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CHINAGEM: A Monash-Styled Dynamic CGE Model of China

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Acronyms and Initials

BOTE	**B**ack **O**f **T**he **E**nvelope model
CGE	**C**omputable **G**eneral **E**quilibrium
CHINAGEM	**CHIN**a **A**pplied **G**eneral **E**quilibrium **M**odel
CoPS	**C**entre **o**f **P**olicy **S**tudies
GDP	**G**ross **D**omestic **P**roduct
GNE	**G**ross **N**ational **E**xpenditure
GNP	**G**ross **N**ational **P**roduct
UNDP	**U**nited **N**ations **P**opulation **D**ivision
WDI	**W**orld **D**evelopment **I**ndicators

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1. INTRODUCTION

This document provides an overview of CHINAGEM database and equation structure. We also demonstrate how to construct a baseline via historical and forecast simulations. We aim to provide CHINAGEM users with a practical guide.

CHINAGEM is a MONASH-style dynamic Computable General Equilibrium (CGE) model of China. It is a framework for:

- estimating changes in tastes and technology and for generating up-to-date input-output tables (historical simulations);
- explaining periods of economic history in terms of driving factors such as policy changes, changes in world commodity prices and changes in tastes and technology (decomposition simulations);
- generating forecasts for industrial, occupational and regional variables using detailed extrapolations of trends in tastes and technology together with a wide variety of projections from organizations specializing in macro, export, tourism and policy forecasting (forecast simulations); and
- calculating the deviations from explicit forecast paths for macro and micro variables which would be caused by the implementation of proposed policy changes (policy simulations).

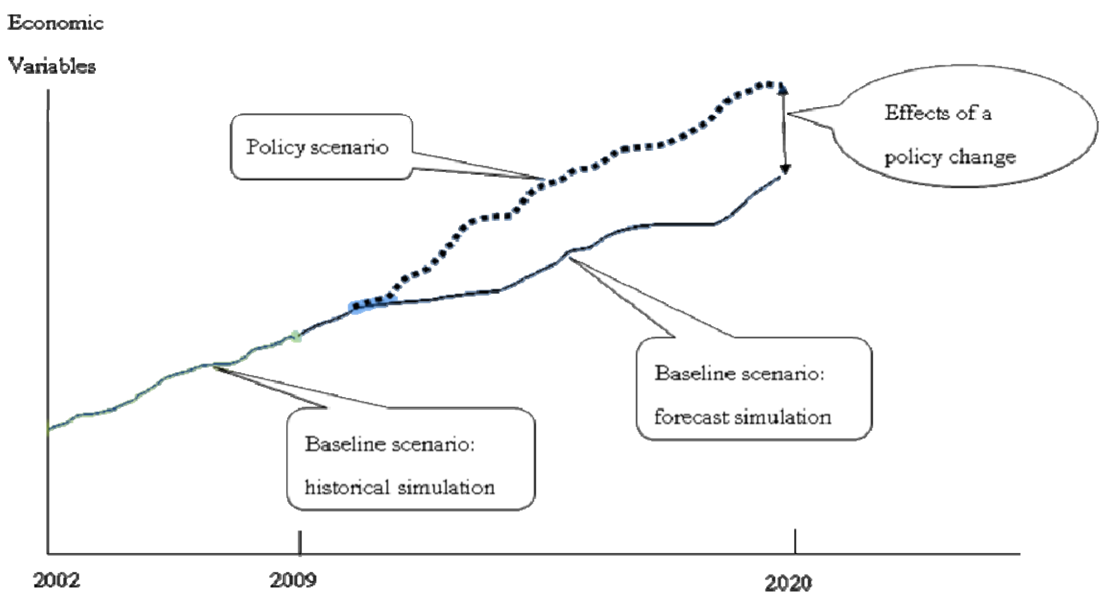
CHINAGEM is a large system of equations describing behaviours of economic agents and linkages between sectors of the economy and between China and the rest of the world. The core part of CHINAGEM contains widely accepted economic theories such as consumer and producer optimisation behaviour. The core model can be applied with attached modules that capture specific characteristics of the Chinese economy such as rural-urban labour migration.

CHINAGEM simulations start from a base year for which a detailed input-output table is available, e.g., the year 2002. The input-output table is used to construct a model database that portrait a picture of the Chinese economy for that year. The model database provides an initial solution for the CHINAGEM equation system. The CHINAGEM equation system has a quantity and a price variable corresponding to every value in the input-output database. A CHINAGEM simulation moves each of the components of the input-output database, thereby taking us to another picture of the economy.

Typically the number of variables is larger than the number of equations in CHINAGEM. The equation system can be used to solve for changes in endogenous variables – the number of which equals to the number of equations – due to changes in exogenous variables. The classification of endogenous/exogenous variables – which variables are to be solved for by CHINAGEM – is flexible[1]. One variable can be endogenous in one simulation and exogenous in another.

A historical simulation moves each of the observable components of the input-output database for year t to their value in year t+1, thereby taking us to the picture of the Chinese economy in the year t+1. When we have arrived at the current year where historical data are no longer available, the forecast simulations moves the picture of the CHINESE economy forward to a future year. The historical and forecast simulations form a baseline scenario (Figure 1.1). A policy simulation can show the effects of a change in economic policy, e.g. implementing social security reform, as deviation in economic variables from the baseline scenario (Figure 1.1).

Figure 1.1. Historical, forecast and policy simulations



CHINAGEM was developed from the MONASH model (Dixon and Rimmer 2002) – a recursive dynamic CGE model of the Australian economy. Since the 1990s, the MONASH model has been applied in economic policy analysis on a broad range of issues such as trade reform; tax reform; competition reform; large project appraisals; contributions of various economic sectors;

[1] A specification of endogenous/exogenous variables is called a closure.

fiscal relationships between federal and regional governments; forecasting greenhouse gas emissions; forecasting regional employment by detailed occupations; population aging and related issues; effects of political events on tourism; employment and wage policies; and macroeconomic policies during economic down-turn. In the past decade, the MONASH model has become a platform for developing dynamic CGE models for other economies. MONASH-style dynamic models are applied in policy analysis in the US, Finland, China, Vietnam, Malaysia, Poland, and under multi-country frameworks.

MONASH-style modelling emphasizes developing a realistic baseline to support policy analysis. Much modelling effort is devoted to incorporate historical data into the baseline with which to compare policy scenarios. The advantage of calculating policy effects as deviations from the realistic baseline is that it brings a growth perspective into the analysis. The following are some examples:

1. The Chinese finance and insurance sector has been growing faster than national real GDP. If the trend continues, investment and services trade liberalisation in a future year that leads to productivity improvement in the finance and insurance sector would have a bigger impact on the whole economy than would be calculated in a model that did not take account of underlying trends.

2. The realistic baseline allows the analysis to separate global trends and effects of policy. By taking out effects of policy implemented from a realistic baseline for a historical period, we separate growth in trade achieved despite of the existence of barriers from the effects of reducing trade barriers. Growth achieved despite of barriers is driven by technology evolution in the global economy. By adding onto a realistic baseline additional policy changes over both historical and forecast periods, we gain insights on how economic policies can help a nation adapt to changes in global economic trends.

3. Investment and services trade liberalisation may create new business opportunities in different parts of the world. In reality, businesses adjust to take advantage of such opportunities. Dynamic modelling based on realistic baseline allows policy changes be analysed against such background. For example, rapid productivity improvement in China creates trade and investment opportunities for other countries. Static simulation of such productivity improvement emphasis negative terms of trade impact on neighbouring countries; however, dynamic simulation also shows positive factors on neighbouring countries due to businesses taking advantage of new opportunities in

China (Mai et al. 2009). Such changes are picked up in the realistic baseline as increased trade and investment linkages between China and its neighbouring countries.

As the world becomes more and more integrated, there is an increasing demand for comprehensive analytical tools such as MONASH-style dynamic models. More importantly, there is an increasing demand for highly skilled CGE analysts. CHINAGEM is designed as an entry point for CGE modellers to develop their analytical skills. It is also designed as a platform for research institutes to develop CGE models suitable for their research portfolio. A comprehensive training program is offered by the Centre of Policy Studies (CoPS) in conjunction with the application of CHINAGEM. With CHINAGEM, analytical capacity grows with the degree of comprehensiveness of the model.

The essential steps towards building CGE analytical capacity via CHINAGEM is the following:

- **Step 1**: Attending basic training courses. The three fundamental courses are:
    - Practical GE Modelling Course;
    - Dynamic GE Modelling Course; and
    - Constructing a CGE Database Course.
- **Step 2**: Applying existing CGE models, such as CHINAGEM, in policy applications with small modification of the model and database. CoPS offers consultation services to help CHINAGEM users in policy applications.
- **Step 3**: Developing your own model by adding new modules and relevant database to CHINAGEM to advance your institute's policy research. This stage requires your institute's modelling team to have significant mathematical and economic background. CoPS offers consultation services to provide software and model development support.
- **Step 4:** The ultimate skill in CGE modelling is the art of using CGE models as a thinking framework for policy and economic analysis. The key to developing this skill is the Back-Of-The-Envelop (BOTE) model technique that is introduced and reinforced throughout CoPS' training courses and consultation services. Often CGE modelers can be overwhelmed by the amount of numbers produced by the model. The BOTE model provides a map or a strategy for CGE analysts to understand the model results and derive policy insights.

This document has five sections. Section 1 is this introduction. In Section 2 we provide a description of the equation system and the database. In Section 3, we introduce how to incorporate observed data to develop the historical part of the baseline. In Section 4, we introduce how to use information derived from the historical simulation to develop the forecast part of the baseline. In Section 4, we also demonstrate how to use CHINAGEM to analyse the effects of a policy change. In the concluding section, we discuss our plan for further development of CHINAGEM.

2. DATABASE, EQUATIONS AND SOLUTION METHOD OF CHINAGEM

In this section we provide a description of the core part of the CHINAGEM equation and database. In Section 2.1 we introduce the structure of the model database. In section 2.2 we provide an overview of the mathematical structure of CHINAGEM and its solution method. In section 2.3 we present a stylised version of the equation system.

2.1. The structure of the CHINAGEM database

Figure 2.1 sets out the structure of the CHINAGEM input-output database in three parts: an absorption matrix; a joint-production matrix; and a vector of import duties. The first row in the absorption matrix, V1BAS, ..., V6BAS, shows flows in year t of commodities to producers, investors, households, exports, public consumption and inventory accumulation. Each of these matrices has C×S rows, one for each of C commodities from S sources. C is the number of commodities in the model (e.g. 137 for the year 2002 database, see Appendix I) and S is 2 (domestic and imported). V1BAS and V2BAS each have *I* columns where *I* is the number of CHINAGEM industries (137 for the 2002 database). Thus, the typical component of V1BAS is the value of good c from source s [good (c,s)] used by industry i as an input to production, and the typical component of V2BAS is the value of (c,s) used to create capital for industry i. V3BAS to V6BAS each have one column. In standard applications, CHINAGEM recognises one household, one foreign buyer, one category of public demand and one category of inventory demand[2]. In the input-output database, no imported commodity is exported without being processed in a domestic industry. Consequently, V4BAS(c,s) is zero wherever s= "imp".

[2] CHINAGEM can be extended to have more than one agent.

Figure 2.1. The CHINAGEM Input-Output Database

		Absorption Matrix					
		1	2	3	4	5	6
		Prod-ucers	Invest-Ors	House-holds	Exports	Govern-ment	Invent-ories
	Size	← I →	← I →	← 1 →	← 1 →	← 1 →	← 1 →
Basic Flows	↑ $C \times S$ ↓	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS
Margins	↑ $C \times S \times N$ ↓	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	V6MAR
Sales Taxes	↑ $C \times S$ ↓	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	V6TAX
Labour	↑ M ↓	V1LAB_O					
Capital	↑ 1 ↓	V1CAP					
Land	↑ 1 ↓	V1LND					
Other Costs	↑ 1 ↓	V1OCT					
Production Taxes	↑ 1 ↓	V1PTX					

C = Number of commodities
I = Number of industries
S = 2; domestic and imported
M = Number of occupations
N = Number of commodities used as margins

	Joint Production Matrix
Size	← I →
↑ C ↓	MAKE

	Import Duty
Size	← 1 →
↑ C ↓	V0TAR

All of the flows in V1BAS, ..., V6BAS are valued at basic prices. The basic price of a domestically produced good (s= "dom") is the price received by the producer (that is the price paid by users excluding sales taxes, transport costs and other margin costs). The basic price of an imported good is the landed-duty-paid price, i.e., the price at the port of entry just after the commodity has cleared customs.

Costs separating producers or ports of entry from users appear in the input-output data in the margin matrices and in the a row of sales-tax matrices. The margin matrices, V1MAR, ..., V6MAR, show the values of N margin commodities used in facilitating the flows identified in V1BAS, ..., V6BAS. For the 2002 database, N=8. The eight commodities that can be used as margins are five types of transport, warehousing, insurance, and trade (retail and wholesale services). Imports are not used as margin services.

Each of the matrices V1MAR, ..., V6MAR has C×S×N rows. These correspond to the use of N margin commodities in facilitating flows of C commodities from S sources (producers and ports of entry). V1MAR and V2MAR have *I* columns identifying *I* industrial producers and *I* industrial capital creators, and V3MAR to V6MAR each have one column. The typical components of V1MAR and V2MAR are the values of margin commodity n used in facilitating the flow of (c,s) to industry i for current production and for capital creation. Similarly, the typical components of V3MAR to V6MAR are the values of margin commodity n used in facilitating flows of (c,s) to households, ports of exit[3], governments and stocks of inventories[4]. As with the BAS matrices, all the flows in the MAR matrices are valued at basic prices. In the case of margin flows, we assume that there is no cost separation between producers and users, i.e., there are no margins on margins.[5] Hence, there is no distinction between prices received by the suppliers of margins (basic prices) and prices paid by users of margins (purchasers' prices).

[3] It should be emphasized that V4MAR contains transport and other margin costs incurred in facilitating export flows from Chinese producers to Chinese ports. It does not include transport and other margin costs incurred outside China.

[4] In the current implementation of the CHINAGEM model there are no margins on inventory accumulation. Consequently, V6MAR does not appear in the TABLO code.

[5] Some readers may be concerned about the treatment of taxes charged on margin services such as road transport. These are handled as taxes paid by margin industries either on their outputs or their inputs (e.g., petrol). They are not treated as charges which separate the price received by the margin producer from the price paid by the margin user. Consequently, they are not treated as charges which can cause different users to pay different amounts per unit of service received.

V1TAX, …, V6TAX record collections of sales taxes.[6] The entries in these matrices show sales taxes. The typical component of V1TAX, for example, is the sales tax paid as a result of the flow of good (c,s) to industry i for use as an intermediate input. While most of the entries in sales-tax matrices are non-negative, it is possible to use negative entries to represent subsidies.

Unlike production taxes and import duties (both of which are included in the basic prices of commodities), sales taxes can be levied at different rates on different users. Consequently, in the CHINAGEM database, the ratio of V1TAX(c,s,i) to V1BAS(c,s,i), for example, may differ from the ratio of V3TAX(c,s) to V3BAS(c,s). There may also be differences in the sales tax rates implied by the database on flows of (c,"dom") and (c,"imp") to the same users. Such differences can arise from differences in the sub-commodities making up (c,"dom") and (c,"imp"). Consider, for instance, the commodity Beverages & tobacco. Assume that domestically produced Beverages & tobacco consist largely of tobacco while the imported commodity consists largely of beverages. If rates of sales taxes charged to households on tobacco differ from those charged on beverages, then V3TAX(c,"dom")/V3BAS(c,"dom") and V3TAX(c,"imp")/V3BAS(c,"imp") will differ.

Payments by industries for labour are recorded in Figure 2.1 in the matrix V1LAB_O. The vectors V1CAP and V1LND show payments by industries for their use of fixed capital and land. The current CHINAGEM database shows non-zero land rentals only for agricultural and mining industries. Other industries are treated as though they use no scarce land. The vector V1OCT records other costs incurred by industries e.g. the costs of holding inventories. The vectors V1PTX show collections of taxes on production.

The final two data items in Figure 2.1 are V0TAR and MAKE. V0TAR is a C×1 vector showing tariff revenue by imported commodity. The joint-product matrix, MAKE, has dimensions C×*I*. Its typical component is the output (valued in basic prices) of commodity c by industry i.

Together, the absorption and joint-production matrices satisfy two balance conditions. First, the column sums of MAKE, which are values of industry outputs, are identical to the values of industry inputs. Hence, the i-th column sum of MAKE equals the i-th column sum of V1BAS, V1MAR, V1TAX, V1LAB_O, V1CAP, V1LND, V1OCT and V1PTX.

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[6] In the current implementation of the CHINAGEM model there are no sales taxes on inventory accumulation. Consequently, V6TAX does not appear in the TABLO code.

Second, the row sums of MAKE, which are basic values of outputs of domestic commodities, are identical to basic values of demands for domestic commodities. If c is a non-margin commodity, then the c-th row sum of MAKE is equal to the sum across the (c,"dom")-rows of V1BAS to V6BAS. If c is a margin commodity, then the c-th row sum of MAKE is equal to the direct uses of domestic commodity c, i.e., the sum across the (c,"dom")-rows of V1BAS to V6BAS, plus the margins use of commodity c. The margins use of c is the sum of the components in the (cc,s,c)-rows of V1MAR to V6MAR for all commodities cc and both sources s.

An implication of the two balance conditions (reflecting the equality between the sum of the column sums and the sum of the row sums of MAKE) is that the total value of inputs to domestic production equals the total value of demands for domestic products:

Sum(V1BAS) + Sum(V1MAR) + Sum(V1TAX) +
Sum(V1LAB_O) + Sum(V1CAP) + Sum(V1LND) +
Sum(V1OCT) + Sum(V1PTX)
= Sum(V1BAS) + Sum(V2BAS) + Sum(V3BAS)
+ Sum(V4BAS) + Sum(V5BAS) + Sum(V6BAS)
+ Sum(V1MAR) + Sum(V2MAR) + Sum(V3MAR)
+ Sum(V4MAR) + Sum(V5MAR) + Sum(V6MAR)
- [Sum(V1BAS(imp)) + Sum(V2BAS(imp)) + Sum(V3BAS(imp))
+ Sum(V4BAS(imp)) + Sum(V5BAS(imp)) + Sum(V6BAS(imp))] , (2.1.1)

where

Sum(X) is the sum of all the components in the matrix X; and

V ϕ BAS (imp) is the matrix formed by the imports rows (s="imp") of V ϕ BAS for ϕ=1,...,6.

From here we can show that the CHINAGEM input-output database satisfies the national income identity: GDP from the income side equals GDP from the expenditure side. The identity is established by cancelling Sum(V1BAS) and Sum(V1MAR) from the two sides of (2.1.1) and by adding Sum(V0TAR) and Sum(VϕTAX), ϕ=2,...6, giving

Sum(V1LAB_O) + Sum(V1CAP) + Sum(V1LND) + Sum(V1OCT)

+ Sum(V1PTX) + Sum(V0TAR)+ $\sum_{\phi=1}^{6} \mathrm{SUM}(\mathrm{V}\phi\mathrm{TAX})$

= Sum(V2BAS) + Sum(V2MAR) + Sum (V2TAX)
+ Sum(V3BAS) + Sum(V3MAR) + Sum(V3TAX)
+ Sum(V4BAS) + Sum(V4MAR) + Sum(V4TAX)

$$+ \text{ Sum(V5BAS)} + \text{Sum(V5MAR)} + \text{Sum(V5TAX)}$$

$$+ \text{ Sum(V6BAS)} + \text{Sum(V6MAR)} + \text{Sum(V6TAX)}$$

$$- \; [\sum_{\phi=1}^{6} \text{ Sum(V}\phi\text{BAS(imp))} \; - \; \text{Sum(V0TAR)}] \; . \qquad (2.1.2)$$

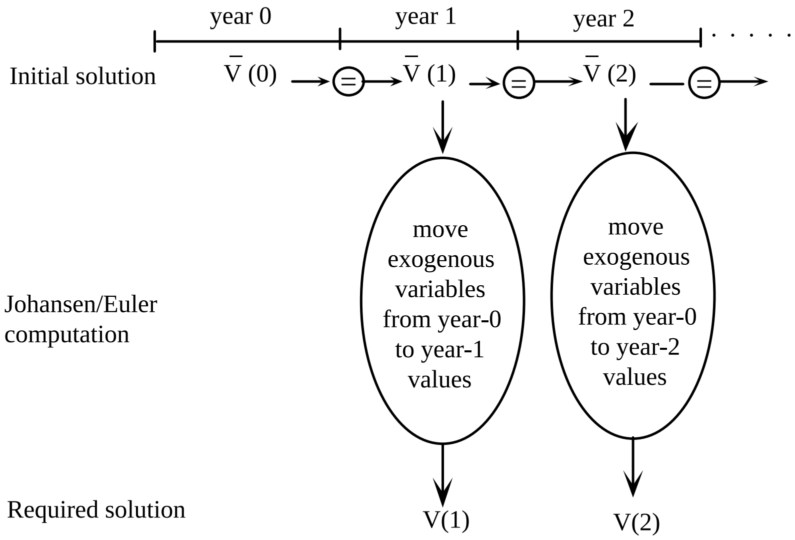
The LHS of (2.1.2) is the income measure of the GDP, i.e., returns to factors plus indirect taxes. The RHS of (2.1.2) is the expenditure measure of GDP, i.e., expenditure on investment *plus* expenditure on consumption *plus* expenditure on exports (f.o.b.) *plus* public expenditure *plus* inventory accumulation *minus* imports (c.i.f.).

As we move from the picture of the economy provided by our initial input-output database, (2.1.2) provides an important check on our computations. We should always find that the percentage changes from the initial situation in the income and expenditure measures of GDP are equal.

From the data and initial solution for year 0, there are several ways of generating data and initial solutions for other years. One possibility is to use the same data and initial solution for every year. This is the approach in Figure 2.2, in which the initial solution for every year t, $\overline{\nabla}$ (t), is $\overline{\nabla}$ (0) or the model input-output database. Under this approach, the Johansen/Euler calculation for year t generates the effects on endogenous variables of moving the exogenous variables from their initial year-t values (i.e., their year-0 values) to their required year-t values. Another approach (Figure 2.3) is to use the required solution for year t-1 (including the solution for the input-output flows)[7] as the initial solution for year t. We adopt this second approach for year-to-year CHINAGEM simulations because it usually involves Johansen/Euler computations of the effects of relatively small movements in the exogenous variables (from their year t-1 to their year t values). A difficulty with using the year-0 solution as the initial solution for all years is that as we move away from year 0, the Johansen/Euler computations may require increasing numbers of steps to generate accurate solutions. This is because in year 10, for example, the values of the exogenous variables may be far from their values in year 0.

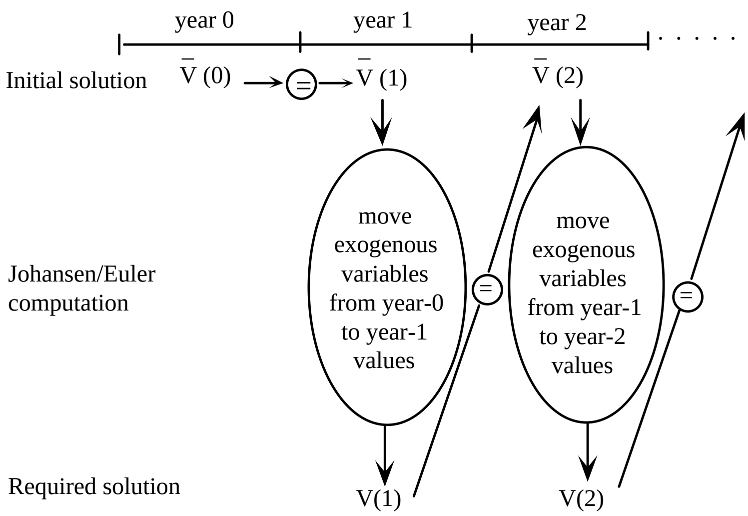
[7] Our solution for year t-1 contains values for all prices and quantities. From these, we can create year-(t-1) input-output flows. These become the input-output data in our computation for year t.

Figure 2.2. A sequence of solutions using the solution for year 0 as the initial solution for year t



Source: Dixon and Rimmer 2002.

Figure 2.3. A sequence of solutions using the required solution for year t-1 as the initial solution for year t



Source: Dixon and Rimmer 2002.

2.2. Overview of the mathematical structure of CHINAGEM and introduction to the Johansen/Euler solution method

We represent CHINAGEM as

$$F(V(t)) = 0 \quad , \tag{2.2.1}$$

where V(t) is a vector of length n referring to prices, quantities and other variables for year t and F is a vector function of length m, m<n.

The computational approach that we have adopted for CHINAGEM depends on being able to solve the model one year at a time. For year t we specify values for n-m exogenous variables and solve (2.2.1) for the remaining m endogenous variables. By obtaining a sequence of linked solutions for years τ, τ+1, τ+2, ..., we generate time paths for variables. Links between the annual solutions are provided by lags. For example, we assume that capital stocks at the beginning of year τ+1 (variables in the solution for year τ+1) equal capital stocks at the end of year τ (variables in the solution for year τ).[8]

Within any sequence of solutions, we obtain the solution for year t [i.e., we solve (2.2.1)] by the Johansen/Euler[9] method. This method requires an initial solution, $\overline{V}$(t), satisfying (2.2.1). Starting from this initial solution, we obtain the required solution for year t by calculating the effects on endogenous variables of moving the exogenous variables away from their values in the initial solution to their values in the required solution.

Johansen/Euler deviation computations are made by solving systems of linear equations. In a one-step computation, we can use the system

$$H(\overline{V}(t))\, dV = 0 \quad , \tag{2.2.2}$$

where $H(\overline{V}(t))$ is the m$\times$n matrix of first-order partial derivatives of F evaluated at $\overline{V}$(t) and dV is the n$\times$1 vector of deviations in the values of the n variables away from $\overline{V}$(t). The LHS of (2.2.2) is an approximation to the vector of changes in the F functions caused by changing the variable values from $\overline{V}$(t) to $\overline{V}$(t) + dV. Because we are looking for a new solution to (2.2.1),

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[8] We may also wish to impose forward links. For example, we may wish to assume that profit expectations held in year τ (variables in the τ solution) depend on profit outcomes in year τ+1 (variables in the τ+1 solution). Forward links pose difficulties for our one-year-at-a-time computational method. These can be overcome by an iterative method (see Dixon and Rimmer, 2002, section 21; and Dixon *et al.* , 2005).

[9] So named in recognition of the contributions of Johansen (1960) who applied a version of this method to solve his CGE model of Norway, and Euler, the eighteenth century mathematician who set out the theory of the method as an approach to numerical integration. Early examples of applications of the Johansen method include Taylor and Black (1974), Staelin (1976), Keller (1980), Dixon et. al.(1977), and Dixon *et. al.* (1982).

we put this vector of approximate changes equal to zero. We recognize that in going from the initial solution for year t to the new solution, we must leave the values of the F functions unchanged from zero.

Rather than using systems such as (2.2.2) in which all the variables are changes [dV], we work with systems in which some of the variables are changes and some are percentage changes. Percentage changes are more convenient than changes because with percentage changes we don't have to worry about units. But not all variables can be treated as percentage changes because some variables (e.g. the balance of trade) naturally pass though zero. In this case, percentages become undefined.

With the variables being a mixture of changes and percentage changes, (2.2.2) becomes

$$A(\bar{V}(t))\, v = 0 \qquad (2.2.3)$$

where (with the t's omitted for convenience) the (q,r)-th component of $A(\bar{V})$ is given by:

$$A_{q,r}(\bar{V}) = \begin{cases} H_{q,r}\left(\bar{V}\right) * \dfrac{\bar{V}_r}{100} & \text{if r is a percentage change variable} \\ H_{q,r}\left(\bar{V}\right) & \text{if r is a change variable} \quad . \end{cases} \qquad (2.2.4)$$

To solve the model we must first divide the variables into two groups, n-m exogenous variables and m endogenous variables. Then, we rewrite (2.2.3) as

$$A^{\alpha}(\bar{V}) * v_{\alpha} + A^{\beta}(\bar{V}) * v_{\beta} = 0 \qquad (2.2.5)$$

where

$A^{\alpha}(\bar{V})$ is the m x m matrix formed by the m columns of $A(\bar{V})$ corresponding to the endogenous variables;

$A^{\beta}(\bar{V})$ is the m x (n-m) matrix formed by the n-m columns of $A(\bar{V})$ corresponding to the exogenous variables; and

v_{α} and v_{β} are the vectors of movements in the endogenous and exogenous variables.

Given values for the n-m exogenous variables, in a one-step Johansen/Euler procedure we solve (2.2.5) for the exogenous variables as:

$$v_\alpha = -\left(A^\alpha(\bar{V})\right)^{-1} * A^\beta(\bar{V}) * v_\beta \tag{2.2.6}$$

Among the questions which will have occurred to the reader are the following:

(i) how do we obtain the initial solution $\bar{V}$ (t);

(ii) can we be sure that $A^\alpha(\bar{V})$ is non-singular;

(iii) how do we evaluate the coefficients of systems such as (2.2.3), i.e., how do we evaluate A($\bar{V}$); and

(iv) does (2.2.6) produce an accurate solution for the effects on the endogenous variables of movements in the exogenous variables away from their initial values, and if not what can be done.

Detailed answers to all these questions can be found in Dixon and Rimmer (2002, chapter 3) and Dixon et. al. (1982 Chapter 5). Here we provide brief intuitive answers.

The answer to question (i) is that $\bar{V}$ comes mainly from the model's input-output database which shows the value of flows of commodities and factors to each industry. By adopting suitable units for quantities, we can assume that prices are initially one and that the input-output data reveals not only values but also quantities. The balance properties of the input-output database (discussed in section 2.1) mean that these quantity flows satisfy the condition that demands equal supplies for each commodity. At the same time, the value flows satisfy the condition that costs equal revenues for each industry. The input-output prices and quantities also fit the demand and supply functions in CHINAGEM. This is because it is these prices and quantities that are used in calibrating the demand and supply functions. For example, assume that our model contains Cobb-Douglas demand functions of the form:

$$X(i) = \delta(i) * \frac{C}{P(i)} \tag{2.2.7}$$

where X(i) is household demand for commodity i; P(i) is the price of commodity i; C is total household expenditure; and δ(i) is a parameter. Values for P(i) and X(i) can be deduced from the input-output data after applying our units convention and C can be observed directly from the input-output data. These values for P(i), X(i) and C satisfy (2.2.7) because the value for the parameter δ(i) is set from the input-output table at the share of commodity i in household expenditure.

The answer to question (ii) is that that singularity of $A^{\alpha}(\overline{V})$ will cause the Johansen/Euler method to fail. However, this is not really a computational difficulty. Rather, it indicates that we have not set our model a question that it can answer by any computational method. This is because singularity of $A^{\alpha}(\overline{V})$ implies that the variables we have chosen to be endogenous [V_α] are not functions of those we have chosen to be exogenous [V_β]. This means that there are either no values or multiple values for the endogenous vector that are compatible with the specified movements in the exogenous vector (see Dixon *et al.* (1982, sections 8, 30-36 and 47).

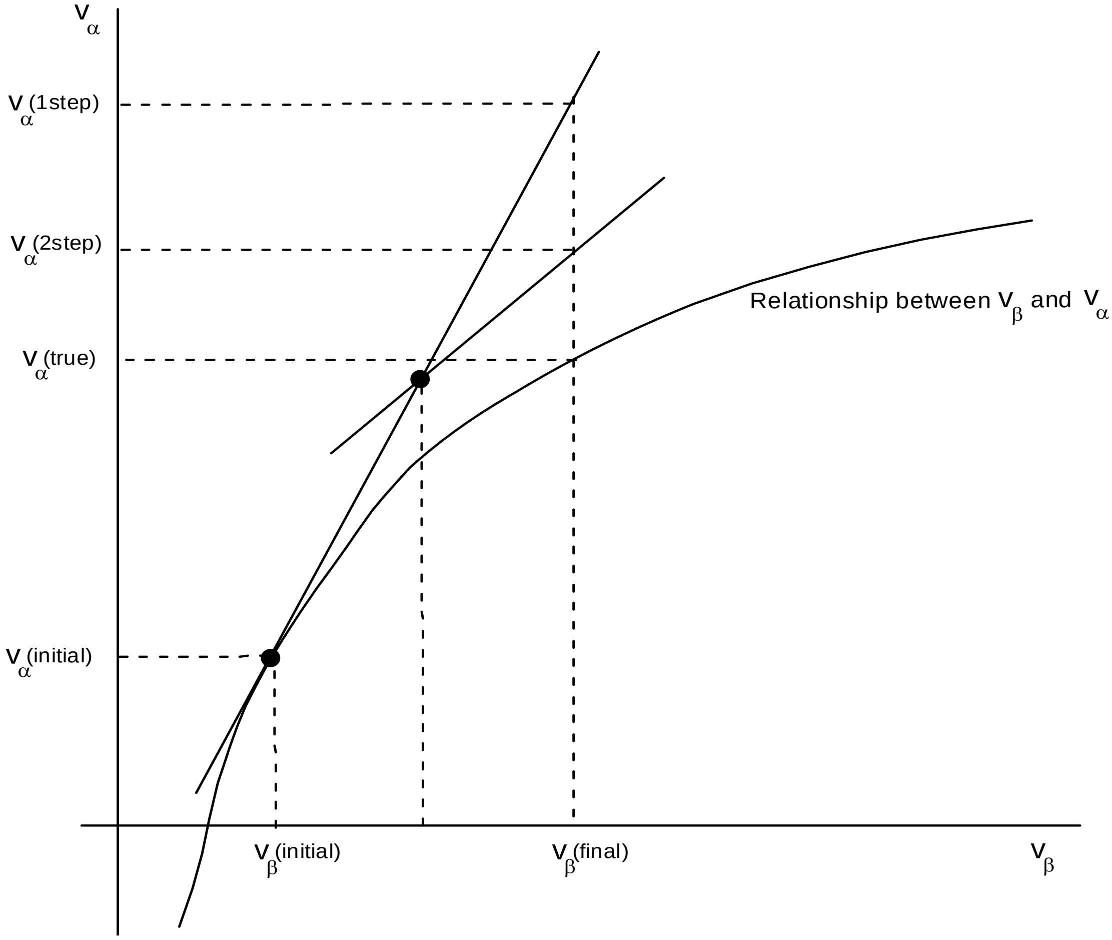
The answer to question (iii) is that many of the components of A($\overline{V}$) are zeros and plus ones or negative ones. For example, (2.2.7) in percentage changes is

$$x(i) - c - p(i) = 0 \tag{2.2.8}$$

where x(i), c, and p(i) are percentage changes in the corresponding uppercase variables. The row of A($\overline{V}$) corresponding to (2.2.8) would have plus one in the column for x(i), negative one in the column for c, negative one in the column for p(i) and zero in all other columns. Other equations are represented in A($\overline{V}$) by more complicated coefficients. However, most of these are evaluated by applying simple formulas to the model's database. Many of these formulas combine cost and sales shares calculated from input-output data with substitution parameters.

Figure 2.4 is a helpful diagram for thinking about the answer to question (iv). The curve in this figure represents (2.2.1) as a one-equation, two-variable model. If we use (2.2.6) to compute the effect of moving V_β from $V_\beta(\text{initial})$ to $V_\beta(\text{final})$ then the error is $V_\alpha(\text{1step})$ - $V_\alpha(\text{true})$. However, we can reduce this error by a multi-step computation. In a two-step procedure, we start by using (2.2.6) to compute the effects of moving V_β halfway from its initial value to its final value. Then we see what has happened to all prices and quantities and we update the database. In the second step, we compute the effects of V_β moving from its halfway value to its final value. In this second step we use (2.2.6) but with V set at the value it reached at the end of the first step. In effect, we use (2.2.6) with an updated value for the derivative of V_α with respect to V_β. Note that Figure 2.4 implies that the errors in a one-step procedure are approximately halved in a two-step procedure. This idea can be exploited in GEMPACK to generate highly accurate solutions in a very small number of steps.

Figure 2.4. The effects on V_α of moving V_β from V_β(initial) to V_β(final) computed by 1 and 2 step Johansen/Euler procedures



2.3. Stylised version of the CHINAGEM model

This section describes a stylized version of CHINAGEM together with a trial closure. Our aim is to give readers an intuitive understanding of where the major groups of CHINAGEM equations fit into the overall structure of the model.

Table 2.1 lists the stylized equations in groups. Table 2.2, which is presented in three parts, defines the notation used in Table 2.1. The first two parts of Table 2.2 list the endogenous and exogenous variables in the trial closure. The third part lists other notation from Table 2.1. In subsection 2.3.1 we work through Table 2.1 and then in subsection 2.3.2 we discuss the closure set out in Table 2.2.

2.3.1. Equations in the Stylized version

(a) Composition of outputs and inputs

The first five equations in Table 2.1 are concerned with the compositions of industry outputs and inputs. Each industry in CHINAGEM can produce a variety of domestic commodities, (c,1) c=1, 2, …,N_C. Industry i chooses the composition of its output to maximize revenue subject to a transformation frontier. This gives commodity supply functions of the forms shown in (2.3.2) and (2.3.1). In (2.3.2) the total output of (c,1) [X0COM(c)] is the sum over industries of outputs [X0(c,1,i), i = 1, 2, … N_I], and in (2.3.1) the output of (c,1) by industry i is a function of prices (P_1) of domestic commodities and of the level of i's activity [X1TOT(i)]. The level of i's activity determines the distance of i's transformation frontier from the origin. We assume constant returns to scale implying that an x per cent increase in X1TOT(i) allows industry i to produce x per cent more of all commodities. An x per cent increase in activity can be achieved with an x per cent increase in all inputs. Thus, as indicated in equations (2.3.3) to (2.3.5), i's demands for inputs are proportional to X1TOT(i). They also depend on input prices and on technology variables (A_{1i}, A_{PFi}) that affect the location and shape of i's isoquants. The input prices enter i's demand functions via cost-minimizing assumptions. With the particular production functions adopted in CHINAGEM, the demands by industry i for inputs of domestic and imported good c [X1(c,s,i), s= 1,2] depend on the prices [P_s(c), s= 1,2] of the two varieties of good c, and the demands by industry i for primary factors [L(i) and K(i)] depend on the wage rate (W) and the rental price [Q(i)] of i's capital.

Table 2.1. Stylized Representation of the CHINAGEM Equations

	Dimension	Identifier
Composition of outputs and inputs		
$X0(c,1,i) = X1TOT(i)*\psi_{0c1i}(P_1)$	$N_C N_I$	(2.3.1)
$X0COM(c) = \Sigma_i X0(c,1,i)$	N_C	(2.3.2)
$X1(c,s,i) = X1TOT(i)*\psi_{1csi}(P_1(c), P_2(c), A_{1i}, A_{TWIST})$	$N_C N_S N_I$	(2.3.3)
$L(i) = X1TOT(i)*\psi_{Li}(W, Q(i), A_{PFi})$	N_I	(2.3.4)
$K(i) = X1TOT(i)*\psi_{Ki}(W, Q(i), A_{PFi})$	N_I	(2.3.5)
Inputs to capital creation and asset prices		
$X2(i,s,j) = X2TOT(j)*\psi_{2isj}(P_1(i), P_2(i), A_{2j}, A_{TWIST})$	$N_C N_S N_I$	(2.3.6)
$PI(j) = \psi_{PIj}(P_1, P_2, A_{2j})$	N_I	(2.3.7)
Household demands for commodities		
$X3(i,s) = \psi_{3is}(C, P3_1, P3_2, A_3, A_{TWIST})$	$N_C N_S$	(2.3.8)
Exports		
$X4(i) = \psi_{4i}(PE(i)) + A_4(i)$	N_C	(2.3.9)
Government demands		
$X5(i,s) = A_5(i,s)*A_{(5)}$	$N_C N_S$	(2.3.10)
Demands for margin services		
$X3MAR(k,s,i) = A3MAR(k,s,i)*X3(k,s)$	$N_c^2 N_S$	(2.3.11)
Supply equals demand for commodities		
$X0COM(i) = \Sigma_j X1(i,1,j) + \Sigma_j X2(i,1,j) + X3(i,1)$		
$+X4(i) + X5(i,1) + \Sigma_k \Sigma_s X3MAR(k,s,i)$	N_C	(2.3.12)
$X0IMP(i) = \Sigma_j X1(i,2,j) + \Sigma_j X2(i,2,j) + X3(i,2) + X5(i,2)$	N_C	(2.3.13)
Zero profits in production, importing, exporting and distribution		
$\Sigma_i P_1(i) X0(i,1,j) = \Sigma_i \Sigma_s P_s(i) X1(i,s,j) + W*L(j) + Q(j)*K(j)$	N_I	(2.3.14)
$P_2(i) = [PM(i)/\Phi]*TM(i)$	N_C	(2.3.15)
$P_1(i) = [PE(i)/\Phi]/T4(i)$	N_C	(2.3.16)
$P3_s(k) = P_s(k)*T3(k,s) + \Sigma_i P_1(i)*A3MAR(k,s,i)$	$N_C N_S$	(2.3.17)

….continued

Table 2.1 continued

	Dimension	Identifier
Indirect taxes		
$T4(i) = A_{0T}(i)*A_{4T}(i)$	N_C	(2.3.18)
Definitions of macro variables		
$CPI = \psi_{CPI}(P3_1, P3_2)$	1	(2.3.19)
$WR = W/CPI$	1	(2.3.20)
$LTOT = \Sigma_j L(j)$	1	(2.3.21)
$KTOT = \Sigma_j K(j)$	1	(2.3.22)
$GDP = C + \Sigma_j PI(j)* X2TOT(j) + \Sigma_s \Sigma_i P_s(i)*X5(i,s)$		
$+ \Sigma_i[PE(i)/\Phi]*X4(i) - \Sigma_i[PM(i)/\Phi]*X0IMP(i)$	1	(2.3.23)
Capital stocks, investment and rates of return		
$K_+(j) = (1-D(j))*K(j) + X2TOT(j)$	N_I	(2.3.24)
$IKRATIO(j) = X2TOT(j)/K(j)$	N_I	(2.3.25)
$K_+(j)/K(j) - 1 = \psi_{KG}(EROR(j)) + A_{KG}(j) + A_{KGT}$	N_I	(2.3.26)
$EROR(j) = \psi_{ERORj}(Q(j), PI(j)) + A_{EROR}(j)$	N_I	(2.3.27)
Balance of payments and GNP		
$NFLF_+ = NFLF + CAD*\Phi$	1	(2.3.28)
$CAD = \Sigma_i(PM(i)/\Phi)*X0IMP(i) - \Sigma_i(PE(i)/\Phi)*X4(i) + R0IF*(NFLF/\Phi)$	1	(2.3.29)
$GNP = GDP - R0IF*(NFLF/\Phi)$	1	(2.3.30)
Function for private and public consumption		
$C + \Sigma_s \Sigma_i P_s(i)*X5(i,s) = A_C*GNP$	1	(2.3.31)
The government accounts		
$PSD = \Sigma_s \Sigma_i P_s(i)X5(i,s) - \Sigma_s \Sigma_k[T3(k,s) - 1]P_s(k)X3(k,s)$		
$- \Sigma_i(TM(i)-1)[PM(i)/\Phi]X0IMP(i) - \Sigma_i(T4(i)-1)*P_1(i)*X4(i)$		
$+ TRANSFERS$	1	(2.3.32)
Sticky-wage specification for policy simulations		
$\left[\frac{WR}{WR_f} - 1\right] = \left[\frac{WR_{lag}}{WR_{flag}} - 1\right] + \alpha\left[\frac{LTOT}{LTOT_f} - 1\right] + A_{WR}$	1	(2.3.33)

….continued

Table 2.1 continued

	Dimension	Identifier
Technical and preference change		
$A_3(i) = A_{3G}(i) * A_{3F}(i)$	N_C	(2.3.34)
$A_{3G}(i) = A_{CG}(q), \quad \forall\ i \in G(q)$	N_C	(2.3.35)
Equations for facilitating historical and forecast simulations		
$CG(q) = \Sigma_{j \in G(q)} \Sigma_s X3(j,s)$	N_{CG}	(2.3.36)
Total number of equations:		
$N_c^2 N_S + N_C N_I + 3N_C N_S + 2N_C N_S N_I + 8N_I + 9N_C + N_{CG} + 11$		

(b) Inputs to capital creation and asset prices

With the capital-creation functions used in CHINAGEM, cost-minimizing assumptions produce input-demand functions of the form (2.3.6): the demand for inputs of commodity i from source s to be used by industry j for capital creation depends on the quantity of capital creation [X2TOT(j)] in industry j, on the prices of domestic and imported commodity i, and on variables (A_{2j}) reflecting the technology for creating units of capital for use in industry j. As implied by (2.3.7), the cost [PI(j)] of a unit of capital in industry j depends on input prices and technology. We assume that the cost of creating a unit of capital is also the price at which a unit can be sold (the asset price).

(c) Household demands for commodities

Demands for commodities by households are derived in CHINAGEM from utility maximization subject to a budget constraint. A stylized version of the resulting demand functions is given in (2.3.8) which shows household demands as functions: of the household budget (C); of variables reflecting household preferences (A_3); and of purchasers' prices to households of domestic commodities ($P3_1$) and imported commodities ($P3_2$). In CHINAGEM, *all* demands for commodities depend on purchasers' prices. In the stylized version we simplify CHINAGEM by assuming that margins occur only on commodity flows to households and that the only indirect taxes are tariffs, export taxes and taxes on consumption. Thus, in (2.3.3), (2.3.6) and (2.3.7) we used basic prices.[10]

[10] The basic price of a domestic commodity is the price received by producers and the basic price of an imported commodity is the landed-duty-paid price.

Table 2.2. Notation in the Stylized Model

		Dimension	Determining equation
I. Endogenous variables in the trial closure			
T4(i)	Power of tax on exports of commodity i	N_C	(2.3.18)
P_1	Basic prices of domestic commodities	N_C	(2.3.16)
P_2	Basic prices of imported commodities	N_C	(2.3.15)
$P3_1$, $P3_2$	Vectors of household purchasers' prices for domestic and imported commodities	$N_C N_S$	(2.3.17)
CPI	Consumer price index	1	(2.3.19)
W	Wage rate	1	(2.3.20)
Q(j)	Rental rate on capital in industry j	N_I	(2.3.14)
X1TOT(j)	Activity level in industry j	N_I	(2.3.5)
X0(i,1,j)	Output of commodity (i,1) by industry j	$N_C N_I$	(2.3.1)
X0COM(i)	Total output of commodity (i,1)	N_C	(2.3.2)
X1(i,s,j)	Input of (i,s) to production in industry j	$N_C N_S N_I$	(2.3.3)
L(j)	Employment in industry j	N_I	(2.3.4)
PI(j)	Asset price of capital in industry j	N_I	(2.3.7)
EROR(j)	Expected rate of return in industry j	N_I	(2.3.27)
K_+(j)	End-of-year stock of capital in industry j	N_I	(2.3.26)
X2TOT(j)	Investment in industry j	N_I	(2.3.24)
IKRATIO(j)	Ratio of investment to capital in industry j	N_I	(2.3.25)
X2(i,s,j)	Input of (i,s) to j's capital creation	$N_C N_S N_I$	(2.3.6)
A_3(i)	Household preferences with respect to good i	N_C	(2.3.34)
X3(i,s)	Household consumption of commodity (i,s)	$N_C N_S$	(2.3.8)
X5(i,s)	Government consumption of good (i,s)	$N_C N_S$	(2.3.10)
X3MAR(k,s,i)	Margin use of domestic good i in facilitating the flow of (k,s) from producers and ports of entry to households	$N_c^2 N_S$	(2.3.11)
X4(i)	Exports of commodity i	N_C	(2.3.12)
X0IMP(i)	Total imports of commodity i	N_C	(2.3.13)
A_4(i)	Slack in export-demand function for i	N_C	(2.3.9)

….continued

Table 2.2 continued

		Dimension	Determining equation
LTOT	Total employment	1	(2.3.21)
KTOT	Total start-of-year capital stock	1	(2.3.22)
GDP	Gross domestic product	1	(2.3.23)
CG(q)	Consumption in qth group of commodities	N_{CG}	(2.3.36)
A_{WR}	Slack in wage-determination equation	1	(2.3.33)
PSD	Public sector deficit	1	(2.3.32)
CAD	Current account deficit	1	(2.3.29)
$NFLF_+$	End-of-year net foreign liabilities in foreign currency	1	(2.3.28)
GNP	Gross national product	1	(2.3.30)
A_C	Aggregate propensity to consume	1	(2.3.31)
$A_{3G}(i)$	Household preferences corresponding to $A_{CG}(q)$	N_C	(2.3.35)
Total number of endogenous variables:			
	$N_c^2 N_S + N_C N_I + 3N_C N_S + 2N_C N_S N_I + 8N_I + 9N_C + N_{CG} + 11$		

II. Exogenous variables in the trial closure

K(j)	Start-of-year capital stock in industry j
NFLF	Start-of-year net foreign liabilities in foreign currency
WR_{lag}	Real wage rate in previous year
WR_{flag}	Forecast for real wage rate in previous year
WR_f	Forecast for real wage rate
$LTOT_f$	Forecast for total employment
TM(i)	Power (one plus the rate) of tariff on imports of commodity i
T3(k,s)	Power of tax on household consumption of good (k,s)
TRANSFERS	Transfers from the public sector to households,e.g., unemployment benefits and interest on the public debt
PM(i)	Foreign currency c.i.f. price of imports of commodity i
ROIF	Rates of interest or dividends applying to net foreign liabilities
Φ	Exchange rate
C	Total household expenditure
WR	Real wage rate

….continued

Table 2.2 continued

PE(i)	Foreign-currency price of exports of commodity i
All the A's except A_C, A_{WR} and $A_4(i)$, $A_{3G}(i)$ and $A_3(i)$ for all i	Potential slack variables and variables used to represent shifts in technology and preferences
III. Other notation	
N_C	Number of commodities (The latest version of CHINAGEM has 137 commodities)
N_I	Number of industries (The latest version of CHINAGEM has 137 industries)
N_S	Number of sources (2 in CHINAGEM, namely domestic and imported)
N_{CG}	Number of commodity groups for which data on household consumption are available
D(j)	Depreciation rate in industry j, treated as a parameter
G(q)	Set of industries in the group q
α	Positive parameter

(d) Exports

The treatment of exports in CHINAGEM differs between two groups of commodities. In the stylized version we show only one treatment: we relate foreign demand for domestic good i [X4(i)] to the foreign-currency price [PE(i)] and to a shift variable [A_4(i)]. If the shift variable is exogenous, then by shocking it we can simulate the effects of movements in the foreign-demand curve for commodity i. If the shift variable is endogenous, then it can be allowed to adjust to accommodate an exogenous forecast for either X4(i).

(e) Government demands

In CHINAGEM, equations such as (2.3.10) allow for different treatments of government demands for commodities. Changes in government demand for a particular commodity (i,s) or for all commodities can be introduced by shocks to A_5(i,s) or $A_{(5.)}$. Alternatively $A_{(5.)}$ can be used as an endogenous variable which adjusts so that government spending meets a budget constraint.

(f) Demands for margin services

With A3MAR(k,s,i) set exogenously, (2.3.11) implies that the use of commodity i (e.g. retail trade) as a margin service in facilitating the flow of commodity (k,s) from producers or ports of entry to households is proportional to household demand for (k,s). CHINAGEM contains equations similar to (2.3.11) for flows of commodities to all users. As mentioned in the discussion of (2.3.8), in the stylized version we assume that there are no margins services associated with commodity flows except those to households.

(g) Supply equals demand for commodities

In (2.3.12) we equate the supply (output) of commodity (i,1) to the sum of demands for (i,1). Similarly, in (2.3.13) we equate the supply (imports) of (i,2) to the sum of demands for (i,2). Consistent with CHINAGEM, imported commodities are not directly exported or used to satisfy margin demands.

(h) Zero profits in production, importing, exporting and distribution

Equations (2.3.14) to (2.3.17) are stylized versions of the CHINAGEM zero-pure-profits conditions for production, importing, exporting and distribution. The LHS of (2.3.14) is revenue in industry j and the RHS is costs. The LHS of (2.3.15) is the price [P_2(i)] received by importers of commodity i and the RHS is the cost of importing a unit of i made up of the foreign-currency price [PM(i)] converted to domestic currency via the exchange rate [Φ] and inflated by the power of the tariff [TM(i)]. The LHS of (2.3.16) is the cost of exporting a unit of commodity i (that is the revenue foregone by not selling on the domestic market) and the RHS is the revenue received per unit of export made up of the foreign-currency price [PE(i)] converted to domestic currency and deflated by the power of the export tax [T4(i)]. The LHS of (2.3.17) is the price paid by households for commodity (k,s). This is equal to the cost of supplying a unit of (k,s) to households and is made up of the price received by producers or importers [P_s(k)] inflated by the power of the consumption tax [T3(k,s)] *plus* the costs of transferring units of (k,s) from producers or ports of entry to households. As mentioned in our discussion of (2.3.12) and (2.3.13), we assume that transferring (margin) activities use only domestic commodities, e.g. domestic transport and domestic retail trade. Thus the cost of commodity i used in transferring a unit of (k,s) to households is the price of domestic commodity i [P_1(i)] multiplied by the number of units of i [A3MAR(k,s,i)] required per unit of transfer.

(i) Indirect taxes

CHINAGEM contains many equations expressing the power (one plus the rate) of an indirect tax as the product of various shift variables. Equation (2.3.18) is an example. The shift variable A_{0T}(i) in (2.3.18) links the power of export tax for a commodity to the power of tax for consumer, intermediate, investment use of the commodity. With this facility, we can simulate a reduction in the power of tax for a commodity (e.g. petrol) to all users.

(j) Definitions of macroeconomic variables

Equations (2.3.19) to (2.3.23) are a sample of the macro definitions used in CHINAGEM. Equation (2.3.19) defines the consumer price index (CPI) as a function of the vectors [$P3_1$ and $P3_2$] of consumer prices for domestic and imported goods. Equation (2.3.20) defines the real wage rate as the nominal wage rate deflated by the CPI. Equations (2.3.21) and (2.3.22) define total employment and total capital stock as sums across industries, and equation (2.3.23) is the GDP identity in nominal terms.

(k) Capital stocks, investment and rates of return

Equation (2.3.24) relates capital stock in industry j at the end of the year [K_+(j)] to depreciated capital stock from the beginning of the year [(1-D(j))*K(j)] and investment during the year [X2TOT(j)]. Equation (2.3.25) defines the ratio of investment to capital in industry j. When the shift variable, A_{KG}(j), in (2.3.26) is exogenous, capital growth in industry j during the year, and hence investment, is determined by j's expected rate of return [EROR(j)]. If A_{KG}(j) is endogenous, then investment in industry j can be determined by an alternative mechanism, for example via (2.3.25) with IKRATIO(j) set exogenously. With its shift variable [A_{EROR}(j)] set exogenously, (2.3.27) determines the expected rate of return in industry j as a function of the current rental rate [Q(j)] and asset price [PI(j)] of j's capital. Under this treatment, expectations are static or adaptive.

(l) Balance of payments and GNP

CHINAGEM contains a detailed description of the balance of payments. This includes equations for the year-to-year accumulation of different types of foreign assets and liabilities and equations for associated incomes and payments. In the stylized version given in (2.3.28) and (2.3.29), we show a single accumulation equation relating the end-of-year foreign-currency value of net foreign liabilities to the start-of-year value and to the foreign-currency value of the current account deficit (CAD*Φ). The current account deficit is shown as the trade deficit (imports less exports) plus interest and dividend payments on net foreign liabilities.

Equation (2.3.30) defines GNP as GDP less the domestic-currency value of net interest and dividend payments to foreigners.

(m) Function for private and public consumption

With the shift variable A_C set exogenously, (2.3.31) links movements in total household and government expenditure to movements in GNP.

(n) The government accounts

Equation (2.3.32) defines the public sector deficit (PSD) as government consumption expenditures *less* tax collections *plus* transfers. In this stylized equation, we recognize only the taxes (consumption taxes, import duties and export taxes) appearing in other stylized equations and we treat transfers as a single item with no explaining equations. The core CHINAGEM also contains other taxes and other sources of government income.

(o) Sticky-wage specification for policy simulations

Policy results are generated in CHINAGEM as deviations from explicit forecasts. This requires several equations that relate policy values for variables to forecast values. For example, as indicated by (2.3.33), we often assume in policy simulations that the proportionate deviation in year t in the real wage rate from its forecast value [WR/WR_f – 1] equals the proportionate deviation in year t-1 [WR_{lag}/WR_{flag} – 1] *plus* a positive multiple of the proportionate deviation in year t in total employment [$LTOT/LTOT_f$ – 1]. In other words, we assume that while employment is above its forecast level, the real wage deviation will be increasing. In simulations in which we want a different approach to wage determination, we can endogenize the shift variable A_{WR}.

(p) Technical and preference change

CHINAGEM contains many equations that represent various technical and preference changes. Equation (2.3.34) gives an example. Variable $A_{3G}(q)$ is consumer preference with respect to groups of consumption goods (for example, food, consumer durables and household services). Each of these groups contains many commodities. The variable $A_{3G}(q)$ allow a change in consumer preference in favor of, for example, consumer durables to be simulated.

In CHINAGEM, this subsection of the model code also contains other technical change equations that allow changes in the ratio of capital to labour, domestic to imported goods, etc.

(q) Equations for facilitating historical and forecast simulations

Available data in China on outputs, inputs, prices, consumption, and other variables occur in various industrial/commodity classifications. So that we can use these data, we include in CHINAGEM many equations that define variables at different levels of aggregation. This is illustrated by (2.3.36) which defines consumption [CG(q)] in the qth group of commodities, e.g. all commodities in the agricultural sector. In most simulations, sectoral variables such as CG(q) are endogenous. However, in historical simulations they may be exogenized and given shocks reflecting observed movements. When CG(q) is exogenized, we endogenize a variable, $A_{3G}(q)$ in Euqation (2.3.34), which moves the preference of commodities in group q.

2.3.2. A trial closure of the stylized version of CHINAGEM

To check our understanding of the stylized model, it is useful to write a trial list of exogenous variables that we think should constitute a closure. We have composed such a list in part II of Table 2.2. If we cannot show that our trial list constitutes a closure, then we should check the list and equations. If we fail to find an error, then we should reassess our understanding of how the stylized model transforms values of exogenous variables into outcomes for endogenous variables.

In writing our trial list, we had in mind a short-run policy closure[11]. In such a closure we would expect to be able to include on the exogenous list all start-of-year stock variables, all lagged variables, all forecast variables and all policy instruments. This explains the inclusion in part II of Table 2.2 of the variables from K(j) down to TRANSFERS. PM(i) and ROIF are included because both are naturally exogenous: there are no equations in the stylized model (or in

[11] By a short-run closure, we mean one that is used in computing a solution for year t+1 starting from a solution for year t. By a policy closure, we mean one that is used in computing deviations from a forecast path caused by changes in policy variables or in other naturally exogenous variables.

CHINAGEM) for explaining either foreign-currency import prices or foreign rates of interest. For the numeraire in our trial closure we use the exchange rate (Φ).

In a short-run policy simulation, none of the next three variables [C, WR and PE(i)] in part II of Table 2.2 would normally be exogenous. We would expect to explain: movements in C by movements in national income via (2.3.31); movements in WR by deviations in total employment and lagged deviations in WR via (2.3.33); and movements in PE(i) by movements in exports of i via (2.3.9). In the trial closure we exogenize C, WR and PE(i) because, as we will see shortly, this makes it easy to establish that our trial exogenous list is a closure. To exogenize C, WR and PE(i), we endogenize the shift variables A_C, A_{WR} and A_4(i) appearing in (2.3.31), (2.3.33) and (2.3.9). Because we would expect in a short-run policy simulation to exogenize taste and technology variables, almost all the other A variables are exogenous. The only exception is A_3(i) which is endogenized due to equation (2.3.34).

Establishing the validity of our trial closure now becomes easy because with this particular list of exogenous variables our stylized model is recursive. As indicated by the last column in part I of Table 2.2, we can start a solution of the stylized model by using (2.3.18) to determine T4(i). Having determined T4(i) we can then use (2.3.16) to determine P_1(i) for all i. Equation (2.3.15) can be used to determine P_2(i) for all i, then allowing us to use (2.3.17) to determine $P3_1$ and $P3_2$. Proceeding in this way through part I of Table 2.2, we establish the validity of our trial closure by showing that a value for each endogenous variable can be determined for any given values of the exogenous variables.

The only slight difficulty occurs when we reach the rental rate on j's capital, Q(j). As indicated in part I of Table 2.2, Q(j) can be computed using (2.3.14) after the determination T4(i), P_1, P_2, …, W. This can be done by first using (2.3.1), (2.3.3), (2.3.4) and (2.3.5) to eliminate the quantity variables [X0(i,1,j), X1(i,s,j), L(j) and K(j)] from (2.3.14) and then cancelling out X1TOT(j), thereby creating an equation in which Q(j) is the only unknown. In effect, we create an equation which exploits constant returns to scale to express the rental rate on j's capital purely in terms of input prices and technology variables.

We develop new closures for CHINAGEM by starting from a simple closure and making variable-by-variable modifications. This process can be visualized via our stylized model. For example, starting from the exogenous list in part II of Table 2.2, we could develop a more interesting short-run policy closure by endogenizing C, WR and PE(i) and exogenixing A_C, A_{WR},

A_4(i). This would give us a closure in which policy shocks could affect aggregate consumption, the real wage and export prices by affecting natonal income, employment and export volumes.

We could then move to a long-run closure by: endogenizing the start-of-year capital stock, K(j) and exogenizing EROR(j); by endogenizing A_{KG}(j) and exogenizing IKRATIO(j); and by endogenizing A_{WR} and exogenizing LTOT.

Table 2.3 presents the list of exogenous variable of the long-run closure for the stylised version of CHINAGEM. It also presents swaps between endogenous and exogenous variables performed to generate this long-run closure from the trial closure presented in Table 2.2.

Finally, we could move towards forecast and historical closures by exogenizing variables for which we have either forecasts or historical observations and endogenizing corresponding A terms representing shifts in technologies, consumer preferences and export-demand functions. For example, by exogenizing CG(q) and endogenizing A_{3G}(q), we can inform model observed changes to the consumption of groups of commodities (household appliances, food and household services), and solve for changes in consumer preferences with respect to these commodity groups using a simulation with the historical closure.

Table 2.3. A long-run closure for CHINAGEM

I. list of exogenous variables of the trial closure presented in Table 2.2	
EROR(j)	Expected rate of return in industry j
NFLF	Start-of-year net foreign liabilities in foreign currency
WR_{lag}	Real wage rate in previous year
WR_{flag}	Forecast for real wage rate in previous year
WR_{f}	Forecast for real wage rate
$LTOT_{f}$	Forecast for total employment
TM(i)	Power (one plus the rate) of tariff on imports of commodity i
T3(k,s)	Power of tax on household consumption of good (k,s)
TRANSFERS	Transfers from the public sector to households,e.g., unemployment benefits and interest on the public debt
PM(i)	Foreign currency c.i.f. price of imports of commodity i
ROIF	Rates of interest or dividends applying to net foreign liabilities
Φ	Exchange rate
A_{C}	Aggregate propensity to consume
LTOT	Total employment
IKRATIO(j)	Ratio of investment to capital in industry j
A_4(i)	Slack in export-demand function for i
All the A's Except A_{WR}, A_{KG}(j), A_{3G}(i), and A_3(i) for all i	Potential slack variables and variables used to represent shifts in technology and preferences
II. Swap of exogenous and endogenous variables from trial closure of Table 2.2 to generate a long-run closure presented below	
Swap	WR = LTOT
Swap	K(j) = EROR(j)
Swap	A_{KG}(j) = IKRATIO(j)
Swap	PE(i) = A_4(i)
Swap	C = A_C

3. THE HISTORICAL SIMULATION

In this section, we demonstrate how to incorporate historical data into CHINAGEM in order to understand how the Chinese economy evolved from one year to another. For this purpose, we start from the 2002 input-output database and perform historical simulations to the year 2009. In section 3.1 we explain the choice of endogenous/exogenous variables for the historical simulation. In section 3.2 we present how we inform CHINAGEM changes in macroeconomic variables. In section 3.3 we demonstrate how we inform CHINAGEM changes in commodity and industry variables using energy sectors as an example.

3.1. How to develop closure for historical simulation

The long-run closure presented in Table 2.3 is a typical closure used in simulations with CGE models. In this closure, quantities and prices of production outputs and inputs, consumption, and international trade are endogenous variables; while production technology and consumer preferences are exogenous variables. In a conventional policy simulation, the CGE model is informed of a change in a technology or policy variables (such as a deterioration in agricultural productivity or a tariff cut), and the model calculates the resulting changes to GDP, consumption, output, employment and other endogenous variables.

In a historical simulation, the model operates in a reverse fashion with GDP, production, consumption and international trade exogenous, and the corresponding technical and preference change variables (such as multi-factor productivity) endogenous. In a historical simulation, the model is informed of changes in GDP, consumption, investment, and other observed variables during a historical period. It then calculates the necessary changes in technology and preferences.

In this section, we discuss how to develop a closure for the historical simulation from the long-run closure presented in Table 2.3. Our experience in the past two decades shows that the following practice is desirable for the historical simulations to be informative.

1. It is important to first inform the model observed changes to macroeconomic variables before introducing industry and commodity details.
2. It is important to incorporate data step by step into the historical simulation instead of introducing all data in one go.

3. It is important to employ Back-Of-The-Envelop (BOTE) analysis to verify simulation result as each piece of information is incorporated into the model.

CHINAGEM is a very large model that can have up to millions of equations and variables, depending on the version of the database and additional modules attached to the core model. The detail is necessary for answering practical policy questions. However, the few equations listed in Box 3.1 can provide a good understanding of the fundamentals of the model. Together they form the BOTE model that is very useful in explaining simulation results[12]. In the following paragraphs, we use the BOTE model presented in Box 3.1 to explain how to conduct a historical simulation.

The historical simulation is an effort to understand how the various economies in the model evolved from 2002 to 2009. In the context of the BOTE model, we force the model to replicate observed growth in the following macroeconomic variables for the period 2002-2009:

- consumption (C), investment (I), government expenditure (G), exports (X) and imports (M);
- GDP price index (P_g), and
- Population (POP) and employment (L).

The model has dynamic equations that link the economies from one year to the next. One such equation block models the accumulation of physical capital where the capital stock in the following year equals the capital stock in the current year plus investment in the current year minus depreciation (Equation (3.5) in Box 3.1; or Equation (2.3.24) in the stylised version of CHINAGEM presented in Table 2.1).

For the first year of the historical simulation, the growth in K is determined by I in the database. In the subsequent years, once we inform the model the growth in investment (I), the growth in aggregate capital stock (K) is determined by the equation block modelling the accumulation of capital stock through investment in the model.

[12] The BOTE model can have more or less equations than those listed in Box 3.1. For a detailed discussion about the BOTE analysis, see Dixon et. al. 1982 and Dixon and Rimmer 2002)

Box 3.1 The BOTE Model

The two most important relationships in the MMC model are the GDP identity and the aggregate production function:

$$Y = C + I + G + X - M\ , \quad \text{and} \tag{3.1}$$

$$Y = \frac{1}{A} * F(K, L)\ , \tag{3.2}$$

where Y is GDP;
C is consumption;
I is investment;
G is government expenditure;
X is exports;
M is imports;
K is aggregate capital stock;
L is aggregate employment; and decreases in A allow for technological progress.

Equilibrium in the capital market requires the real cost of capital to be equal to the marginal physical product of capital. Hence:

$$\frac{Q}{P_g} = \frac{1}{A} * F_k(K/L)\ . \tag{3.3}$$

where
Q is the rental per unit of capital;
P_g is the price of a unit of GDP; and
F_k is the partial derivative of F with respect to K. We write F_k as a function of K/L under the assumption that F is homogenous of degree one.

Labour-market equilibrium requires:

$$\frac{W}{P_g} = \frac{1}{A} * F_\ell(K/L)\ , \tag{3.4}$$

where
W is the wage rate; and
F_ℓ is the partial derivative of F with respect to L.

The final equation in our BOTE model explains capital in the current plus one year as the sum of net capital in the current year plus investment. Hence:

$$K_1 = K + I - D. \tag{3.5}$$

where
K and K_1 are the capital stock in the current and following year respectively; and
I and D are investment and depreciation in the current year.

We start the historical simulation by informing the model C, I, G, X, and M; Y is thus determined by Equation (3.1) in Box 3.1. Since we have informed the model I, K is determined by Equation (3.5). Since Y and K have been determined, once we inform the model L, changes in technology (A) will be solved for by the aggregate production function, Equation (3.2). Since growth in the GDP price index (P_g) is also tied down, Equation (3.3) will solve for the capital rental (Q) and Equation (3.4) will solve for the wage level (W).

At the industry level, we force the model to replicate historical growth for output (Y_i), employment (L_i), wages (W_i) and the price of output (P_i)[13]. Consequently, the industry versions of the aggregate production function (3.2) and factor market equilibrium conditions (3.2) and (3.3) can jointly solve for industry specific capital stock (K_i), rental (Q_i) and technology (A_i).

Starting from the long-run closure (Table 2.3), we make the following closure changes as we introduce macroeconomic data into CHINAGEM.

- **Step 1**. Closure changes to activate capital supply and accumulation equations. For this purpose, we exogenise A_{KG}(j) and endogenise IKRATIO(j) (see equations (2.3.25 and 2.3.26) in Table 2.1). We should also endogenise expected rate of return EROR(j) and allow K(j) to be determined by total investment in database – this is equivalent to K(j) being exogenous.

- **Step 2**. To incorporate historical changes in C, we exogenise C and endogenise average propensity to consume A_C (see equation (2.3.31) in Table 2.1)[14].

- **Step 3**. To incorporate historical changes in I, we exogenise I and endogenise the shift in capital supply curve (a non-industry specific equivalent of A_{KG}(j) in (2.3.26) in Table 2.1).

- **Step 4**. To incorporate historical changes in G, we exogenise G and endogenise $A_{(5)}$ (see equation (2.3.10) in Table 2.1).

- **Step 5**. To incorporate historical changes in M, we exogenise M and endogenise the preference change variable in favour of imports relative to domestically produced goods A_{TWIST} (equations 2.3.3, 2.3.6, and 2.3.8 in Table 2.1).

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[13] i denotes industry i. In the 2002 database, there are 137 industries.

[14] At this step, we should also incorporate historical changes in population due to the way consumption demand is specified in CHINAGEM. Population is an exogenous variable in the long-run closure, we therefore do not need to change closure to incorporate historical changes in population into CHINAGEM.

- **Step 6**. To incorporate historical changes in X, we exogenise X and endogenise shift of export demand curve (a non-commodity specific equivalent of A_4(i) in (2.3.9) in Table 2.1). At this step, it is also necessary to endogenise A; otherwise, we have over-identified GDP (structural singularity). Up to this step, on the left hand side of (3.1), GDP is determined by C+I+G+X-M. On the right hand side, K is pre-determined by I in database; and A and LTOT are exogenous and zero. To endogenise A, we exogenise the GDP price index and incorporate its historical change into CHINAGEM.
- **Step 7**. LTOT is exogenous in the long-run closure. We therefore do not need to make closure changes to incorporate historical changes in LTOT.

The above steps are necessary for CHINAGEM to replicate how macroeconomic environment has evolved for China during a given historical period. It is important to at least inform the model how income and expenditure side of GDP evolved and how price level changed. This provides a macroeconomic framework for industry/commodity part of the historical simulation to begin. In CoPS Dynamic GE training courses, participants practice to implement this step by step using a training course model.

In practical policy analysis, a lot more macroeconomic information is required to produce a sensible baseline, such as:

- changes in wage level if the change produced by the model after implementing the above seven steps does not agree with historical data;
- changes in foreign assets and liability related variables; and
- changes in import prices by commodity.

To gain a good sense of how this work, CoPS offers consultation via CHINAGEM projects where a baseline suitable for a particular policy question is developed.

When introducing historical changes of industry/commodity variables into CHINAGEM, a good strategy is to first look at changes to aggregate sectors, such as output and employment changes by agricultural, industry, and services sectors. Close study of more detailed industries, such as output, exports, imports, and employment in the coal mining and wheat industries can follow afterwards. As discussed in section 2.3, via variables like CG(q) and A_{3G}(q), users can incorporate, e.g. consumption data by main categories (grain, fruit and vegetables, meat and egg, beverages, consumer durables and various services) instead of by all 137 commodities for which statistics are not available.

3.2. Data sources and data consistency issues

The following is a list of useful data for developing historical simulations for China:

- World Bank: World Development Indicators for data on income and expenditure side GDP in both constant and current prices in local currency or USD; population and working age population;
- IMF: data on foreign assets and liabilities;
- China input-output tables 1992, 1997, 2002 and 2007;
- China Statistical Yearbook: income and expenditure side GDP; price indices; industry output; wages; etc.
- China Labour Statistical Yearbook: employment and wage by industries;
- United National Population Division: population and labour force data;
- China Rural Statistical Yearbook and the Cost and Revenue of Agricultural Products in China: agricultural output and labour productivity;
- United Nation: COMTRADE for trade statistics
- China Energy Statistical Yearbook: energy balance tables;
- BP and International Energy Agency: energy data;
- EAI: CO2 emission data;
- United Nation Industrial Development Organisation: manufacturing data
- Food and Agriculture Organisation: data on agricultural products;
- Various China statistical yearbooks on investment, high tech industries, trade, and various services sectors; and
- CoPS' population and labour force forecast based on China population data rather than model life tables.

The list above contains multiple sources for data on the same variable; because it is very useful to cross verify data from different sources and see if they tell the same story. The most rewarding experience of historical simulation for an economist is that CHINAGEM provides a framework for putting economic data from different sources into a coherent picture. The strategy for incorporating seemingly contradictory information is to decide which number or source has priority. Box 3.2 shows an example of the practice.

In Box 3.2, value of GDP is considered as most important or most widely cited. To understand China's growth pattern, we adjusted expenditure components of GDP accordingly. For a baseline that is developed for the purpose of trade analysis, one may take, for example, the values of total exports and imports as the most important numbers and adjust GDP level and the rest of the components accordingly.

Similarly, when we obtain consumption growth by various consumption categories, the implied change by commodity most likely do not add up to the change in total consumption calculated from the growth rate in aggregate consumption that is consistent with GDP growth. A good strategy is to take the aggregate consumption number as the one with higher priority. However, we do want to maintain changes in the patterns of consumption by commodity such as consumption of grain grew slower than that of meat and eggs, and consumption of transport and communication grew faster than that of food and clothing.

Box 3.2 Data Consistency Issues

Data from different sources are invariably inconsistent with one another; even data from the same source could be inconsistent for various reasons. To understand what occurred to the Chinese economy during 2002-2009, a major task involved is to absorb information presented from various data sources and make them coherent.

For example, the growth rates of consumption, investment, government expenditure, exports, imports and real GDP during 2002-2009 should be coherent in terms of the GDP identity. Here we take *World Development Indicators* (WDI) as the data source for the growth rates of real GDP and its expenditure components. Before we impose on the model these growth rates, we check whether the real GDP growth and the growth rates of its components satisfy the GDP identity:

$$Y = C + I + G + X - M \qquad (3.1)$$

Where GDP, C, I, G, X, and M are levels of GDP, consumption, investment, government expenditure, exports and imports.

To do this, we multiply the levels of C, I, G, X and M in the 2002 CHINAGEM database (for which the main source of data is the 2002 input-output table) with the respective WDI growth rates to see if the implied changes in GDP components sum to the level of GDP in the CHINAGEM database multiplied by the WDI growth rate for real GDP. We illustrate this here for the year 2003.

	2002 levels in CHINAGEM database	WDI rates of growth in 2003	Resulting changes in 2003	Scaled rates of growth
	(a)	(b)	(a)*(b)/100	
Consumption	528793	6.3	33395	5.4
Investment	436551	17.5	76316	14.8
Government	188600	5.8	10888	4.9
Stock	17122	0.0*	0	0.0
Exports	307920	26.8	82447	22.7
Imports	-219955	24.8	-54461	21.0
Real GDP	1259030	10.0	125903	
Sum of GDP components			148584	

Note: * changes in stock are assumed to be zero.

We can see from the above calculation that the growth rates of GDP components imply a larger change in real GDP (148584) than that suggested by the real GDP growth rate of 10 per cent (125903).

To deal with this inconsistency in data, we scale the growth rates of GDP components proportionally so that they are consistent with the real GDP growth rate of 10 per cent for the year 2003 (in terms of GDP identity). In this case, we choose to consider real GDP growth as being more reliable than the growth rates of its components. We therefore maintain the real GDP growth as 10 per cent for China in 2003.

While the growth rates of GDP components are adjusted, the pattern presented by the WDI data is preserved. That is, consumption grew slower and investment grew faster than real GDP (see the middle and last column in the table above), and trade grew much faster than real GDP.

This way, we have incorporated information presented by the WDI database regarding the growth rates of all the six macroeconomic variables into the historical simulation while maintaining the data coherence in terms of the GDP identity.

Tables 3.2 presents the growth rates of GDP and its expenditure components during 2002-2009 from the historical simulation. For comparison, WDI data is presented in Table 3.1.

Table 3.1. WDI: growth rates of real GDP and components

2002-2009, per cent

	Real GDP	GDP price index	Real Consumption	Real Investment	Government Expenditure	Export Volumes	Import Volumes
2003	10.0	2.6	6.3	17.5	5.8	26.8	24.8
2004	10.1	6.9	6.6	12.0	6.9	28.4	22.5
2005	10.4	3.8	8.4	14.3	11.4	24.3	11.4
2006	11.6	3.6	9.6	13.3	9.8	23.3	14.3
2007	13.0	7.4	8.9	10.0	9.5	19.9	13.9
2008	9.0	7.2	7.0	8.8	10.7	7.8	3.6
2009*	8.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2002-2008	10.7	5.3	7.8	12.6	9.0	21.5	14.9

n.a. not available. * The 2009 GDP growth number is from China Statistical Yearbook.

Source: World Bank, *World Development Indicators*, on-line data.

Table 3.2. Historical simulation: growth rates of real GDP and components

2002-2009, per cent

	Real GDP	GDP price index	Real Consumption	Real Investment	Government Expenditure	Export Volumes	Import Volumes
2003	10.0	2.6	5.4	14.8	4.9	22.7	21.0
2004	10.1	6.9	5.9	10.7	6.1	25.2	20.0
2005	10.4	3.8	5.7	9.7	7.8	16.5	7.8
2006	11.6	3.6	7.7	10.7	7.9	18.8	11.5
2007	13.0	7.4	9.5	10.7	10.2	21.4	15.0
2008	9.0	7.2	6.9	8.7	10.5	7.7	3.5
2009	8.7	5.3	6.7	8.5	10.3	7.5	3.4
2002-2009	10.4	5.3	6.8	10.5	8.2	17.1	11.7

Source: simulation results.

Tables 3.1 and 3.2 shows that China enjoyed a high average GDP growth of 10.4 per cent from 2002 to 2009. Within Gross National Expenditure (GNE), real investment (or gross fixed capital formation) grew much faster than real private and government consumption indicating a high saving rate in China. Both export and import volumes grew at double digits, much faster than real GDP and GNE. The volume of export grew faster than the volume of imports contributing to China's current account surplus during the period.

Table 3.3 shows that China's total employment has been declining in the past ten or so years due to a long-term trend of declining in working age population. The reduction in the growth rate of employment is larger than that in population due to shift in population structure.

Table 3.3. Labour force and employment growth

Annual and average annual growth rates, per cent

	China Statistical Yearbook (number of persons employed)	UNPD (population aged 15-64)	UNPD (total population)	CHINAGEM baseline from 2002 database (number of persons employed)	CHINAGEM baseline from 2002 database (total population)
1998	1.2	n.a.	n.a.	n.a.	n.a.
1999	1.1	n.a.	n.a.	n.a.	n.a.
2000	1.0	n.a.	n.a.	n.a.	n.a.
2001	1.3	n.a.	n.a.	n.a.	n.a.
2002	1.0	n.a.	n.a.	n.a.	n.a.
2003	0.8	n.a.	n.a.	0.8	0.6
2004	1.1	n.a.	n.a.	1.1	0.6
2005	0.8	n.a.	n.a.	0.8	0.6
2006	0.8	n.a.	n.a.	0.8	0.6
2007	0.8	n.a.	n.a.	0.8	0.5
2008	0.6	n.a.	n.a.	0.6	0.5
2009	n.a.	n.a.	n.a.	0.7	0.5
2002-2009	0.8 [a]	n.a.	n.a.	0.8	0.6
2005-2010	n.a.	1.0	0.6	0.7	0.6
2010-2015	n.a.	0.5	0.6	0.5	0.6
2015-2020	n.a.	-0.0	0.5	0.3	0.5

[a] 2002-2008. n.a. not available.

Source: China Statistical Yearbooks, WDI, and United Nation Population Division (UNPD), and simulation results

Table 3.4 shows that agricultural, forestry and fishing sector grew much slower than industry and services. The growth in the services sector starts to catch up to that of industry. In a number of years during 2002-2009, services sector grew faster than industry. The CHINAGEM baseline maintains this pattern shown in WDI data. However, the numbers are different because they are adjusted to agree with 2002 input-output database and real GDP growth. The adjustment was carried out in a similar manner as with GDP expenditure components discussed in Box 3.2.

Table 3.4. Growth of value added by industry groups

	Agriculture	Industry	Services
CHINAGEM simulation results			
2003	2.1	10.4	12.2
2004	6.8	12.0	9.7
2005	5.6	12.6	10.2
2006	4.9	12.7	12.8
2007	3.4	13.6	15.5
2008	5.3	8.9	10.1
2009	3.7	9.4	9.6
2002-2009	4.5	11.4	11.4
WDI data			
2003	2.5	12.7	14.9
2004	6.3	11.1	9.0
2005	5.2	11.7	9.5
2006	5.0	13.0	13.1
2007	3.7	14.7	16.7
2008	5.5	9.3	10.5
2002-2008	4.7	12.1	12.3

Source: CHINAGEM simulation results; The World Bank, WDI, on-line data.

Table 3.5 shows the preference, technology, shift in export demand and other behaviour and structural changes calculated from the historical simulation. These behaviour and structural change will be used to project Chinese economy forward in the forecast simulations subject to the following considerations:

1. The large outward shift in export demand curve (rapid growth in feq_qen) was due to rapid growth in exports for heavy manufacturing industries such as iron and steel. This is a special feature of the period 2002-2007 when China started to export TVs, refrigerators, washing machines, iron and steel, etc. in addition to clothing and toys. The heavy manufacturing industries was liberalised to foreign and domestic private capital following China's WTO entry in 2001 (Mai 2001). The reform greatly facilitated the production and export growth for these goods. When projecting forward, it is better to use historical simulation results for a longer time period, say for the period 1997-2007. The historical simulation for the period 1992-1997 is not recommended because it showed a rapid growth in the output and exports of light manufacturing industries. During 1992-1996, light manufacturing industries experienced a much more rapid growth in productivity relative to heavy manufacturing and services sectors (Mai et. al 2003). China's light manufacturing industries took off in the early 1990s When Den

Xiaoping went to Southern China and encouraged reform that moved Hong Kong and Taiwan's clothing and shoe factories into Southern China.

2. Preference in favour of imports grew positively during 2002-2007 (see column 5 in Table 3.5) reflecting a global trend repeatedly shown in historical simulations for different time periods and for different countries. Due to reduced trade during the 2008-2009 global recession, preference in favour of imports was not evident for the period 2002-2009 (see column 6 of Table 3.5). The slowing down in export growth led to a significant reduction in imports growth. It is preferable to use 2002-2007 results (column 5 in Table 3.5) when projecting forward.

3. Table 3.5 also shows that China's average propensity to consume declined during 2002-2009. This trend was also evident from historical simulations from 1997 database. This is the fundamental cause of China's growing trade surplus in the past two decades.

4. a1primgen in Table 3.5 should not be considered as overall productivity improvement. In the simulations, many other productivity variables with industry and commodity dimension also changed. The resulting total factor productivity improvement for 2002-2009 was estimated to be about 5 per cent per annum.

Table 3.5. Historical simulation: changes in preference and technology etc variables

Macro variables	2002-2007 per cent	2002-2009 per cent	Corresponding preference and technical change variables	2002-2007 per cent	2002-2009 per cent
Consumption	6.8	6.8	apc_gnp	-4.1	-3.3
Investment	11.3	10.5	d_f_eeqror*	-0.003	-0.003
Government	7.4	8.2	f5tot	7.4	8.2
Exports	20.9	17.1	feq_gen	48.1	42.3
Imports	15.0	11.7	twistsrc_c	6.3	-0.1
GDP price index	4.9	5.3	a1primgen	-6.7	-6.3
Output by aggregate sectors			fac_a		
Agriculture	4.6	4.5	fac_a(aff)	-6.4	-5.4
Industry	12.3	11.4	fac_a(ind)	0.0	-0.4
Services	12.1	11.4	fac_a(srv)	2.0	1.7

Note: * This is a change variable instead of a percentage change variable.

Source: simulation results.

4. FORECAST AND POLICY SIMULATIONS

In section 4.1 we demonstrate how to use preference and technical changes derived from historical simulations to project model forward into a future year. This portraits how the Chinese economy is likely to evolve if historical trends prevail. In section 4.2 we illustrate how to take into account possible future changes that may cause the Chinese economy to deviate from its historical trend of growth.

4.1. China to 2020: what if historical trends prevail

The second and third column of Table 4.1 contains estimation obtained from historical simulation for the period 2002-2009. The fourth column of Table 4.1 contains changes in preference and technology used to project the Chinese economy forward to 2020. Due to reasons discussed in Section 3.2, we referenced estimates from 1997-2002 historical simulations to determine trends in the outward shift of export demand curve (feq_qen) and preference in favour of imports (twistsrc_c) for the forecast period.

Table 4.1. Historical and forecast simulation: changes in preference and technology

Preference and technical change variables	Historical simulation 2002-2007 per cent	Historical simulation 2002-2009 per cent	Forecast simulation 2009-2020 per cent
apc_gnp	-4.1	-3.3	-3.3
d_f_eeqror*	-0.003	-0.003	-0.003
f5tot	7.4	8.2	8.2
feq_gen	48.1	42.3	24.3
twistsrc_c	6.3	-0.1	8.9
a1primgen	-6.7	-6.3	-6.3
fac_a			
fac_a(aff)	-6.4	-5.4	-5.4
fac_a(ind)	0.0	-0.4	-0.4
fac_a(srv)	2.0	1.7	1.7

Note: * This is a change variable instead of a percentage change variable.
Source: simulation results.

In addition to preference and technical change variables presented in Table 4.1, we also incorporated into the forecast simulation preference and technical change variables by commodity and industry. Furthermore, we also inform CHINAGEM changes to other exogenous variables such as labour supply and population. For these variables, we take on board trends predicted by UNPD forecasts, such as a larger reduction in the growth rates of working age population relative to that of total population.

To assign values presented in the fourth column of Table 4.1 to the preference and shift variables in the forecast simulation, the closure swaps adopted in the historical simulation is reversed:

1. Consumption is endogenised and average propensity to consume is exogenised;
2. Investment is endogenised and shift in capital supply curve exogenised;
3. Government expenditure is endogenised and the corresponding shift variable is exogenised;
4. Imports is endogenised and preference in favour of imports is exogenised;
5. Exports is endogenised and shift in export demand curve is exogenised; and
6. GDP price index is endogenised and economy-wide all primary factor productivity is exogenised.

Similar closure reverse from the historical-simulation closure is also performed for preference and technology variables by commodity and industry.

The average annual percentage changes in macroeconomic variables for the historical and forecast simulations are presented in Table 4.1. The key features of the forecast-simulation results are the following:

1. Real GDP growth in the forecast period is lower than in the historical period mainly due to lower growth in employment and the consequent lower growth in capital stock. The lower growth in employment is due to a rapid reduction in the growth of working age population.
2. Due to declining average propensity to consume, the forecast period continue to see slower growth in consumption than in GDP resulting increasing trade surplus.
3. Agricultural sector continue to grow slower than industry and services and the service sector grows as fast as the industrial sector.

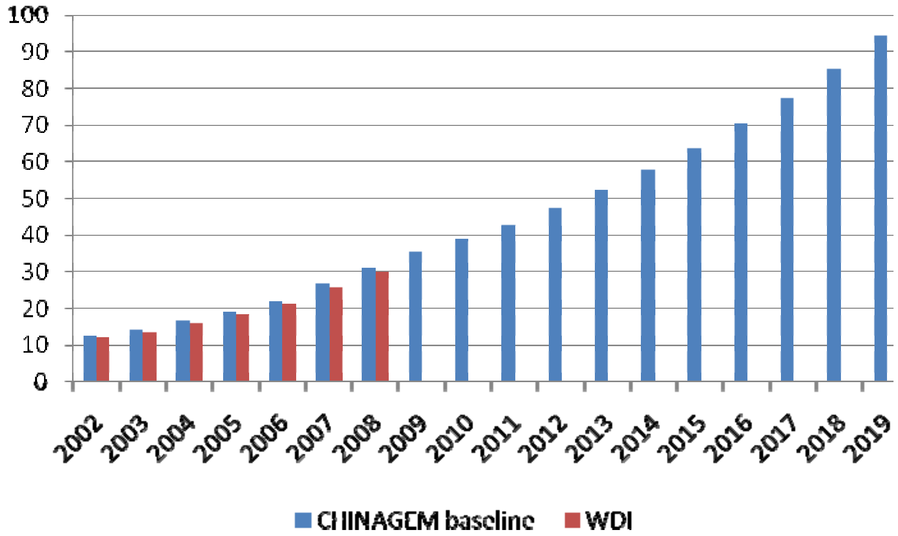
Table 4.2. Historical and forecast simulation: macroeconomic indicators, per cent

	History	Forecast
	Average annual growth 2002-2009	Average annual growth 2009-2020
Real GDP	10.4	8.9
All Primary Factor Augmented Productivity	4.9	4.9
Capital stock	9.0	8.1
Effective labour input	1.4	0.7
Employment (persons)	0.8	0.4
Real wage	11.6	8.9
Rate of return	-2.9	-5.8
GDP price index	5.3	1.3
Consumption	6.8	4.1
Investment	10.5	6.7
Government	8.2	8.2
Exports	17.1	14.2
Imports	11.7	10.6
Output of aggregate sectors		
Agriculture Forestry Fishing	4.5	3.8
Industry	11.4	9.7
Services	11.4	9.8

Source: simulation results.

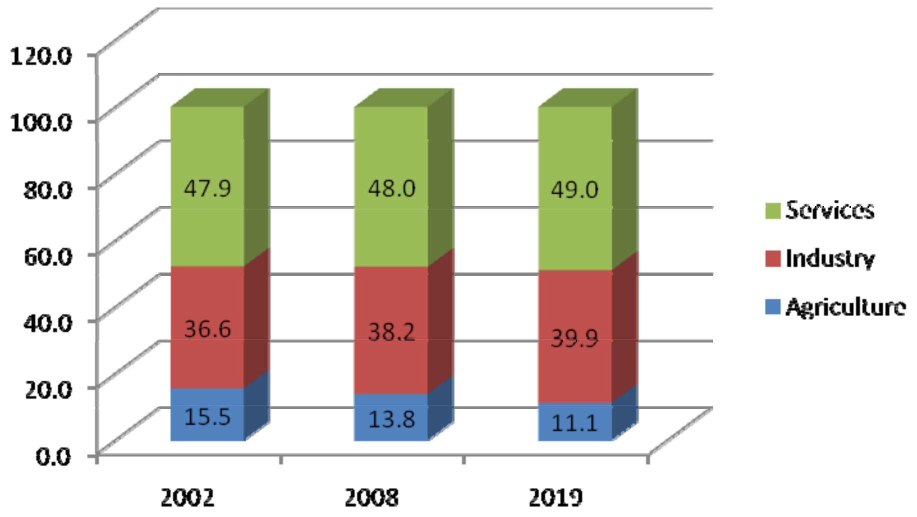
Figure 4.1 shows the level of GDP in current prices obtained from the historical and forecast simulations. If historical trends adopted for the forecast simulation prevails, China's GDP is likely to be about 95 trillion RMB by 2019.

Figure 4.1. Historical and forecast simulation: Current price GDP 2002-2020, trillion RMB



Figures 4.2 and 4.3 present share of agriculture, industry and services in GDP. The forecast period continue to see a declining share of agriculture sector and increasing share of the industry as well as the service sectors.

Figure 4.2. Historical and forecast simulation: share of agriculture, industry and services in GDP, 2002-2020, per cent



4.2. China to 2020: how would the future be different from history

Policy simulations serve to show how the Chinese economy would evolve differently from the historical trends due to various changes in economic policy and economic environment. To investigate how future is likely to be different from history, it is preferable to investigate the following issues:

1. **Rising savings rate and declining average propensity to consume**. This trend has prevailed for thirty years for China. The resulting trade surplus has been the main cause of trade disputes with the US. With an under-developed financial sector, household savings lack ways of preserving its value, reinforcing the feeling of insecurity that was the cause for high savings in the first place. Cash holdings in the hands of households lead to various speculative activities especially in the property market, causing housing price to rise.

2. **Less favourable export demand**. The recent global economic downturn raised the alarm for China that revenues from exports may no longer be as reliable as they were in the past. Export demand conditions look less promising with increasing anti-

dumping and other trade dispute cases with the US and EU, rising labour costs, looming labour rights and intellectual property rights issues, and potential carbon tariffs levied by the EU.

3. **Rising labour costs**. While establishing social security schemes brings benefits in the long-run, in the short-run, contributions to such schemes raise labour costs. Recently, the central government was also considering increasing minimum wage as a way to improve income distribution.

4. **China has achieved industrialisation**. After thirty years of industrialisation, the industry share in GDP has been close to forty per cent in the past few years[15]. China's light manufacturing industries boomed in the 1990s and the heavy manufacturing industries started to grow rapidly since the early 2000. The development was due to entry of domestic and foreign private capital into these industries (Mai 2001 and Mai et. al. 2003). The rapid growth in heavy manufacturing industries in recent years served to boost the health of state controlled share holding companies, paving way for the reform in the financial and other services sectors.

5. **It is the services sector's turn to grow**. When China joined the WTO in 2001, China made an effort to open up its services sectors as well as the heavy manufacturing sectors (Mai 2001). However, reform in the services sector did not proceed as fast as those in manufacturing. The benefits from services sector reform can be many folds:

    a. Facilitate the development of small- to medium-sized firms and preserve the value of household savings. A highly active black financial market (民间金融) indicates that the formal financial sector is not meeting the demand for financial services of households and small- to medium-sized enterprises.

    b. Reduce reliance on exports and generate domestic-demand driven growth. The less favourable export conditions might become a blessing facilitating reform in the services sector and thus begin a period of domestic-demand driven growth.

    c. Boost household consumptions and thus reduce trade surplus. An increase in the varieties and quality of services may well boost household consumption in services. Furthermore, development of services industries requires

[15] The WDI data shows that China's industry share has been over forty per cent in the past decade. Input-output data, however, shows a higher services share and a lower industry share relative to what the WDI data indicates.

accumulation of human capital which leads to increased consumption in education and training which, in turn, leads to higher income.

6. **Greenhouse gas abatement policies**. With increased awareness of climate change issue, carbon tax and emission trading schemes are under policy consideration for China. However, a preferable way to achieve greenhouse gas abatement is to improve energy efficiency. China's energy efficiency in electricity generation is much lower than that of developed countries.

When conducting a policy simulation, the closure is similar to that of forecast simulation described in section 4.1. However, in a policy simulation, we may choose to activate sticky wage adjustment equation (equation (2.3.33) in Table 2.1). This is done by endogenise aggregate employment and exogenise the shift variable in the wage adjustment equation (A_{WR} in equation (2.3.33) in Table 2.1).

In the coming section, we illustrate how to design simulations to assess the effects of achieving greenhouse gas abatement via improving energy efficiency in electricity generation.

5. FURTHER DEVELOPMENT OF CHINAGEM

This document accompanies the release of CHINAGEM version 1.01. An updated version CHINAGEM 1.02 will be available later in the year. Currently, we are working on the following:

1. Documentation: we are working on a user manual for CHINAGEM that provides a detailed discuss on every equation blocks. The manual would be useful to users who wish to conduct model development work starting from CHINAGEM.

2. 2007 input-output database: CHINAGEM version 2.01 with 2007 input-output database will be released early next year. The 2007 database will be equipped to address many greenhouse gas related issues. For example, it will have electricity generation by types of fuels and an electricity distribution industry. This allows user of electricity to respond to relative cost changes of electricity generated by different fuels.

3. Various modules are being developed that can readily be attached to the core model for more specialised analysis such as climate change module, rural-urban migration module, population module, a module that calculates accumulation of social security funds, accumulation of human capital, and top down regional module with margin demands.

4. CHINAGEM-REG: a bottom-up regional version of CHINAGEM.

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Appendix I List of industries in 2002 CHINAGEM database

1	SOYBEANS	39	WoolTextiles
2	CORN	40	SilkTextiles
3	WHEAT	41	TextProc
4	RICE	42	KnitMill
5	Millet	43	ClothesShoes
6	VEGETABLES	44	Leather
7	APPLES	45	Sawmills
8	Citrus	46	Furniture
9	Grapes	47	PaperProd
10	OtherCrops	48	Printing
11	Pigs	49	CultureGoods
12	SheepGoats	50	ToysSportEqp
13	OthLivestock	51	PetrolRef
14	Cotton	52	Coking
15	Pork	53	BasicChem
16	OthMeat	54	Fertlizr
17	Eggs	55	Pesticide
18	Milk	56	PaintsDyes
19	Forest	57	OrganChem
20	Logging	58	SpecChemical
21	Fishing	59	ChemDly
22	OtherAg	60	Medicine
23	CoalMineProc	61	ChemFibre
24	CrudeOilGas	62	RubberPrd
25	FerrOre	63	PlasticPrd
26	NFerrOre	64	Cement
27	SaltMine	65	Glass
28	NMtlMine	66	China
29	GrainMillOil	67	Fireproof
30	AnimalFood	68	NMtlMinPr
31	VegetOils	69	IronSmelt
32	SugarRef	70	SteelSmelt
33	FishProc	71	SteelProc
34	OtherFood	72	AlIronSmelt
35	Wines	73	NFerrSmelt
36	OtherBev	74	NFerrProc
37	Tobacco	75	IronProc
38	CottonTextil	76	Boilers

77	MtlwrkMch	108	WaterTrans
78	SpeclMch	109	AirPass
79	AgrMchn	110	AirFreight
80	SplEqpNEC	111	PipeTrns
81	RailEqp	112	Warehousing
82	MotorVhc	113	Post
83	MVParts	114	Telecomms
84	Ships	115	ComputSrvc
85	OthTransEqp	116	Trade
86	Genratrs	117	Hotels
87	HhldElec	118	Restaurant
88	ElcMchNEC	119	Finance
89	ElecCommsEqp	120	Insurance
90	Computers	121	RealEstate
91	ElctronEqp	122	Leasing
92	ElctronParts	123	CommerclSrvc
93	HomeVideoTV	124	Tourism
94	OthElecEqp	125	Research
95	Meters	126	TechSrvc
96	OfficeEqp	127	GeolGeogTech
97	ArtsCrafts	128	WaterTechSvc
98	OtherManufac	129	PublicSrvc
99	Scrap	130	ResidentSrvc
100	ElecSteam	131	Education
101	GasSupply	132	Health
102	WaterSupply	133	SocWelfare
103	Construction	134	ArtsFilmTV
104	RailPass	135	Sports
105	RailFreight	136	RecreatSrvc
106	RoadTrans	137	PublicAdmin
107	UrbanTrans		