

The structure of the CERD model: a CGE model of the Chinese Economy with Regional Dimensions¹

Introduction

Many general equilibrium models of the Chinese economy have been constructed (for examples see Lloyd and Zhang 2001). However, few models have included regional details due to data limitations. Yang and Huang (1997) used representative types of households to approximate the regional impacts of trade liberalisation. Diao, Fan and Zhang (2002) presented a general equilibrium model with partial disaggregation, i.e. distinguishing nine regions within agricultural sectors. The PRCGEM model (Fan and Zheng 2000, 2001) distinguished 124 commodities and 31 regions within China. However, strictly speaking, it is not a multi-regional model as it follows the tops-down approach, like the MONASH model (Peter et al. 1996). Moreover, the sectors are not sufficiently detailed to carry out food policy analysis.

This document describes the construction of the CERD general equilibrium model, which is based on the 1997 provincial input–output tables and therefore provides the best possible regional disaggregation of the Chinese economy.

Overview of CERD

As the name CERD suggests, it is a multi-regional model of the Chinese economy. It identifies 28 regions, with each region corresponding to one province, autonomous region, or municipality in mainland China. However, there are some exceptions, as Hainan, Ningxia and Tibet are included in Guangdong, Gansu and Qinghai respectively. Multi-regional models have generally followed the so called ‘tops-down’ approach, where a central model is solved and then the regional distribution is undertaken using the shares of the various regions, as, for example, in the MONASH model. By contrast, CERD uses the ‘bottoms-up’ approach. Each region in CERD is treated as an open economy with its own agents and behavioural functions, which are mainly drawn from the model presented in Yang and Huang (1997). As shown in Figure 1, agents in each region make their decisions on the demand for, and supply of, commodities and primary factors, and regional economies are linked through commodity and factor flows.

The diagram shows that CERD mimics a global model of multiple regions, like GTAP (Hertel 1997). However, it has some special features. First, the regional links in CERD are more intensive than in a global model, especially for the movement of primary factors. For example, in a global model labour is usually immobile across countries, while CERD

¹ This section is based on Jiang (2002a).

allows partial mobility across regions within China. Second, CERD assumes perfect mobility of capital across domestic regions and sectors.

As labour and capital can move across regional boundaries, it is important to distinguish between the use and ownership of these factors, to better calculate regional household income and consumption. This makes CERD superior to other CGE models.

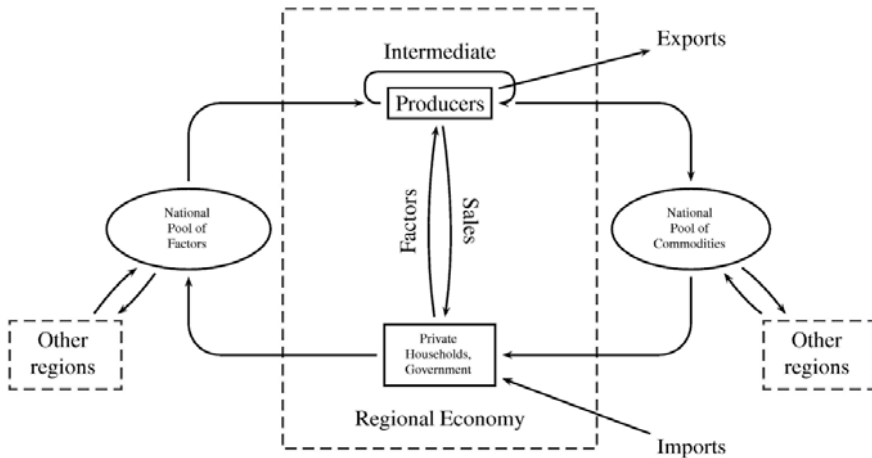


Figure 1. Structure of CERD

Another feature of CERD is that rural and urban households are distinguished in each region according to their possession of primary factors. This feature is very important, and appropriate, for the analysis of the Chinese economy where rural and urban areas are still separated to some extent because of several restrictions, although significant improvements have been made in reducing these restrictions. For example, the household registration system, which identifies a person as a rural or urban resident, is still in effect and prevents people from freely moving across regions, especially from countryside to cities.

Another difference between CERD and global models, or other China models, is its treatment of regional links. Ideally, inter-regional flows of commodities and factors would be presented in the model. However, such information is not available, as there are no ‘customs posts’ in each province to register ‘imports’ from, and ‘exports’ to, other provinces. To avoid arbitrary decisions in creating the database, CERD models inter-regional trade indirectly via a national pool of commodities and factors. Each region sells its excess supply to, and buys excess demand from, the national pool (Figure 1).

CERD also distinguishes regional and national governments, which allows the analysis of transfer payments between governments.

Finally, CERD has a fairly detailed representation of commodities. There are 51 sectors in the model, among which are 12 agricultural sectors, 25 industrial sectors, one construction sector, and 13 service sectors (see Table 27). The three most important food grains, wheat, paddy rice and corn, are separately identified.

Conventions

Variables

Each variable has two forms: in levels and percentage change. The former is represented by upper-case letters and the latter by lower-case letters. The relationship between these two representations is defined as:

$$x = \Delta X/X \times 100$$

In most cases, a variable is a vector or a matrix. For example, regional sectoral output, X or x , is a matrix with two dimensions: sector and region. Therefore, the range of arguments should be included in the variable name, e.g. $X(j, r)$ or $x(j, r)$, $j \in IND$, $r \in RGN$, where IND and RGN are, respectively, collections of sectors and regions called *sets*. If a specific value of the variable is concerned, e.g. wheat output in Jiangsu Province, it can be written as $X(\text{"wheat"}, \text{"jiangsu"})$.

The following is an incomplete list of the most frequently used arguments in the discussion:

i commodity j sector r region v factor d destination h household s source.

The definitions of all variables used in CERD can be found in Table 28.

Equations

Most of the equations in CERD are expressed in linear form and conform to the General Equilibrium Modelling Package (GEMPACK) syntax as closely as possible. Below is a listing of the linear form of some basic functions:

Level form		Linear form
$Z = X \cdot Y$	\Rightarrow	$z = x + y$
$Z = X/Y$	\Rightarrow	$z = x - y$
$Z = X^\alpha$	\Rightarrow	$z = \alpha \cdot x$
$Z = X + Y$	\Rightarrow	$Z \cdot z = X \cdot x + Y \cdot y$ or $z = (X/Z)x + (Y/Z)y$

where X , Y and Z are level variables, x , y and z are the corresponding linear variables, and α is a parameter.

Coefficients and parameters

The above linear transformation has explicitly shown parameter α . Note that X , Y and Z appear in the last linear function. The purpose of linearising functions is to form a system of linear functions, so that a computer package (e.g. GEMPACK) can solve it. Therefore the values of X , Y and Z should be pre-set during each step of the simulation, that is, they cannot be treated as variables but are treated as *coefficients*. However, as they are associated with those level variables, their values should be updated after each step of the simulation (Harrison and Pearson 2002). In contrast, the value of parameter α does not change from one step of the simulation to another. Therefore, coefficients and parameters are different. To distinguish them, coefficients are denoted by upper-case letters and parameters by Greek letters.

As seen from the above discussion, there are two types of coefficients: absolute values, e.g. X , Y and Z , and shares, e.g. X/Z and Y/Z . To avoid excess notation, an absolute value

coefficient is given a name the same as its associated level variable in this document². The names of share coefficients normally begin with “S”, “SH” or “SHR”.

Sets

As introduced above, a *set* defines the domain of a variable’s argument. It is denoted by upper-case letters, e.g. *IND* and *RGN*, while its elements are usually denoted by lower case and put in quotation marks when referred to, e.g. “*wheat*” and “*jiangsu*”. Table 29 lists all sets used in CERD.

Regional economies

There are three types of agents in each region: firms, private households and governments. This section describes the behaviour of these agents.

Firms

Demand for primary factors

Each sector in each region is represented by a firm producing a single commodity. Perfect competition and constant returns to scale are assumed for all firms. Production is modelled by a nest of technologies (Figure 2).

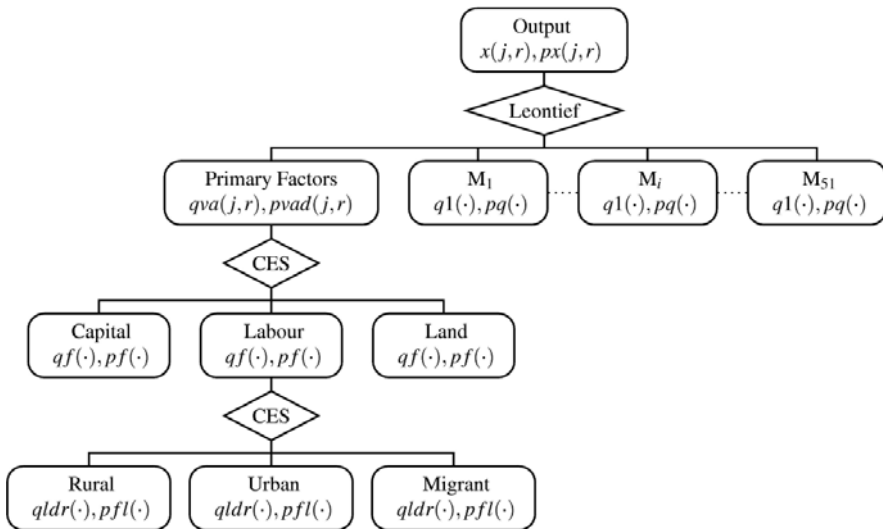


Figure 2. Production nesting

At the first tier of the nest, the technology is Leontief, that is, the production of a good, $X(j, r)$, requires fixed proportions of intermediate inputs, $Q1(i, j, r)$, and aggregated primary factors, or value added, $QVA(j, r)$:

² The treatment in the computer coding is different. As GEMPACK does not distinguish between upper and lower case letters, coefficients are given a name different to associated linear variables.

$$QI(i, j, r) = \frac{SQ(i, j, r) \cdot X(j, r)}{AO(j, r) \cdot AI(i, j, r)} \quad \forall i \in COM, j \in IND, r \in RGN$$

$$QVA(j, r) = \frac{SVA(j, r) \cdot X(j, r)}{AO(j, r) \cdot AVA(j, r)} \quad \forall j \in IND, r \in RGN$$

where $SQ(i, j, r)$ and $SVA(j, r)$ are, respectively, shares of intermediate inputs and value added in output; $AO(j, r)$, $AI(i, j, r)$ and $AVA(j, r)$ are, respectively, output-, input-, and value added-augmenting technical changes. The linearised versions of these two equations are represented by equations (1) and (2) in Table 15. The shares do not appear in the linearised equations because they are fixed, by definition.

At the second tier, the value added is an aggregation of labour, capital, and land with constant elasticity of substitution (CES):

$$QVA(j, r) = AF(j, r) \left[\sum_{v \in FAC} (SF(v, j, r))^{\frac{1}{\sigma_p(j)}} (QF(v, j, r))^{\frac{\sigma_p(j)-1}{\sigma_p(j)}} \right]^{\frac{\sigma_p(j)}{\sigma_p(j)-1}}$$

where $AF(j, r)$, $SF(v, j, r)$ and $\sigma_p(j)$ s are, respectively, the technological shifters, the shares of individual factors, and the elasticities of substitution between factors. A profit maximising firm's demand for primary factors is determined by:

$$QF(v, j, r) = SF(v, j, r) [AF(j, r)]^{\sigma_p(j)-1} QVA(j, r) \left[\frac{PVAD(j, r)}{PF(v, j, r)} \right]^{\sigma_p(j)}$$

where $PVAD(j, r)$ and $PF(v, j, r)$ are, respectively, prices of value added and individual primary factors. The linearised demand function is represented by equation (3) in Table 15. Equation (4) states that the price of the value added is the average of factor prices.³

The demand for intermediate inputs, combined with the demand of households and government and other demands, will be discussed later. The demand is a CES aggregation of commodities from different sources.

At the third tier, demands for different types of labour are determined. The labour demand by non-agricultural sectors is a CES aggregation of rural, urban and migrant labour, while agricultural sectors demand only rural labour. Therefore, there are four types of labour in the demand side: “*agri*” labour, which is rural labour used in agricultural sectors; and “*rural*”, “*urban*” and “*migrant*” labour, which are used in non-agricultural sectors (see Figure 3).

³ This form of average is true for CES and CET functions. Suppose Q is a CES aggregation of Q_1 and Q_2 . The price of Q is determined by $PQ = P_1Q_1 + P_2Q_2$. Taking the total differential of this equation and dividing both sides by PQ gives:

$$p + q = \frac{P_1Q_1}{PQ} (p_1 + q_1) + \frac{P_2Q_2}{PQ} (p_2 + q_2) .$$

Applying the relations $q_1 = q + \sigma(p - p_1)$ and $q_2 = q + \sigma(p - p_2)$ into the above equation and collecting items gives:

$$p = \frac{P_1Q_1}{PQ} p_1 + \frac{P_2Q_2}{PQ} p_2 .$$

Agricultural sectors	Non-agricultural sectors	
$qf(\text{"labour"}, j, r)$ $ql(\text{"agri"}, r)$ $plu(\text{"agri"}, r)$	$qldr(\text{"rural"}, j, r)$ $ql(\text{"rural"}, r)$ $plu(\text{"rural"}, r)$	Rural
	$qldr(\text{"urban"}, j, r)$ $ql(\text{"urban"}, r)$ $plu(\text{"urban"}, r)$	Urban
	$qldr(\text{"migrant"}, j, r)$ $ql(\text{"migrant"}, r)$ $plu(\text{"migrant"}, r)$	Migrant

Figure 3. Demand for different types of labour

Equation (5) in Table 15, which has a form similar to equation (2), determines the demand for “*rural*”, “*urban*”, and “*migrant*” labour in each of the non-agricultural sectors. Equation (6) aggregates the prices of these three types of labour. Equations (7) and (8) assign labour prices, which imply that each type of labour has the same price even when being employed in different sectors. Equations (9) and (10) calculate the total demand for each type of labour in a region.

Sales of products

Commodities produced by firms are sold to three destinations: local (regional) market, other regions in China, and overseas (exports). The sales to each destination are modelled as a process with a constant elasticity of transformation (CET). Equation (11) in Table 16 shows that the sales to a destination are determined by the amount of the commodity concerned, $com(i, r)$, the relative price of the commodity in each destination, $pp(i, r, d) - px(i, r)$, and the elasticity of transformation, σ_r . Equation (12) states that the commodity price is an aggregation of prices in every destination.

Households

There are two types of households, rural and urban, in each region. They are classified according to their possession of primary factors. Rural households own all primary factors used in agricultural sectors and part of the factors used in non-agricultural sectors. The share of rural households in non-agricultural factors is drawn from the share of township and village enterprises (TVEs) in different sectors.

Supply of primary factors

Each household owns an endowment of primary factors, $QFAH(v, h, r)$, and allocates the endowment to different uses according to the CET process. The factor supply functions are grouped in Table 17.

Labour is divided into rural and urban labour. Labour supplied by the rural household can be used in all sectors in its own region as well as in other regions, i.e. as migrant labour. By contrast, labour supplied by the urban household can be used only in non-agricultural sectors in its own region (Figure 4). These assumptions are based on the fact that currently there is a huge amount of surplus labour in rural areas and that urban households are not willing to engage in agricultural activities.

Equation (13) in Table 17 determines rural households' supply of the different types of labour in a region, $qlrh(l, r)$, $l \in LU1 = \{\text{"agri"}, \text{"nagr"}, \text{"migrant"}\}$, in a typical CET format. The supply of each type of labour is determined by each rural household's endowment of labour, $qfah(\text{"labour"}, \text{"rural"}, r)$, the relative price of the particular type of labour, $pl(l, r) - plr(r)$, and the elasticity of transformation, δ_1 . Note that a slack variable, $qlslack(l, \text{"rural"}, r)$, is also included in order to model unemployment in some model closures.

	Rural household $qfah(\text{"labour"}, \text{"rural"}, r)$ $plr(r)$	Urban household
Agricultural sectors	$qlrh(\text{"agri"}, r)$ $pl(\text{"agri"}, r)$	
Non-agricultural sectors	$qlrh(\text{"nagr"}, r)$ $pl(\text{"nagr"}, r)$	$qfah(\text{"labour"}, \text{"urban"}, r)$ $pl(\text{"urban"}, r)$
Other: Migrant	$qlrh(\text{"migrant"}, r)$ $pl(\text{"migrant"}, r)$	

Figure 4. Supply of different types of labour

Equation (14) determines the aggregated price of labour supplied by the rural household, $plr(r)$, in a form explained in footnote (3). Migrant labour moves into a national pool, which is discussed in the regional linkage section.

It is assumed that capital is perfectly mobile across regions and sectors, and there is no difference between capital owned by rural households and that owned by urban households. Therefore, there is no specific transformation function governing the supply of capital to each sector in each region. Only a summation equation (15), is needed to calculate the total supply of capital, which will be equal to total demand set by the market clearing condition (equation 50). Capital in every region has the same price, as suggested by equation (16).

Land is owned only by rural households. It is not mobile across regions, but is partly mobile across agricultural sectors. The imperfect mobility of land reflects both natural and policy restrictions on land uses. No land is used in non-agricultural sectors. Similarly, the supply of land to each (agricultural) sector, $qas(j, r)$, is determined by a CET process described by equation (17)—exactly the same as the GTAP model—depending on the household's endowment of land, $qfah(\text{"land"}, \text{"rural"}, r)$, the relative price of land in the sector concerned, $pas(j, r) - pfa(\text{"land"}, r)$, and the elasticity of transformation, $\delta_4(r)$. Equation (18) aggregates sectoral land prices into a single regional price.

Household income

Table 18 describes the calculation of household income. The primary source of household income is returns to factors. Incomes are calculated separately for rural and urban households. Rural household gross income, $y_g(\text{"rural"}, r)$, is the sum of revenues from supplying land, capital and labour (equation 19), while urban household gross income, $y_g(\text{"urban"}, r)$, is the sum of revenues from supplying capital and labour (equation 20). Each household's net income, $y_n(h, r)$, is its gross income net of income taxes (equation 21), while each household's disposable income, $y_d(h, r)$, is net income plus government transfer payments, $transf_r(h, r)$ (equation 22).

It should be noted that, in equations (19) and (20), each household's income is calculated according to its possession of primary factors $qfah(v, h, r)$, rather than the use of them. This is necessary for the accuracy of regional income calculations because of the mobility of labour and capital. This specification might lead to some bias in the calculation because of migrant labour. Specifically, it may underestimate (overestimate) income, and thus the consumption, of regions with net inflows (outflows) of migrant labour. However, most migrant labourers are seasonal workers and send most of their earnings back to their households. In this sense, the current approach is more accurate than that based on the use of factors. If it is found that more migrants choose to reside in their work place permanently, the calculation could be adjusted by changing $qfah("labour", h, r)$ in the current framework.

Household saving and consumption

Each household allocates its disposable income to savings and consumption. Saving is a fixed proportion of disposable income, determined by the marginal propensity to save, $save_p(h, r)$, (equation 23 in Table 19). The remaining disposable income, $y_c(h, r)$, is for consumption (equation 24).

Household consumption is modelled by a constant difference in elasticity (CDE) system. CDE functions are more flexible than CES functions in modelling consumer behaviour, and are used by the GTAP model (Hertel 1997). The relationship between per capita utility, $uc(h, r)$, and per capita real consumption expenditure, $y_c(h, r) - cpi(h, r) - pop(h, r)$, is given by equation (25), and the consumption demand for individual commodities, $q3(i, h, r)$, is given by equation (26). With this CDE system, the cross-price and income elasticities, $EP(i, k, h, r)$ and $EY(i, h, r)$ are not constant, as suggested by equations [b] and [c] in Table 19. Other equations in the table show some necessary calculations of coefficients for the system, including the Engel summation, $ENGEL\ 0(h, r)$, in equation [a], and the Allen partial elasticity of substitution between commodities, $APE(i, k, h, r)$ in [d1] and [d2].

Government

There are two levels of government: regional and central. To simplify the treatment, it is assumed that tax collections (except import tariffs and export taxes), government saving, and consumption are made by regional governments, while the central government serves only to transfer payments to regional governments.⁴ Therefore, each regional government's revenue, calculated by equation (27) in Table 20, is the sum of consumption, production and income taxes and the transfers from the central government, while the central government collects import tariffs and export taxes, as suggested by equation (28). The behavioural equations of the central government could be suppressed in the model so long as its budget constraint (29) is imposed.

Each regional government's saving and consumption behaviour (shown in Table 21) is similar to that of private households (see Table 19). First, a fixed proportion of total government revenue, $save("gov", r)$, is saved according to the government's propensity to save, $save_p("gov", r)$, as suggested by equation (30). The remaining revenues are then

⁴ If the central government was allowed to consume, it would also make decisions about where the commodities are bought and spent. This would unnecessarily increase the burden of computation as this activity can be embodied in the decision-making process of individual regional governments.

allocated to consumption, $govconv(r)$, or transferred to individual private households in the region, $transf_r(h, r)$. The transfer payment is a policy instrument and set exogenously; therefore the government's consumption expenditure can be determined by equation (31).

Once the expenditure on consumption is determined, the government's utility from consumption, $uc("gov", r)$, is determined by equation (32), which, in turn, determines government demand for each commodity, $q5(i, r)$, through equation (33). The demand function (33) implies that government's utility is a Cobb-Douglas function of the consumed commodities.

Other demands

Investment

Equations (34)–(36) in Table 22 describe regional investment demand. Regional aggregate real investment, $ir(r)$, is determined by the relative prices of returns to capital, $pfa("capital", r)$, the price of investment goods, $ip(r)$, and the elasticity of investment, $\gamma(r)$ (equation 34). The commodities used in the production of this aggregate investment, $q2(i, r)$, are given by equation (35), which implies that the aggregate investment is a Cobb-Douglas function of individual commodities. Equation (36) aggregates the prices of individual commodities into the price of investment. National investment is the sum of regional investments, which is discussed in the regional linkage section.

Demand for exports

Equations (37) and (38) determine the world demand for exports.

$\sum_{s \in WLD} S1(i, s) \cdot pe(i, s)$ shows the average export price of commodity i , and

$\sum_{i \in COM} \sum_{s \in WLD} S2(l, s) \cdot pe(l, s)$ the average export price of all commodities.

Therefore, world demand for exports of a commodity, $qw4(i)$, is determined by the relative price of commodity i in the world market, and the elasticity of export, $\beta(i)$. The world demand for exports is split into demand for exports from China and demand from the rest of the world, $q4(i, s)$, $s \in WLD = \{“chn”, “row”\}$, through a typical CES process.

Regional commodity demand

As shown in Figure 5, regional demand for a commodity, $Q(i, r)$, is the sum of each firm's demand for intermediate goods and services, investment demand, and consumption demand of households and the government:

$$Q(i, r) = \sum_{j \in IND} Q1(i, j, r) + Q2(i, r) + \sum_{h \in HHD} Q3(i, h, r) + Q5(i, r)$$

The linearised form is given by equation (39) in Table 23.

Total demand is a CES aggregation of demands for imported and domestically produced goods; with the latter, in turn, a CES aggregation of goods produced locally, i.e. within the region, and those from other regions, i.e. the national pool. Equations (40)–(43) calculate the user prices of, and demand for, goods from different sources.

This type of demand nesting has a couple of advantages. Firstly, it allows different elasticities of substitution between domestic and imported goods and between goods from different domestic regions. This reflects the usual perception that the domestic market is more

integrated than the global market. Secondly, as almost all models distinguish domestic and foreign products, this nesting permits the use of parameters drawn from other models.

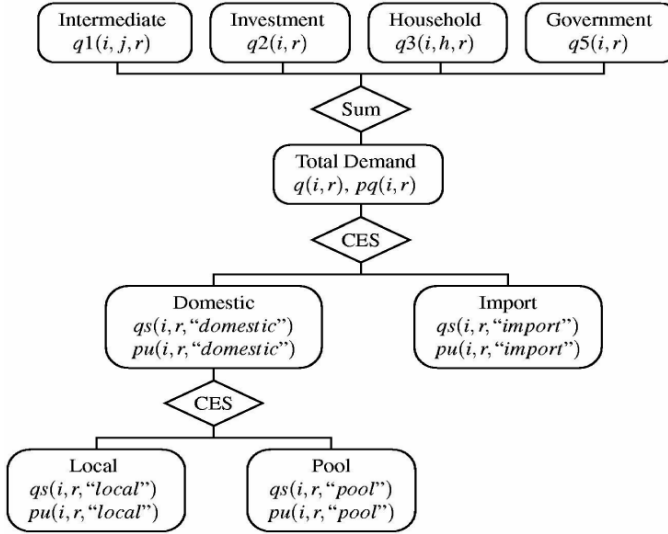


Figure 5. Regional commodity demand

Regional linkages

This section describes the links between regions and between domestic and world markets. The regional market equilibrium conditions are also introduced in this section, as they involve demand and supply from outside the region.

Factor markets

As shown in Figure 3, there are four types of labour in the demand side: rural labour used in agricultural sectors, $ql("agri", r)$; and rural, urban and migrant labour used in non-agricultural sectors, $ql("rural", r)$, $ql("urban", r)$ and $ql("migrant", r)$. There are also four types of labour in the supply side as shown in Figure 4: agricultural and non-agricultural labour supplied by rural households, $qlrh("agri", r)$ and $qlrh("nagr", r)$; labour supplied by urban households, $qfah("labour", "urban", r)$; and migrant labour supplied by rural households, $qlrh("migrant", r)$. The markets for the first three types of labour in each side can be equated within one region, as presented by equations (44)–(46) in Table 24, while the migrant labour market clearing conditions are more complicated.

As illustrated in Figure 6, migrant labour in the national pool is the sum of migrant labour supplied by each region; they are then allocated to each region to meet the demand according to a CET process. Equations describing these processes are given by equations (47) and (48) in Table 24. Equation (49) calculates the national price of migrant labour, $plms$. It should be noted that $plms$ is the aggregation (or average) of the user price of migrant labour in each region, $plu("migrant", r)$, rather than the average of the supply price, $pl("migrant", r)$. This

may reflect the fact that the migrant labour market is to some extent a buyer's market. The supply of migrant labour in rural households depends on its perceived price, or the price from the hypothetical national pool, which is a mixture of user prices in all regions.

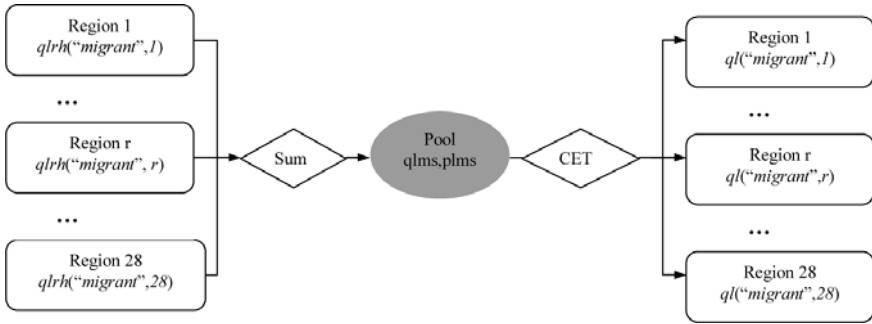


Figure 6. National migrant labour market

Because capital is perfectly mobile across regions and sectors, the market clearing condition (equation 50) simply equates the total demand and supply. On the other hand, land is partly mobile across agricultural sectors within a region, therefore, its supply and demand should be matched for each (agricultural) sector in each region, as stated by equation (51), similar to the structure of GTAP.

Commodity markets

Commodity market clearing conditions are grouped in Table 25. Equation (52) equates the supply of, and demand for, locally produced commodities. Equation (53) calculates the world supply of imports to China, $qms(i)$, which depends on the elasticity of import supply, $\varepsilon(i)$, and the world price, $pm(i)$. In equation (54) this import supply satisfies the total demand for imports from all regions.

Equation (55) presents the market clearing condition for the export market, in which total exports equal the sum of exports from the regions.

Equations (56)–(58) describe the market clearing conditions for commodity markets in the national pool in a similar manner to the market clearing for migrant labour. First, the amount of a commodity in the national pool, $cdo(i)$, is a sum of the supply of that commodity from all regions, $cd(i, r, "pool")$, as stated by equation (56). Then $cdo(i)$ is allocated to individual regions to meet their demand according to a CET process given by equation (57). The allocation depends on the elasticity of transformation, $\sigma_d(i)$, and the price of the commodity in each region, $por(i, r)$, relative to the price in the pool, $po(i)$. Equation (58) aggregates regional prices into the national price.

Price linkages

The price linkage equations are given in Table 26. Equation (59) is the zero pure profit condition, which determines the producer's price of commodity i in region r , $pps(i, r)$. Since the firms are assumed to maximise profits, the quantity changes drop out when the net profit equation is totally differentiated in the neighbourhood of an optimum (see, e.g. Varian 1978). This leaves an equation relating the input price and the output price, where

these percentage changes are weighted by value for the agent's price. For computational convenience we use different variables to refer to the firm's prices for composite intermediate inputs (pq) and endowment commodities (pf).

Most of the remaining equations in Table 26 describe the relationship between supply and demand prices of a commodity or a primary factor. The difference between supply and demand prices arises from various taxes and transaction costs.

Equation (60) defines producer price including indirect tax. The power of indirect tax (ti) is defined in equation (74).

Equation (61) describes the linkages between market prices and agents' purchase prices of commodities produced locally. The price difference is caused by commodity taxes (tca and tc). These commodity taxes can potentially vary, not only across commodities, but also across regions. However, the tax on a commodity from different sources (local, imports, or other domestic regions) in the same region has the same value.

Equations (62) through (64) refer to the procedures for importing commodities from overseas into the national import commodity pool, and then from the national import commodity pool to the regional markets. These equations show the effects of import tariffs (tm), defined by equation (73), exchange rates (phi), transportation costs ($tmtr$) and commodity taxes on the import price in each region.

Equation (65) links the commodity price in the pool to the agents' purchase price by adding commodity taxes and transport costs ($totr$).

Equation (66) links the export price in specific regions (pp) to the national export commodity pool ($ppex$). Equation (67) shows the relationship between prices in the national export pool ($ppex$) and China's export price valued in foreign currency (pe).

Equations (68) through (72) link the demand and supply prices of land, capital and labour. As labour is of four types (i.e. agricultural labour, rural labour in the non-agricultural sector, migrant labour, and urban labour), and the CERD model allows the labour supply tax (tfl) to differ by region and labour type, there are four equations to reflect such relationships.

Figures 7 and 8 illustrate the commodity price and factor price linkages in the CERD model.

Data

Input–output data

A feature of CERD is that its database was compiled on the basis of the provincial 44-sector input–output tables for 1997.⁵ The 44-sector classification follows the 40-sector classification in the 1997 national input–output table (National Accounts Department 1999), with the agricultural sector further disaggregated into five sections. There are 28 provincial tables available.⁶ These provincial input–output data were aggregated in the model into three regions. The eastern coastal region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and

⁵ China's 1997 provincial input–output tables are the latest tables available for this project. The 2002 national and regional input–output tables for China have not been officially released. The database of the CERD model can be updated if the new provincial input–output tables become available.

⁶ Input–output tables for Hainan, Ningxia and Tibet are not available.

Hainan; the central region includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan; and the western region includes Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia, Qinghai, Tibet and Xinjiang.

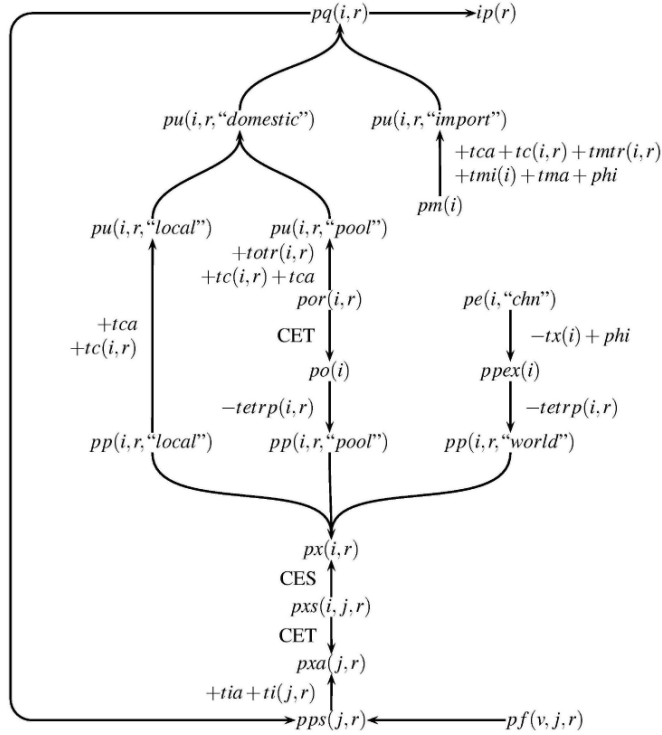


Figure 7. Commodity price linkages

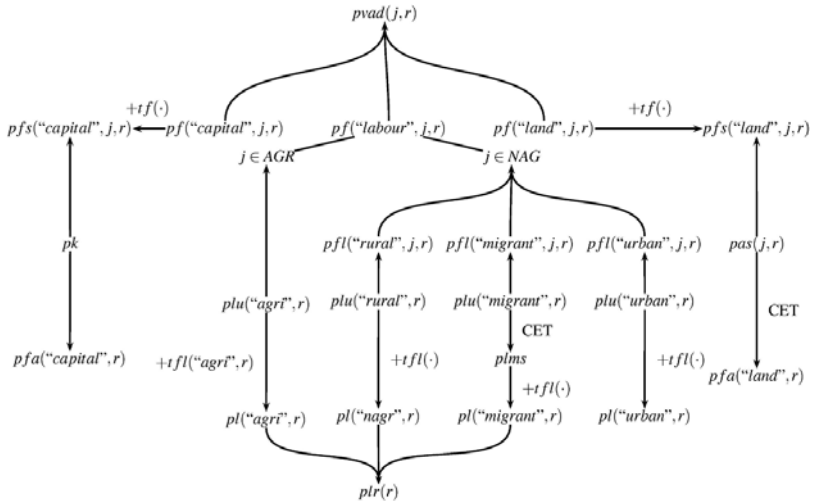


Figure 8. Factor price linkages

To analyse the impact of China's WTO accession on the agricultural sector in more detail, the crops sector in the original 44-sector table was split into nine sectors: rice, wheat, corn, pulses, other grains, cotton, oilseeds, vegetables and fruits, and other crops. The split was based on the provincial crops production database (Ministry of Agricultural and State Planning Commission 2001, unpublished data).

Other data and parameters were drawn from GTAP database 5, Yang and Huang (1997) and the China Statistical Yearbook series.

Regional trade

Five provinces (Anhui, Chongqing, Guizhou, Heilongjiang and Shandong) have data on net exports only.

An ideal way to model inter-regional trade would be to identify each region's inflows from, and outflows to, each of the other regions. However, such data are not available. Therefore, two alternative ways could be offered. First, a probability model is used to predict the trade between two regions, which is then adjusted by a gravity model. The distance between the two regions adversely affects trade.

$$\text{Trade} = f(DS)$$

Second, inter-regional trade is modelled via a national pool. There is no direct trade between the two regions. The national pool serves as an intermediary for regional trade. CERD models inter-regional trade indirectly via a national pool of commodities and factors. Each region sells its excess supply to, and buys excess demand from, the national pool. These relationships have been described above.

Model closure

Endowments of primary factors are exogenous. There are labour-slack variables to allow for unemployment. But in the simulations described above these slack variables are set at zero, leaving wages to adjust for full employment.⁷

All tax rates including tariff rates and technological shifters are set exogenously. Exogenous tax rates imply that government revenues will change along with changes in production, income and trade. The share of transfer payments from central government to regional governments does not change; that is, payments to each region change at the same rate.

The marginal propensities to save are fixed, although they vary across households and regions. The difference between national savings and aggregate investment is the net capital inflow, which is equal to the trade deficit. The model allows two closures to simulate the effects of trade liberalisation: no control on the trade balance, and forcing the change in the trade balance to be zero.

⁷ The treatment here implies no change in the employment (or unemployment) level embodied in the database.

Table 15. Firms' demand for intermediate and primary factors

(1) Intermediate demand		
$ql(i, j, r) = x(j, r) - ao(j, r) - ai(i, j, r)$		$\forall i \in COM, j \in IND, r \in RGN$
(2) Value-added demand		
$qva(j, r) + ava(j, r) = x(j, r) - ao(j, r)$		$\forall j \in IND, r \in RGN$
(3) Primary factors demand		
$af(v, j, r) = qva(j, r) - af(v, j, r) - \sigma_p(j)$		$\forall v \in FAC, j \in IND, r \in RGN$
$\{pf(v, j, r) - af(v, j, r) - pvad(j, r)\}$		
(4) Aggregated value-added price		
$pvad(j, r) = \frac{\sum_{v \in FAC} IF(v, j, r) \cdot [pf(v, j, r) - af(v, j, r)]}{\sum_{v \in FAC} IF(v, j, r)}$		$\forall j \in IND, r \in RGN$
(5) Demand for different types of labour by non-agricultural sectors		
$qldr(l, j, r) = qf("labour", j, r) - \sigma_l(j)$		
$\{pfl(l, j, r) - pf("labour", j, r)\}$		$\forall l \in LSI, j \in NAG, r \in RGN$
(6) Demand prices for labour by non-agricultural sectors		
$pf("labour", j, r) = \frac{\sum_{l \in LSI} [LR(l, j, r) \cdot pfl(l, j, r)]}{\sum_{l \in LSI} LR(l, j, r)}$		$\forall j \in NAG, r \in RGN$
(7) Labour prices in agricultural sector are equal		
$pf("labour", j, r) = plu("agri", r)$		$\forall j \in AGR, r \in RGN$
(8) Labour prices used by different non-agricultural sectors are the same		
$pfl(l, j, r) = plu(l, r)$		$\forall l \in LSI, j \in NAG, r \in RGN$
(9) Demand for agricultural labour by agricultural sectors		
$ql("agri", r) = \frac{\sum_{j \in AGR} [IF("labour", j, r) \cdot qf("labour", j, r)]}{\sum_{j \in AGR} IF("labour", j, r)}$		$\forall r \in RGN$
(10) Demand for different types of labour by non-agricultural sectors		
$ql(l, r) = \frac{\sum_{j \in NAG} [LR(l, j, r) \cdot qldr(l, j, r)]}{\sum_{j \in NAG} LR(l, j, r)}$		$\forall l \in LSI, r \in RGN$
Coefficients:		
$IF(v, j, r) = PF(v, j, r) \cdot QF(v, j, r)$		$\forall v \in FAC, j \in IND, r \in RGN$
$LR(l, j, r) = PFL(l, j, r) \cdot QLDR(l, j, r)$		$\forall l \in LSI, j \in NAG, r \in RGN$

Table 16. Firms' supply of products

(11) Sale to different destinations (Demand by different destinations)	
$cd(i, r, d) = com(i, r) + \sigma_r(i) \cdot [pp(i, r, d) - px(i, r)]$	$\forall i \in COM, r \in RGN, d \in DST$
(12) Aggregated price of different destinations	
$\sum_{d \in DST} DSP(i, r, d) \cdot px(i, r) = \sum_{d \in DST} DSP(i, r, d) \cdot pp(i, r, d)$	$\forall i \in COM, r \in RGN$
Coefficients:	
$DSP(i, r, d) = PP(i, r, d) \cdot CD(i, r, d)$	$\forall i \in COM, r \in RGN, d \in DST$

Table 17. Households' supply of primary factors

(13) Supply of different types of labour by rural households	
$qlrh(l, r) = qfah("labour", "rural", r)$ $+ \delta_1 [pl(l, r) - plr(r)] - qlslack(l, "rural", r)$	$\forall l \in LU1, r \in RGN$
(14) Aggregated price of labour supplied by rural households	
$plr(r) = \sum_{l \in LU1} SHRLABR(l, r) \cdot pl(l, r)$	$\forall r \in RGN$
(15) Market clearing equation for capital	
$qk = \sum_{r \in RGN} \sum_{h \in HHD} SHCAP(h, r) \cdot qfah("capital", h, r)$	
(16) Capital is perfectly mobile between regions	
$pfa("capital", r) = pk$	$\forall r \in RGN$
(17) Supply of land to different agricultural sectors	
$qas(j, r) = qfah("land", "rural", r)$ $+ \delta_4(r) \cdot [pas(j, r) - pfa("land", r)]$	$\forall j \in IND, r \in RGN$
(18) Aggregated price of land	
$pfa("land", r) = \sum_{j \in IND} SHLAND(j, r) \cdot pas(j, r)$	$\forall r \in RGN$
Coefficients:	
$SHRLABR(l, r) = \frac{PL(l, r) \cdot QLRH(l, r)}{\sum_{l \in LU1} PL(l, r) \cdot QLRH(l, r)}$	$\forall l \in LU1, r \in RGN$
$RF("labour", "rural", r) = PLR(r) \cdot QFAH("labour", "rural", r)$	$\forall r \in RGN$
$RF("labour", "urban", r) = PL(r) \cdot QFAH("labour", "urban", r)$	$\forall r \in RGN$
$RF("capital", h, r) = PK \cdot QFAH("capital", h, r)$	$\forall h \in HHD, r \in RGN$
$RF("land", h, r) = PFA("land", r) \cdot QFAH("capital", h, r)$	$\forall h \in HHD, r \in RGN$
$SHCAP(h, r) = \frac{RF("capital", h, r)}{\sum_{r \in RGN} RF("capital", h, r)}$	$\forall h \in HHD, r \in RGN$
$SHLAND(j, r) = \frac{PAS(j, r) \cdot QAS(j, r)}{\sum_{j \in IND} PAS(j, r) \cdot QAS(j, r)}$	$\forall j \in IND, r \in RGN$

Table 18. Household income

(19) Rural household gross income	
$INCOMES_G("rural", r) \cdot y_g("rural", r)$	
$= RF("land", "rural", r) \cdot [pfa("land", r) + qfah("land", "rural", r)]$	
$+ RF("capital", "rural", r) \cdot [pk + qfah("capital", "rural", r)]$	
$+ RF("labour", "rural", r) \cdot [plr(r) + qfah("labour", "rural", r)]$	$\forall r \in RGN$
(20) Urban household gross income	
$INCOMES_G("urban", r) \cdot y_g("urban", r)$	
$+ RF("capital", "urban", r) \cdot [pk + qfah("capital", "urban", r)]$	
$+ RF("labour", "urban", r) \cdot [pl("urban", r) + qfah("labour", "urban", r)]$	$\forall r \in RGN$
(21) Household net income	
$y_n(h, r) = y_g(h, r) - ty_a - ty(h, r)$	$\forall h \in HHD, r \in RGN$
(22) Household disposable income	
$INCOMES_D(h, r) \cdot y_d(h, r) = INCOMES_N(h, r) \cdot y_n(h, r)$	
$+ RTRANSF(h, r) \cdot transf_r(h, r)$	$\forall h \in HHD, r \in RGN$
Coefficient:	
$INCOMES_G(h, r) = \sum_{v \in FAC} RF(v, h, r)$	$\forall h \in HHD, r \in RGN$
$INCOMES_N(h, r) = INCOMES_G(h, r) - TAXINC(h, r)$	$\forall h \in HHD, r \in RGN$
$INCOMES_D(h, r) = INCOMES_N(h, r) + RTRANSF(h, r)$	$\forall h \in HHD, r \in RGN$
$RTRANSF(h, r) = TRANSF_R(h, r)$	$\forall h \in HHD, r \in RGN$

Table 19. Household saving and consumption

(23) Household saving		
$save(h,r) = save_p(h,r) + y_d(h,r)$		$\forall h \in HHD, r \in RGN$
(24) Households' expenditure for consumption		
$INCOMES_D(h,r) \cdot [y_d(h,r) + bgtslack(h,r)]$ $= CON(h,r) \cdot y_c(h,r) + SAVINGS(h,r) \cdot save(h,r)$		$\forall h \in HHD, r \in RGN$
(25) Private consumption utility		
$y_c(h,r) = cpi(h,r) + ENGEL0(h,r) \cdot uc(h,r) + pop(h,r)$		$\forall h \in HHD, r \in RGN$
(26) Consumption demand for individual commodities by household		
$q3(i,h,r) = \sum_{k \in COM} EP(i,k,h,r) \cdot pq(k,r)$ $+ EY(i,h,r) \cdot [y_c(h,r) - pop(h,r)] + pop(h,r)$		$\forall i \in COM, h \in HHD, r \in RGN$
Coefficients and Parameters:		
$SAVINGS(h,r) = SAVE(h,r)$		$\forall h \in HHD, r \in RGN$
$CONS(i,h,r) = PQ(i,r) \cdot Q3(i,h,r)$		$\forall i \in COM, h \in HHD, r \in RGN$
$CON(h,r) = \sum_{i \in CMM} CONS(i,h,r)$		$\forall h \in HHD, r \in RGN$
[a] $ENGEL0(h,r) = \sum_{i \in CMM} SHRC(i,h,r) \cdot \gamma(i,r)$		$\forall h \in HHD, r \in RGN$
[b] $EP(i,k,h,r) = [APE(i,k,h,r) - EY(i,h,r)] \cdot SHRC(k,h,r)$ $\beta(i,h) \cdot \gamma(i,h) + \sum_{m \in COM} SHRC(m,h,r) \cdot \gamma(m,h) \cdot \alpha(m,h,r)$		$\forall i, k \in COM, h \in HHD, r \in RGN$
[c] $EY(i,h,r) = \frac{\sum_{m \in COM} SHRC(m,h,r) \cdot \gamma(m,h)}{\sum_{m \in COM} SHRC(m,h,r) \cdot \alpha(m,h,r)}$ $+ \alpha(i,h,r) - \sum_{m \in COM} SHRC(m,h,r) \cdot \alpha(m,h,r)$		$\forall i \in COM, h \in HHD, r \in RGN$
[d1] $APE(i,k,h,r) = \alpha(i,h,r) + \alpha(k,h,r)$ $- \sum_{m \in COM} SHRC(m,h,r) \cdot \alpha(m,h,r)$		$\forall i, k \in COM, h \in HHD, r \in RGN$
[d2] $APE(i,i,h,r) = 2\alpha(i,h,r) - \frac{\alpha(i,h,r)}{SHRC(i,h,r)}$ $- \sum_{m \in COM} SHRC(m,h,r) \cdot \alpha(m,h,r)$		$\forall i \in COM, h \in HHD, r \in RGN$
$SHRC(i,h,r) = \frac{CONS(i,h,r)}{CON(h,r)}$		$\forall i \in COM, h \in HHD, r \in RGN$
$\alpha(i,h,r) = 1 - \beta(i,h)$		$\forall i \in COM, h \in HHD, r \in RGN$

Table 20. Government revenues

(27) Regional government revenue	
$GREV(r) \cdot govrev(r) = \sum_{i \in COM} \{DSU(i, r, "local") \cdot [pu(i, r, "local") + qs(i, r, "local")]$ $- DSP(i, r, "local") \cdot [pp(i, r, "local") + qs(i, r, "local")]$ $+ DSU(i, r, "pool") \cdot [pu(i, r, "pool") + qs(i, r, "pool")]$ $- DPM(i, r) \cdot [por(i, r) + qs(i, r, "pool")]\}$ $+ \sum_{j \in IND} \{PAYA(j, r) \cdot [pxa(j, r) + x(j, r)] - PAYB(j, r) \cdot [pps(j, r) + x(j, r)]\}$ $+ \sum_{h \in HHD} [INCOMES_G(h, r) \cdot y_g(h, r) - INCOMES_N(h, r) \cdot y_n(h, r)]$ $+ CTRANSF(r) \cdot transf_c(r)$	$\forall r \in RGN$
(28) Central government revenue	
$CGREV \cdot cgovrev = \sum_{i \in COM} \{TMM(i) \cdot [pmm(i) + qms(i)] - TMB(i) \cdot [pm(i) + phi + qms(i)]$ $+ TXB(i) \cdot [pe(i, "chn") + phi + q4(i, "chn")] - TXP(i) \cdot [ppex(i) + q4(i, "chn")]\}$	
(29) Budget constraints on central government transfers	
$CGREV \cdot [cgovrev + cbgtslask] = \sum_{r \in RGN} CTRANSF(r) \cdot transf_c(r)$	$\forall r \in RGN$
Coefficients	
$DSU(i, r, s) = PU(i, r, s) \cdot QS(i, r, s)$	$\forall i \in COM, r \in RGN, s \in SRC$
$DPM(i, r) = POR(i, r) \cdot QS(i, r, "pool")$	$\forall i \in COM, r \in RGN$
$PAYA(j, r) = PXA(j, r) \cdot X(j, r), \quad PAYB(j, r) = PPS(j, r) \cdot X(j, r)$	$\forall j \in IND, r \in RGN$
$TMM(i) = QMS(i) \cdot PMM(i), \quad TMB(i) = QMS(i) \cdot PM(i) \cdot PHI,$	
$TXB(i) = Q4(i, "chn") \cdot PE(i, "chn") \cdot PHI, \quad TXP(i) = Q4(i, "chn") \cdot PPEx(i)$	$\forall i \in COM$
$GREV(r) = \sum_{i \in COM} [DSU(i, r, "local") - DSP(i, r, "local") + DSU(i, r, "pool") - DPM(i, r)]$ $+ \sum_{j \in IND} [PAYA(j, r) - PAYB(j, r)] + \sum_{h \in HHD} [INCOMES_G(h, r) - INCOMES_N(h, r)]$ $+ CTRANSF(r)$	$\forall r \in RGN$
$CGREV = \sum_{i \in COM} [TMM(i) - TMB(i) + TXB(i) - TXP(i)]$	
$CTransf(r) = TRANSF_C(r)$	$\forall r \in RGN$

Table 21. Government savings and consumption

(30) Government savings $save_p("gov", r) = save("gov", r) - govrev(r)$	$\forall r \in RGN$
(31) Government expenditure on consumption $GREV(r) \cdot [govrev(r) + bgtslack("gov", r)]$ $= CON("gov", r) \cdot govconv(r) + SAVINGS("gov", r) \cdot save("gov", r)$ $+ \sum_{h \in HHD} RTRANSF(h, r) \cdot transf_r(h, r)$	$\forall r \in RGN$
(32) Nominal government consumption $govconv(r) = uc("gov", r) + cpi("gov", r)$	$\forall r \in RGN$
(33) Government consumption of different commodities $q5(i, r) = uc("gov", r) - [pq(i, r) - cpi("gov", r)]$	$\forall i \in COM, r \in RGN$
Coefficients:	
$CON("gov", r) = \sum_{i \in COM} CONS(i, "gov", r)$	$\forall r \in RGN$
$CONS(i, "gov", r) = PQ(i, r) \cdot Q5(i, r)$	$\forall i \in COM, r \in RGN$
$SAVINGS("gov", r) = SAVE("gov", r)$	$\forall r \in RGN$
$RTRANSF(h, r) = TRANSF_R(h, r)$	$\forall h \in HHD, r \in RGN$

Table 22. Investment and export demand

(34) Regional aggregated real investment $ir(r) = \gamma(r) \cdot [pfa("capital", r) - ip(r)]$	$\forall r \in RGN$
(35) The production of investment goods $q2(i, r) = ir(r) - [pq(i, r) - ip(r)]$	$\forall i \in COM, r \in RGN$
(36) Price of investment $\sum_{i \in COM} INVE(i, r) \cdot ip(r) = \sum_{i \in COM} INVE(i, r) \cdot pq(i, r)$	$\forall r \in RGN$
(37) World demand for exports $qw4(i) = \beta(i) \cdot \sum_{s \in WLD} S1(i, s) \cdot pe(i, s) - \sum_{i \in COM} \sum_{s \in WLD} S2(i, s) \cdot pe(i, s)$	$\forall r \in RGN$
(38) Demand for exports from China $q4(i, s) = qw4(i) - \sigma_w(i) \cdot pe(i, s) - \sum_{k \in WLD} S1(i, k) \cdot pe(i, k)$	$\forall i \in COM, s \in WLD$
Coefficients:	
$INVE(i, r) = Q2(i, r) \cdot PQ(i, r)$	$\forall i \in COM, r \in RGN$
$S1(i, s) = EXPORTS(i, s) / \sum_{j \in WLD} EXPORTS(i, j)$	$\forall i \in COM, s \in WLD$
$S2(i, s) = EXPORTS(i, s) / \sum_{k \in COM} \sum_{j \in WLD} EXPORTS(k, j)$	$\forall i \in COM, s \in WLD$
$EXPORTS(i, s) = Q4(i, s) \cdot PE(i, s)$	$\forall i \in COM, s \in WLD$

Table 23. Regional commodity demand

(39) Market clearing condition for commodities	
$\sum_{j \in IND} INTER(i, j, r) + INVE(i, r) + \sum_{h \in HHG} CONS(i, h, r) \cdot q(i, r)$ $= \sum_{j \in IND} INTER(i, j, r) \cdot q1(i, j, r) + INVE(i, r) \cdot q2(i, r)$ $+ \sum_{h \in HHG} CONS(i, h, r) \cdot q3(i, h, r) + CONS(i, "gov", r) \cdot q5(i, r)$	$\forall i \in COM, r \in RGN$
(40) Aggregated price of domestic and imported products	
$\sum_{s \in SRC1} DSU(i, r, s) \cdot pq(i, r) = \sum_{s \in SRC1} DSU(i, r, s) \cdot pu(i, r, s)$	$\forall i \in COM, r \in RGN$
(41) Aggregated price of local products and inflows from other domestic regions	
$\sum_{s \in SRC2} DSU(i, r, s) \cdot pu(i, r, "domestic") = \sum_{s \in SRC2} DSU(i, r, s) \cdot pu(i, r, s)$	$\forall i \in COM, r \in RGN$
(42) Demand for domestic and imported products	
$qs(i, r, s) = q(i, r) - \sigma_m(i) \cdot [pu(i, r, s) - pq(i, r)]$	$\forall i \in COM, r \in RGN, s \in SRC2$
(43) Demand for local products and inflow from other domestic regions	
$qs(i, r, s) = qs(i, r, "domestic")$ $- \sigma_d(i) \cdot [pu(i, r, s) - pu(i, r, "domestic")]$	$\forall i \in COM, r \in RGN, s \in SRC2$
Coefficient	
$INTER(i, j, r) = PQ(i, r) \cdot Q1(i, j, r)$	$\forall i \in COM, j \in IND, r \in RGN$

Table 24. Primary factors market clearing conditions

(44) Market clearing for agricultural labour $ql("agri", r) = qlrh("agri", r)$	$\forall r \in RGN$
(45) Market clearing for rural labour in non-agricultural sectors $ql("rural", r) = qlrh("nagr", r)$	$\forall r \in RGN$
(46) Market clearing for urban labour in non-agricultural sectors $ql("urban", r) = qfah("labor", "urban", r) - qlslack("urban", "urban", r)$	$\forall r \in RGN$
(47) Total migrant labour $qlms = \sum_{r \in RGN} SLM_S(r) \cdot qlrh("migrant", r)$	
(48) Market clearing for migrant labour $ql("migrant", r) = qlms + \delta_1 \cdot [plu("migrant", r) - plms]$	$\forall r \in RGN$
(49) Aggregated price for migrant labour used by different regions $plms = \sum_{r \in RGN} SLM_D(r) \cdot plu("migrant", r)$	
(50) Market clearing for capital $qk = \sum_{r \in RGN} \sum_{j \in IND} SHCAPD(j, r) \cdot qf("capital", j, r)$	
(51) Land supply equal to demand $qas(j, r) = qf("land", j, r)$	$\forall j \in IND, r \in RGN$
Coefficients:	
$SLM_S(r) = QLRH("migrant", r) / \sum_{s \in RGN} QLRH("migrant", s)$	$\forall r \in RGN$
$SLM_D(r) = \frac{PLU("migrant", r) \cdot QL("migrant", r)}{\sum_{s \in RGN} PLU("migrant", s) \cdot QL("migrant", s)}$	$\forall r \in RGN$
$SHCAPD(j, r) = \frac{IF("capital", j, r)}{\sum_{i \in IND} \sum_{r \in RGN} IF("capital", i, r)}$	$\forall j \in IND, r \in RGN$

Table 25. Commodity market clearing conditions

(52) Supply equal to demand for locally produced commodities		
$cd(i,r,"local") = qs(i,r,"local")$		$\forall i \in COM, r \in RGN$
(53) China's import demand		
$qms(i) = \varepsilon(i) \cdot pm(i)$		$\forall r \in RGN$
(54) Market clearing condition for imported goods		
$qms(i) = \sum_{r \in RGN} SHRIMP(i,r) \cdot qs(i,r,"import")$		$\forall i \in COM$
(55) Market clearing condition for export goods		
$\sum_{R \in RGN} EXP(i,r) \cdot q4(i,"chn") = \sum_{r \in RGN} [EXP(i,r) \cdot cd(i,r,"world")]$		$\forall i \in COM$
(56) Aggregated "national pool" commodities		
$cdo(i) = \sum_{r \in RGN} [SHRPO(i,r) \cdot cd(i,r,"pool")]$		$\forall i \in COM$
(57) Distribution of "national pool" commodities		
$qs(i,r,"pool") = cdo(i) + \sigma_d(i) \cdot [por(i,r) - po(i)]$		$\forall i \in COM, r \in RGN$
(58) Aggregated "national pool" price		
$po(i) = \sum_{r \in RGN} SHRPOR(i,r) \cdot por(i,r)$		$\forall i \in COM$
Coefficients:		
$SHRIMP(i,r) = IMB(i,r) / \sum_{s \in RGN} IMB(i,s)$		$\forall i \in COM, r \in RGN$
$IMB(i,r) = QS(i,r,"import") \cdot PM(i) \cdot PHI$		$\forall i \in COM, r \in RGN$
$EXP(i,r) = CD(i,r,"world") \cdot PP(i,r,"world")$		$\forall i \in COM, r \in RGN$
$SHRPO(i,r) = CD(i,r,"pool") / \sum_{s \in RGN} CD(i,s,"pool")$		$\forall i \in COM, r \in RGN$
$SHRPOR(i,r) = DPM(i,r) / \sum_{s \in RGN} DPM(i,s)$		$\forall i \in COM, r \in RGN$
$DPM(i,r) = POR(i,r) \cdot QS(i,r,"pool")$		$\forall i \in COM, r \in RGN$

Table 26. Price linkage and zero profit conditions

(59) Zero profit condition	
$\left\{ \sum_{i \in COM} INTER(i, j, r) + \sum_{v \in FAC} IF(v, j, r) \right\} \cdot [pps(j, r) + ao(j, r) + profitslack(j, r)]$	
$= \sum_{i \in COM} INTER(i, j, r) \cdot [pq(i, r) - ai(i, j, r)]$	
$+ \sum_{v \in FAC} IF(v, j, r) \cdot [pf(v, j, r) - af(v, j, r) - ava(j, r)]$	$\forall j \in IND, r \in RGN$
(60) $pxa(j, r) = pps(j, r) + tia + ti(j, r)$	$\forall j \in IND, r \in RGN$
(61) $pu(i, r, "local") = pp(i, r, "local") + tca + tc(i, r)$	$\forall i \in COM, r \in RGN$
(62) $pu(i, r, "import") = pmmr(i, r) + tca + tc(i, r)$	$\forall i \in COM, r \in RGN$
(63) $pmm(i) = pm(i) + tm(i) + tma + phi$	$\forall i \in COM$
(64) $pmmr(i, r) = pmm(i) + tmtr(i, r)$	$\forall i \in COM, r \in RGN$
(65) $pu(i, r, "pool") = por(i, r) + totr(i, r) + tca + tc(i, r)$	$\forall i \in COM, r \in RGN$
(66) $pp(i, r, "world") = ppex(i) - tetrp(i, r)$	$\forall i \in COM, r \in RGN$
(67) $ppex(i) = pe(i, "chn") - tx(i) + phi$	$\forall i \in COM$
(68) $pfs(v, j, r) = pf(v, j, r) + tf(v, j, r)$	$\forall v \in FAC1, j \in IND, r \in RGN$
(69) $pl("agri", r) = plu("agri", r) + tfl("agri", r)$	$\forall r \in RGN$
(70) $pl("nagr", r) = plu("rural", r) + tfl("rural", r)$	$\forall r \in RGN$
(71) $pl("migrant", r) = plms + tfl("migrant", r)$	$\forall r \in RGN$
(72) $pl("urban", r) = plu("urban", r) + tfl("urban", r)$	$\forall r \in RGN$
(73) $tm(i) = TARIFF(i) / [100 + TARIFF(i)] \cdot tm_r(i)$	$\forall i \in COM$
(74) $ti(j, r) = TAX_IND(j, r) / [100 + TAX_IND(j, r)] \cdot ti_r(j, r)$	$\forall j \in IND, r \in RGN$
Coefficients:	
$INTER(i, j, r) = PQ(i, r) \cdot Ql(i, j, r)$	$\forall i \in COM, j \in IND, r \in RGN$
$TARIFF(i)$:tariff rate	$\forall i \in COM$
$TAX_IND(j, r)$:indirect tax rate	$\forall j \in IND, r \in RGN$

Table 27. Sectoral classification in the model

Sectors in the model	Code*	Sectors in the model	Code*
Agriculture			
01. Wheat	001	08. Vegetables and fruits	001
02. Paddy rice	001	09. Other crops	001
03. Corn	001	10. Forestry	002
04. Pulses	001	11. Livestock and livestock products	003
05. Other grains	001	12. Fishery	004
06. Cotton	001	13. Other agricultural products	005
07. Oilseeds	001		
Industry and construction			
14. Coal mining and processing	006	27. Metal products	061
15. Crude petroleum and natural gas products	007, 008	28. Machinery and equipment	062–066
16. Metal ore mining	009, 010	29. Transport equipment	067–072
17. Non-metal mineral mining	011–013	30. Electric equipment and machinery	073–075
18. Manufacture of food products and tobacco processing	014–021	31. Electronic and telecommunication equipment	076–079
19. Textile goods	022–027	32. Instruments, meters, cultural and office machinery	080, 081
20. Wearing apparel, leather, furs, down and related products	028, 029	33. Maintenance and repair of machine and equipment	082
21. Sawmills and furniture	030, 031	34. Other manufacturing products	083, 084
22. Paper and products, printing and record media reproduction	032–035	35. Scrap and waste	085
23. Petroleum processing and coking	036, 037	36. Electricity, steam and hot water production and supply	086, 087
24. Chemicals	038–047	37. Gas production and supply	088
25. Non-metal mineral products	048–054	38. Water production and supply	089
26. Metals smelting and pressing	055–060	39. Construction	090
Services			
40. Transport and warehousing	091–097	48. Health services, sports and social welfare	115–117
41. Post and telecommunications	098, 099	49. Education, culture and arts, radio, film and television	118–119
42. Wholesale and retail trade	100	50. Scientific research	120
43. Eating and drinking places	101	51. General technical services	121–123
44. Passenger transport	102–105	52. Public administration and other sectors	124
45. Finance and insurance	106, 107		
46. Real estate	108		
47. Social services	109–114		

* The 124–sector code in 1997 input–output table (National Accounts Department 1999).

Table 28. Definitions of variables

Variable	Argument	Definitions
absp(r)	$r \in \text{ERGN}$	Real aggregate final absorption in region r
abspi(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Real final absorption of good i in region r
af(v,j,r)	$v \in \text{FAC}, j \in \text{IND}, r \in \text{ERGN}$	Factor-augmenting technical change
ai(i,j,r)	$i \in \text{COM}, j \in \text{IND}, r \in \text{ERGN}$	Input-augmenting technical change
ao(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Output-augmenting technical change
ao_avg(r)	$r \in \text{ERGN}$	Sector-generic value added-augmenting technical change
ao1(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Output-augmenting technical change in industry j
ava(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Value added-augmenting technical change in industry j
bgtslack(h,r)	$h \in \text{HHG}, r \in \text{ERGN}$	Household income slacks
bt		Ratio of EXPORTS to IMPORTS
cbgtslack		Central government budget constraint
cd(i,r,d)	$i \in \text{COM}, r \in \text{ERGN}, d \in \text{DST}$	Supply of good i in region r for destination d
cdo(i)	$i \in \text{COM}$	Aggregate supply of domestic good used by other regions
cgovrev		Hypothetical central government revenue (tariff and export tax revenues only)
com(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Regional output of commodity i
comi(i,j,r)	$i \in \text{COM}, j \in \text{IND}, r \in \text{ERGN}$	Output of commodity i by industry j in region r
conr(r)	$r \in \text{ERGN}$	Regional aggregate (private household and government) consumption
cpi(h,r)	$h \in \text{HHG}, r \in \text{ERGN}$	Consumer price indexes for private household and government in region r
cpia(r)	$h \in \text{HHG}, r \in \text{ERGN}$	Aggregate consumer price in region r
DelBOT		Change in balance of trade (million yuan)
EV(h,r)	$h \in \text{HHG}, r \in \text{ERGN}$	Equivalent variation (million yuan)
EV_AGG(r)	$r \in \text{ERGN}$	Aggregate equivalent variation (million yuan)
gdpr(r)	$r \in \text{ERGN}$	Regional real GDP – expenditure side
gdpv(r)	$r \in \text{ERGN}$	Regional nominal GDP – expenditure side
gov_gdp(r)	$r \in \text{ERGN}$	Ratio of government revenues to GDP
govconv(r)	$r \in \text{ERGN}$	Nominal government consumption
govrev(r)	$r \in \text{ERGN}$	Regional government revenues
hhdconr(h,r)	$h \in \text{HHD}, r \in \text{ERGN}$	Real household consumption
ip(r)	$r \in \text{ERGN}$	Price of investment goods
ir(r)	$r \in \text{ERGN}$	Aggregate real investment
iv(r)	$r \in \text{ERGN}$	Aggregate nominal investment
out(l,r)	$l \in \text{LU2}, r \in \text{ERGN}$	Regional output by sector
pas(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Price of land supply
pe(i,d)	$i \in \text{COM}, d \in \text{WRD}$	Foreign currency price of exports
pf(v,j,r)	$v \in \text{FAC}, j \in \text{IND}, r \in \text{ERGN}$	Unit return to primary factors
pfa(v,r)	$v \in \text{FAC}, r \in \text{ERGN}$	Price of aggregate primary factors
p(l,j,r)	$l \in \text{LS1}, j \in \text{NAG}, r \in \text{ERGN}$	Demand price for different types of labour
pfs(v,j,r)	$v \in \text{FAC1}, j \in \text{IND}, r \in \text{ERGN}$	Supply prices of primary factors
pgdp(r)	$r \in \text{ERGN}$	Regional GDP deflator
phi		Exchange rate
pk		Price for capital

Table 28. (cont'd) Definitions of variables

Variable	Argument	Definitions
pl(l,r)	$l \in LU0, r \in \text{ERGN}$	Supply price of different types of labour
plr(l,r)	$l \in LU2, r \in \text{ERGN}$	Real wages
plms		National supply price of migrant labour
plr(r)	$r \in \text{ERGN}$	Aggregate price of labour supplied by rural sector
plu(l,r)	$l \in LS0, r \in \text{ERGN}$	Demand price of labour
pm(i)	$i \in \text{COM}$	Foreign currency prices of imports
pmm(i)	$i \in \text{COM}$	Market prices of imports in national pool
pmmr(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Regional market prices of imports
po(i)	$i \in \text{COM}$	Price of aggregate supply of goods to be used by other regions in pool
pop(h,r)	$h \in \text{HHG}, r \in \text{ERGN}$	Population
por(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Regional producer price of goods to be supplied to other regions
pp(i,r,d)	$i \in \text{COM}, r \in \text{ERGN}, d \in \text{DST}$	Producer price
ppex(i)	$i \in \text{COM}$	Aggregate producer price of exports
pps(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Producer price by industry excluding tax
pq(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Price for absorption
protslack(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Zero profit slack
pu(i,r,s)	$i \in \text{COM}, r \in \text{ERGN}, s \in \text{SRC0}$	User price
pvad(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Price of value added by industry
px(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Aggregate producer price of good
pxa(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Producer price by industry including tax
pxs(i,j,r)	$i \in \text{COM}, j \in \text{IND}, r \in \text{ERGN}$	Producer price by goods and industry
q(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Total absorption of good i in region r
q1(i,j,r)	$i \in \text{COM}, j \in \text{IND}, r \in \text{ERGN}$	Intermediate demand for i by j in r
q2(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Fixed investment demand for i in r
q3(i,h,r)	$i \in \text{COM}, h \in \text{HHD}, r \in \text{ERGN}$	Household demand for i by h in r
q4(i,d)	$i \in \text{COM}, d \in \text{WLD}$	Export demand for i from d
q5(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Government demand for i in r
qas(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Total supply of land in region r
qash(j,h,r)	$j \in \text{IND}, h \in \text{HHD}, r \in \text{ERGN}$	Supply of land by households in region r
qex		National export volume
qex_agg(j,r)	$j \in \text{IND_AGG}, r \in \text{ERGN}$	Aggregated exports
qf(v,j,r)	$v \in \text{FAC}, j \in \text{IND}, r \in \text{ERGN}$	Demand for primary factor v by industry j in region r
qfah(v,h,r)	$v \in \text{FAC}, h \in \text{HHD}, r \in \text{ERGN}$	Supply of aggregate primary factors by household
qfh(v,j,h,r)	$v \in \text{FAC}, j \in \text{IND}, h \in \text{HHD}$	Factor demand by industry and households
qim		National import volume
qim_agg(j,r)	$j \in \text{IND_AGG}, r \in \text{ERGN}$	Aggregated imports
qk		Total supply of capital
ql(l,r)	$l \in LS0, r \in \text{ERGN}$	Demand for labour type l by region r
qldr(l,j,r)	$l \in LS1, j \in \text{NAG}, r \in \text{ERGN}$	Demand for labour type l by industry j in region r
qlrh(l,r)	$l \in LU1, r \in \text{ERGN}$	Supply of labour type l by rural household h in region r
qlms		National total supply of migrant labour
qlmsr(r)	$r \in \text{ERGN}$	Regional supply of migrant labour
qlslack(l,h,r)	$l \in LU0, h \in \text{HHD}, r \in \text{ERGN}$	Labour supply slack

Table 28. (cont'd) Definitions of variables

Variable	Argument	Definitions
qms(i)	$i \in \text{COM}$	Total supply of import i from rest of world
qs(i,r,s)	$i \in \text{COM}, r \in \text{ERGN}, s \in \text{SRC0}$	Demand for good i in region r from source s
qva(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Demand for composite value added by industry j in region r
qw4(i)	$i \in \text{COM}$	Excess world demand for export i
rqex(r)	$r \in \text{ERGN}$	Regional export volume
rqim(r)	$r \in \text{ERGN}$	Regional import volume
rvex(r)	$r \in \text{ERGN}$	Regional export value
rvim(r)	$r \in \text{ERGN}$	Regional import value
save(h,r)	$h \in \text{HHG}, r \in \text{ERGN}$	Household and government saving
Save_p(h,r)	$h \in \text{HHG}, r \in \text{ERGN}$	Household propensity to save
tabsp		National real aggregate final absorption
tabspi(i)	$i \in \text{COM}$	National real final absorption of commodities
tc(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Power of commodity tax
tca		Economy wide power of commodity taxes
tconr		National aggregate consumption
tcpi(h)	$h \in \text{HHG}$	National consumer price index
tcpia		National aggregate consumer price index
tetrp(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Power of transportation cost
tf(v,j,r)	$v \in \text{FAC}, j \in \text{IND}, r \in \text{ERGN}$	Power of factor tax
t(l,r)	$l \in \text{LS0}, r \in \text{ERGN}$	Tax on labour supply
tgdpr		National real GDP
tgdpv		National nominal GDP
tgovconv		National nominal government consumption
thhdconr(h)	$h \in \text{HHD}$	National real household consumption
ti(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Power of indirect tax
ti_r(j,r)	$j \in \text{IND}, r \in \text{ERGN}$	Ad valorem rate of indirect tax
tia		Economy wide power of indirect taxes
tm(i)	$i \in \text{COM}$	Power of tariff
tm_r(i)	$i \in \text{COM}$	Ad valorem rate of tariff
tma		Economy wide power of tariff
tmtr(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Power of transport cost moving import i from port to region r
tot		Terms of trade
totr(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Power of transport cost from pool to regions
totrp(i,r)	$i \in \text{COM}, r \in \text{ERGN}$	Power of transport cost from regions to pool
tout(l)	$l \in \text{LU2}$	National output by sector
tpgdp		National GDP deflator
txex_agg(j)	$j \in \text{IND_AGG}$	Aggregated exports
txim_agg(j)	$j \in \text{IND_AGG}$	Aggregated imports
transf_c(r)	$r \in \text{ERGN}$	Central government transfer to regional government
transf_r(h,r)	$h \in \text{HHD}, r \in \text{ERGN}$	Regional government transfer to households
tsave(r)	$r \in \text{ERGN}$	Total savings
tx(i)	$i \in \text{COM}$	Power of export tax
tx_agg(j)	$j \in \text{IND_AGG}$	Aggregated industrial output
ty(h,r)	$h \in \text{HHD}, r \in \text{ERGN}$	Power of household income tax

Table 28. (cont'd) Definitions of variables

Variable	Argument	Definitions
tya		Economy wide power of income taxes
u(h,r)	$h \in \text{HHG}, r \in \text{RGN}$	Total utility by household
uc(h,r)	$h \in \text{HHG}, r \in \text{RGN}$	Utility from consumption
vex		National export value
vim		National import value
x(j,r)	$j \in \text{IND}, r \in \text{RGN}$	Total output of industry j in region r
x_agg(j,r)	$j \in \text{IND_AGG}, r \in \text{RGN}$	Aggregated industrial output
y_c(h,r)	$h \in \text{HHD}, r \in \text{RGN}$	Household consumption expenditure
y_d(h,r)	$h \in \text{HHD}, r \in \text{RGN}$	Household incomes after tax
y_g(h,r)	$h \in \text{HHD}, r \in \text{RGN}$	Household incomes before tax
y_n(h,r)	$h \in \text{HHD}, r \in \text{RGN}$	Net household income (after income tax)

Table 29. Definitions of sets

Sector	Definition
AGR	Agricultural sectors
COM	Commodities, each corresponds to a sector as classified in Table 27.
DST	Destinations of sales: {"local", "pool", "world"}
FAC	Primary factors: {"land", "labour", "capital"}
FAC1	Primary factors: {"land", "capital"}
HHD	Private households: {"rural", "urban"}
HHG	Private households and government: {"rural", "urban", "gov"}
HHM	Private households and migrant: {"rural", "urban", "migrant"}
IND	Sectors classified in Table 27.
IND_AGG	Aggregate sectors for report purposes
INO	Sectors and "other"
LU0	Labour uses: {"agri", "nagr", "migrant", "urban"}
LU1	Rural labour uses: {"agri", "nagr", "migrant"}
LU2	Labour uses: {"agri", "nagr"}
LS0	Labour sources: {"agri", "rural", "urban", "migrant"}
LS1	Labour sources in non-agricultural sectors: {"rural", "urban", "migrant"}
NAG	Non-agricultural sectors
RGN	Provinces, autonomous regions and municipalities under central government in China
SRC	Sources of commodity supply: {"local", "pool", "import"}
SRC0	Sources of commodity supply: {"domestic", "import", "local", "pool"}
SRC1	Sources of commodity supply: {"domestic", "import"}
SRC2	Sources of commodity supply: {"local", "pool"}
WLD	China or rest of the world: {"chn", "row"}

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