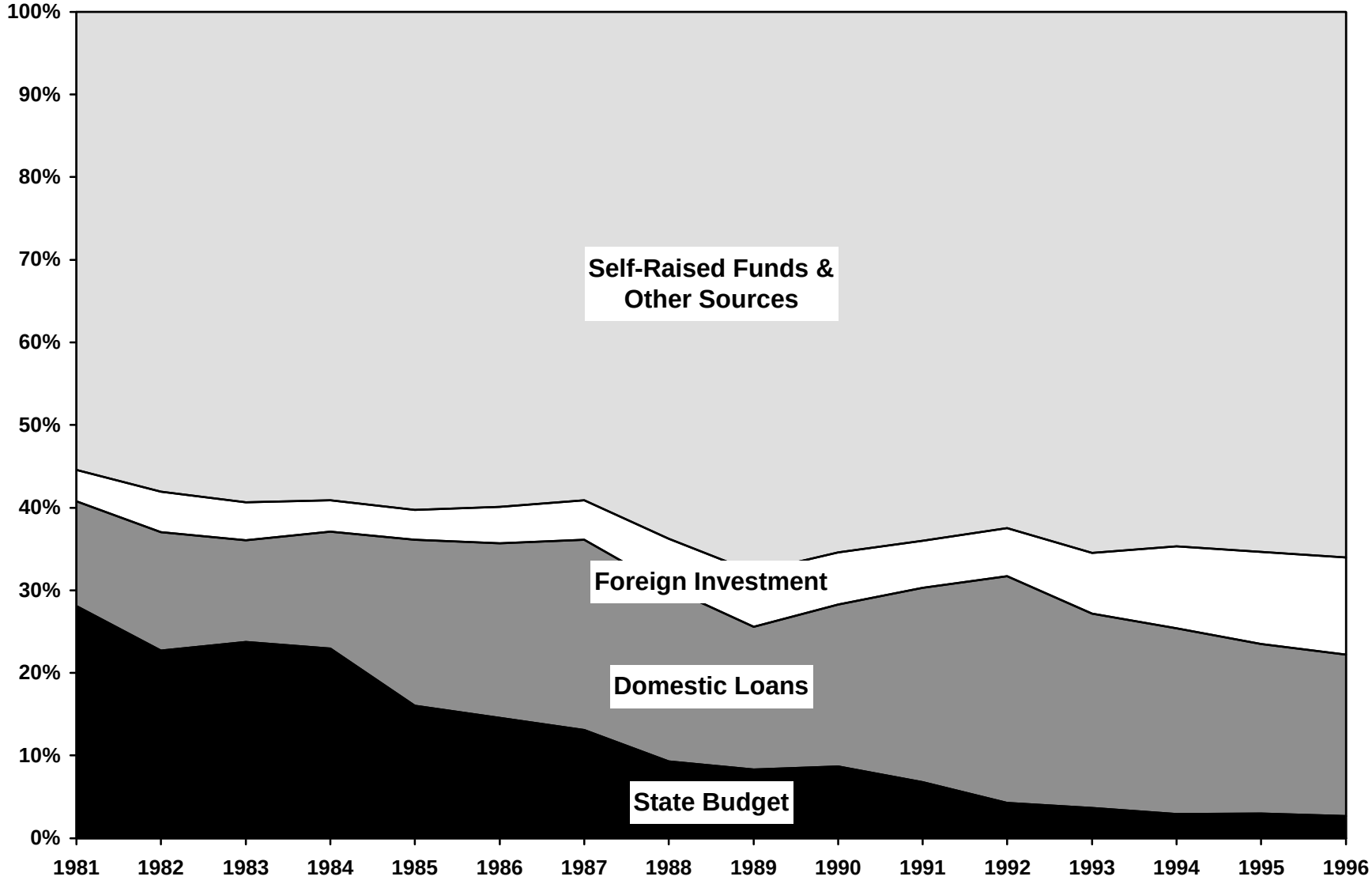
Proportion and Number of Goods Sold at State Set and Market Prices, 1978-96

	1978	1985	1990	1993	1996
Agricultural Products					
Market Prices	6%	40%	52%	88%	79%
State Set Prices	94%	37%	25%	10%	17%
Number of Goods Sold at State Set Prices	113			6	
Retail Sales of Consumer Goods					
Market Prices	3%	34%	53%	94%	93%
State Set Prices	97%	47%	30%	5%	6%
Number of Goods Sold at State Set Prices	158			7	
Industrial Production Materials					
Market Prices	0%		36%	81%	81%
State Set Prices	100%		45%	14%	14%
Number of Goods Sold at State Set Prices	1086			33	

Sources: *Zhongguo Gaige yu Fazhan Baogao 1992-1993* [China Reform and Development Report 1992-1993], p. 54 and *Zhongguo Wujia Nianjian 1997* [Price Yearbook of China 1997], p. 482.

Notes: Totals may not add up to 100% due to rounding and because some goods are sold at “guidance prices.

China: Investment in Fixed Assets by Source of Finance, 1981-96



Source: *China Statistical Yearbook*, various editions.

Social Accounting Matrix with Two-Tier Price System for China

	Expenditures:									
	1 Commodity		2	3	4	5	6	7	8	9
Receipts:	*Plan*	*Market*	Activity	Households	Enterprises	Government Subsidies	Government	Capital Account	Rest of World	Totals
1 Commodity *Plan*			**Plan Intermediate Allocation**	**Plan Household Allocation**			**Plan Government Allocation**	**Plan Investment Allocation**		Total Domestic Sales
Market			**Market Intermediate Demand**	**Market Household Demand**			**Market Government Demand**	**Market Investment Demand**		
2 Activity	**Plan Supply**	**Market Supply**							Exports	Total Sales
3 Households			Labor Income		Enterprise Transfers to Labor					Household Income
4 Enterprises			Capital Income							Enterprise Income
5 Govt Subsidies			Enterprise Subsidies	Consumer Price Subsidies			Government Subsidies			
6 Government	Tariffs		Indirect Taxes		Direct Taxes & Fees			Government Budget Deficit		Government Revenue
7 Capital Account				Household Savings	Depreciation & Enterprise Savings		Government Savings		Net Foreign Savings	Total Savings
8 Rest of World	Imports									Foreign Income
9 Totals	Total Absorption		Total Costs	Household Expenditure	Enterprise Expenditure		Government Expenditure	Total Investment	Foreign Expenditure	

Data Work in Progress

I. Improving the current calibrated model.

(1) Updating SAM from 1992 to 1995.

(2) Incorporating tax system reforms of 1994.

II. Moving from a calibrated model to an econometrically estimated model.

(1) Compile a time series of input-output tables for use in estimating sectoral production functions.

(2) Compile survey data on consumption for use in the estimation of a demand system.

Some Problems with the Data

(1) Tax data

(2) Two-tier price and quantity data

(3) Data by sector below the township (*xiang*) level

(4) Service sector data

(5) Trade data

(6) Data on savings by households and enterprises

(7) Investment data by source

3) Some modeling issues, differences with other models.

Different models very often give very different numerical results, sometimes even results of opposite signs. We shall try to understand why these differences occur by examining the important features that distinguish one model from another.

i) Savings and Investment determination.

Solow models ("myopic", "dynamic recursive") have exogenously set saving rates

$$S_t = \bar{s}_t Y_t = Y_t - P_t C_t$$

Ramsey models ("perfect foresight", "intertemporal equilibrium") have endogenously determined savings. In the simplest case with logarithmic utility functions:

$$\frac{C_t}{C_{t-1}} = \frac{1 + r_t}{1 + \mathrm{r}} \frac{P_{t-1}}{P_t}$$

Myopic models cannot change investment in response to policy changes that will be implemented in the future. E.g. knowing that there will be a carbon tax in the future, but not today, will not increase investment in energy saving capital today. A tax on capital income will have a bigger effect in foresighted models.

ii) Labor supply elasticity.

Models where utility is a function of both goods and leisure will have a labor supply that rises when real wages rise. That is, if there is a tax cut on wages then there will be a bigger labor supply, and generally a positive effect on output compared to models with an inelastic labor supply. In the case of our DE^3 model a carbon tax that lowers taxes will have no effect on labor supply.

iii) The degree of disaggregation of sectors.

A model which divides the economy into more sectors will have more degrees of freedom to substitute one commodity with another. A tax distortion will thus have a smaller welfare cost in this model, for example, a tax on energy will have smaller effects if the economy is allowed to shift from producing energy intensive goods to nonenergy intensive goods. (If there is only one good then such a possibility is ruled out, or if there is only one manufacturing sector, then there is only a little substitution.)

Similarly, if the energy part is more disaggregated the welfare cost will be smaller. For example, if hydroelectricity and nuclear is explicitly included then a carbon tax will reduce the use of fossil fuels and increase the use of hydro and nuclear.

In the case of DE^3, there are only 4 energy sectors: coal mining, crude oil, electricity, petroleum refining. Within the electricity sector (no. 11) the production function

$$Q_{11i} = f(K_{11}, L_{11}, E_{11}, M_{11}, t)$$

would cause the sector to respond to a fossil fuel tax by buying less energy inputs (E_{11}) and using more capital (K_{11}). One may interpret this to mean buying more hydroelectric dams and more nuclear plants, but exactly how this occurs would not be available from this model.

iv) The specification of the production function and substitution elasticities.

How the function $Q_{11i} = f(K_{11}, L_{11}, E_{11}, M_{11}, t)$ is specified obviously affect the degree of substitution of K for E in response to an increase in the price of E. A Leontief type function would allow no substitution (a certain quantity of E is always required to produce a certain quantity of Q), a Cobb-Douglas function have an elasticity of 1 (a 1 percent rise in the relative price PE/PK will reduce the relative inputs of E/K by 1 percent), and other functional forms and parameters will have substitution elasticities between 0 and 1. Low elasticities will produce small input changes and hence high welfare costs.

How the function changes through time will directly affect the level of the projections, but will only indirectly change the effects of policy changes. Levels matter in the following way — a higher rate of energy saving will mean less energy consumption in the future, and then if an energy tax is imposed the tax will generate less revenue. This could then affect the welfare changes.

v) Specification of consumption function, the import demand function, and related substitution elasticities.

As in (iv).

vi) The mobility of capital.

The DE3 model has a dual feature with both fixed and mobile elements. In the mobile stock the total is free to move to any sector in any period:

$$\tilde{K}_t = \sum_j KD_{jt}$$

while the plan portion is fixed in sector j, $\overline{K}_{jt}$.

Models with sector specific capital will have higher costs of adjusting to policy changes. We should point out in this context that the time sequencing of the model is important. It is reasonable to have less mobility in a model which is solved every year, and more mobility in a model which is solved every 5 years.

vii) The presence of fixed factors of production.

In models where there is irreproducible factors like land or oil reserves the cost of adjustment will be higher than if all factors are reproducible. Similarly, the presence and timing of backstop technologies will affect the welfare estimates of policy changes.

viii) One-country versus multi-country models.

Almost all models allow for exports and imports, however, the responses are quite different in these two types. In the one-country model like the DE3 the current account is written as:

$$\overline{CA}_t = \sum \frac{P_i X_i}{1 + s_i^e} - \sum e_t \overline{P}_{it}^* M_i - r(B^*) + transfer$$

where CA and import prices, P*, are exogenous, and e_t is endogenously calculated to meet this equation. In the multi-country models, all the prices are endogenous, e.g. a carbon tax in country A will affect prices in country B, which will affect imports from B to A. In particular, a one country model assumes that any quantity of oil can be imported at the price $\overline{P}_{it}^*$, the other models will have upward sloping supply curves.

Some multi-country models have exogenous CA, while other intertemporal equilibrium models determine this endogenously using asset demand equations. An endogenous CA will allow an economy to borrow in response to a temporary shock, it will allow an explicit accounting of international payments for any carbon permit trading.