Appendix A

Equation System of CWARMEM

1 supply

(1) Crop production

The crop area equation is expressed as

$$AL^{m}_{ic} = AL^{m}_{ic-n} \times \prod_{j}\left(ER^{m}_{j}\right)^{\beta_{ij}} \times (1+\alpha^{m}_{ic})/L \quad (2.1)$$

$$AL^{m}_{ic} = \quad (2.2)$$

where i is commodity indices specific for crops, j is commodity indices specific for all commodities, m is province, country or region index, t is time index, CN = {Chinese provinces}; NCN = {other countries and regions }, AL is crop area, ER is expected revenue per hectare, β is crop area revenue elasticity, α is exogenous adjustment parameter for crop area(including urbanization, policies and disasters), $Limax$ is the ratio of used arable land to maximized allowed cultivated land, $Limax$ is the ratio of used cultivated land to cultivated land at the lowest level arising from policy , P_s is crop producer price, σ is crop production price elasticity and γ is exogenous adjustment parameter for crop yield (including R&D expenditure, investment in water infrastructure and multiple cropping index).

The functional relationship for the expected revenue per hectare equation is

(2.3)

where YD is crop yield, Cs is cost per hectare and Sd is direct subsidies for producer.

The functional form of the cost per hectare equation is as follows

(2.4)

where f is inputs, P_f is price of inputs, SI is index of agricultural subsidies, χ is exogenous adjustment parameter for cost, k is cost price elasticity and ρ is cost subsidy elasticity.

Water demand is calculated as

(2.6)

where WT is water demand and wr is water demand coefficient for each crop per hectare.

Agricultural water is constrained by maximum allowed water. This relationship is

(2.7)

where $WTmax$ is the ratio of used water to maximized allowed water, WT^{m}_{a} is agricultural water used and $AWmax$ is maximum allowed water.

Crop area reduction due to water shortage is determined by the identity

(2.8)

where ΔAW is crop area reduction due to water shortage.

Crop production is estimated as the product of its area and yield. The formula can be expressed as follows:

$$QS^{n}_{tc} = AH^{n}_{tc} \times YD^{n}_{tc} = (AL^{n}_{tc} - \Delta AW^{n}_{tc}) \times YD^{n}_{t(t-1)} \times \prod_{i} \left(P^{n}_{i,t(t-1)}\right)^{\varepsilon_{ij}} \times \prod_{j} \left(P^{n}_{j,t}\right)^{\varepsilon_{ij}} \times (1 + \gamma^{n}_{t}$$

(2.5)

where QS is crop production, AH is area harvested and $\emptyset$ is input price elasticity.

China's cultivated land, constrained by the policy and maximized allowed cultivated land, can be expressed as follows

$$Limax^{t}_{c}$$

(2.9)

$$Lim$$

(2.10)

where MI is multiple cropping index, $AHmax$ is maximized allowed cultivated land and $AHmi\,n$ is cultivated land at the lowest level arising from policy.

(2) Byproduct Production

The functional form of byproduct quantity produced equation is

(2.11)

where QS is byproduct quantity produced, i is commodity indices specific for byproduct, j is products which produce byproduct and tr is conversion ratio.

(3) Livestock Production

The identity for livestock production is

(2.12)

where QS is livestock production, i is commodity indices specific for livestock product, δ is exogenous feeding adjustment parameter (such as urbanization and incidence of livestock disease).

2 Demand

(1) Food Demand

We divide total population into two types: urban residents and rural residents. Different kinds of residents correspond to different income level and diet patterns. Hence, food demand is specified as per capita, income, commodity price and total population. The food demand is given by the identity

$$QF^{n}_{tc} = \sum_{r} QP^{n}_{tcr} \times POP^{n}_{r,t} = \sum_{r} \left[QP^{n}_{r,t(t-1)} \times \prod \left(P^{n}_{i,t}\right)^{\varepsilon_{ij}} \times \left(iNC^{n}_{i}\right.\right.$$

(2.13)

where r is household registration(rural residents, urban residents), QF is food demand, i is commodity indices specific for all commodities, QP is per capita food demand, POP is total population, P_i is consumer price, ε is price or cross price elasticity of food demand, INC is per capita income and η is income food demand elasticities.

(2) Feed Demand

Feed demand[1] is specified as a function of livestock production, feed prices and feed conversion ratio as follows

(2.14)

where QL is feed demand, QS is livestock production, l is commodity indices specific for livestock, f is feed conversion ratio and i,j is commodity indices specific for feed crops(wheat, corn, rice, roots and tubers and other coarse grains).

(3) Seed Demand

The functional form of seed demand equation is

(2.15)

where i is commodity indices specific for crops, QS is seed demand and s_{ti} is seed demand per hectare.

(4) Industrial Demand

Industrial demand is specified as a function of industrial demand and growth rate of food processing sector as follows

(2.16)

where i is commodity indices specific for all commodities, QI is industrial demand, R_I is annual growth rate of food processing sector.

(5) Other Demand

Other demand is the wastage in the processing of production, transport, storage and process. The general specification of other demand is

(2.17)

where i is commodity indices specific for all commodities, QR is other demand and R_o is annual growth rate of other commodity demand.

Total demand is specified as the summation of the components food, feed, industrial, seed and

[1] Since feed consumption of fishery production is generally small and there is no access to these data, CWARMEM model only calculate the feed demand for livestock products (beef, milk, pork, poultry, eggs, sheep and goat).

other demand as follows

(2.18)

Total demand of byproduct is determined by byproduct's feed demand. The general specification of total demand of byproduct is

(2.19)

where i,j is commodity indices specific for byproduct (byproducts of soybeans, cotton seeds, and rapeseeds).

3 Prices and trade

(1) Prices

Prices are endogenous in the system of equations for commodities. World prices are a function of domestic prices, adjusted by domestic subsidies and taxes. Producer and consumer price are specified as follows respectively

$$P^{s}_{c,it} = P_{w,it} \times ER^{s}_{c} \times (1-$$

(2.20)

$$P^{d}_{c,it} = P_{w,it} \times ER^{d}_{c} \times (1+$$

(2.21)

where P_s is producer prices (in terms of domestic currency), P_d is consumer prices (in terms of domestic currency), P_w is world price (in dollar terms), ER is exchange rate (national currency per dollar), TC is the marketing margin, TX is export tax, TM is import tax, PSE is producer subsidy equivalent and CSE is consumer subsidy equivalent.

(2) Trade

The international linkage for sub-models is trade. Commodity trade by country/region is the difference between domestic production and demand. The objective of the model is to minimize the sum of net trade at the international level and seeks world price for a commodity that satisfies the market-clearing condition expressed as follows

(2.22)

where QT is volume of trade.