SUPPLEMENTARY INFORMATION

The asymmetric impacts of feeding China's monogastric livestock with food waste on food security and environment sustainability

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Contents

Mathematically, various ways exist to represent applied general equilibrium (AGE) models, according to Ginsburgh and Keyzer [1]. To identify the optimal solution towards greater sustainability and enable the efficient allocation of resources in the economy, we used the welfare format of the AGE models for our analysis. In the supplementary information, we specified the model for our study by explicitly considering producers, consumers, production goods, consumption goods, and intermediate goods. Subsequently, we presented the calibration of our model. Finally, we provided supplementary figures and tables, along with the sectoral aggregation scheme, social accounting matrices, and emissions data for all the regions in our study.

Supplementary Methods

Objective function

The objective function "social welfare (W)" is the weighted sum of the log utility (U_i) of all consumers, according to Zhu and Van Ierland [2].

$$\mathrm{W} = \max \textstyle\sum_i \alpha_i \log U_i \tag{1}$$

where α_i is the Negishi weight of the representative consumer in each region i (i=China and its main food and feed trading partners (MTP, including Brazil, United States, and Canada)).

Utility function

In our model, the consumer's utility depends on the consumption of rival goods. The utility function is a Cobb-Douglas (C-D) function describing the behaviour of a representative consumer (household to maximise its utility subject to budget constraints) consuming rival goods. The utility function of the consumer in region i is written as:

$$U_i = \textstyle\prod_s C_{i,s}^{\beta_{i,s}} \tag{2}$$

where consumption goods s refers to cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, sugar crops, other non-food crops, monogastric livestock, ruminant livestock, other food, fish, and non-food. $C_{i,s}$ is the consumption of the rival good in region i. $\beta_{i,s}$ is the elasticity of utility concerning the consumption of rival good s in region i, i.e., the expenditure share of consumption good s in consumption of rival goods in region i, and $\sum_s \beta_{i,s} = 1$.

Production function

We present the production functions of seventeen producers, namely, cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, sugar crops, other non-food crops, monogastric livestock, ruminant livestock, compound feed, cereal brans, alcoholic pulps, oil cakes, other food, nitrogen fertiliser, phosphorus fertiliser, fish, and non-food.

The production function of producer j in region i is specified as:

$$Y_{i,j} = A_{i,j}[(KL_{i,j})^{\eta_{1i,j}}(LB_{i,j})^{\eta_{2i,j}}(LD1_{i,j})^{\eta_{3i,j}}(LD2_{i,j})^{\eta_{4i,j}}(NFE_{i,j})^{\eta_{5i,,j}}(PFE_{i,j})^{\eta_{6i,j}}$$

$$(CER_{i,j})^{\eta_{7i,j}}(OSD_{i,j})^{\eta_{8i,j}}(VF_{i,j})^{\eta_{9i,j}}(RT_{i,j})^{\eta_{10i,j}}(SGR_{i,j})^{\eta_{11i,j}}(OTC_{i,j})^{\eta_{12i,j}}$$

$$(COF_{i,j})^{\eta_{13i,j}}(BRAN_{i,j})^{\eta_{14i,j}}(PULP_{i,j})^{\eta_{15i,j}}(CAKE_{i,j})^{\eta_{16i,j}}]^{1-\xi_{i,j}}$$

$$[(CERW_{i,j})^{\delta_{1i,j}}(OSDW_{i,j})^{\delta_{2i,j}}(VFW_{i,j})^{\delta_{3i,j}}(RTW_{i,j})^{\delta_{4i,j}}$$

$$(BRANW_{i,j})^{\delta_{5i,j}}(PULPW_{i,j})^{\delta_{6i,j}}(CAKEW_{i,j})^{\delta_{7i,j}}]^{\xi_{i,j}} \quad (3)$$

where $Y_{i,j}$ is the production of sector j in region i. $A_{i,j}$ is the technological parameter of the production of sector j in region i. $KL_{i,j}$, $LB_{i,j}$, $LD1_{i,j}$ and $LD2_{i,j}$ are capital, labour, cropland, and pasture land inputs for production j in region i, respectively. $NFE_{i,j}$, $PFE_{i,j}$, $CER_{i,j}$, $OSD_{i,j}$, $VF_{i,j}$, $RT_{i,j}$, $SGR_{i,j}$, $OTC_{i,j}$, $COF_{i,j}$, $BRAN_{i,j}$, $PULP_{i,j}$, and $CAKE_{i,j}$ are nitrogen fertiliser, phosphorus fertiliser, cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, sugar crops, other non-food crops, compound feed, cereal bran, alcoholic pulp, and oil cake inputs for the production of sector j in region i, respectively. $CERW_{i,j}$, $OSDW_{i,j}$, $VFW_{i,j}$, $RTW_{i,j}$, $BRANW_{i,j}$, $PULPW_{i,j}$, and $CAKEW_{i,j}$ are food waste (i.e., cereal grains waste, oilseeds & pulses waste, vegetables & fruits waste, roots & tubers waste, cereal bran waste, alcoholic pup waste, and oil cake waste) recycling service as feed input for the production of sector j in region i, respectively. $\xi_{i,j}$ ($0<\xi_{i,j}<1$) is the cost share of food waste for the production of sector j in region i. η_f (f=1, 2, 3, …, 16) is the cost share of each factor and intermediate input for production, and $\sum_{f=1}^{16} \eta_f = 1$. δ_f (f=1, 2, 3, …, 7) is the cost share of each food waste input for production, and $\sum_{f=1}^{7} \delta_f = 1$.

When emissions are outputs of the production process, the emissions intensities of greenhouse gases (GHGs) ($\varepsilon_{gg,i,j}$, kg CO_2 equivalent USD^{-1}), acidification pollutants ($\varepsilon_{ga,i,j}$, kg NH_3 equivalent USD^{-1}), and eutrophication pollutants (EP, $\varepsilon_{ge,i,j}$, kg N equivalent USD^{-1}) from producer j in region i are calculated as:

$$\varepsilon_{gg,i,j} = \frac{EM^{+0}_{gg,i,j}}{Y^0_{i,j}} \quad (4)$$

$$\varepsilon_{ga,i,j} = \frac{EM^{+0}_{ga,i,j}}{Y^0_{i,j}} \quad (5)$$

$$\varepsilon_{ge,i,j} = \frac{EM^{+0}_{ge,i,j}}{Y^0_{i,j}} \quad (6)$$

where $EM^{+0}_{gg,i,j}$ is the emissions of GHGs gg (gg=CO_2, CH_4, and N_2O emissions) from producer j in region i in the base run. $EM^{+0}_{ga,i,j}$ is the emissions of acidification pollutants ga (ga=NH_3, NO_x, and SO_2 emissions) from producer j in region i in the base run. $EM^{+0}_{ge,i,j}$ is the emissions of eutrophication pollutants ge (ge= N and P losses) from producer j in region i in the base run. $Y^0_{i,j}$ is the production of producer j in region i in the base run.

Next, the emissions in different scenarios are calculated by multiplying the current production level by corresponding emission intensities. The total emissions of GHGs, acidification and eutrophication pollutants from all producers in region i are calculated as follows:

$$EMG^{+}_{i,j} = \sum_{gg} \varepsilon_{gg,i,j} * Y_{i,j} * Eqv_{gg}$$

for emissions of GHGs gg = CO_2, CH_4, and N_2O emissions

(7)

$$EMA^{+}_{i,j} = \sum_{ga} \varepsilon_{ga,i,j} * Y_{i,j} * Eqv_{ga}$$

for emissions of acidification pollutants ga = NH_3, NO_x, and SO_2 emissions

(8)

$$EME_{i,j}^{+} = \sum_{ge} \varepsilon_{ge,i,j} * Y_{i,j} * Eqv_{ge}$$

for emissions of eutrophication pollutants ge = N and P losses

(9)

where $EMG_{i,j}^{+}$, $EMA_{i,j}^{+}$, and $EME_{i,j}^{+}$ are the total emissions of GHGs, acidification and eutrophication pollutants from producer j in region i, respectively. Eqv_{gg}, Eqv_{ga}, and Eqv_{ge} are the GWP, AP, and EP equivalent factors based on Goedkoop, et al. [3].

Balance equations

In our applied model, we consider factor inputs (i.e., capital, labour, and land) to be mobile between different sectors but immobile between China and MTP. Cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops are used for direct consumption and intermediate use for monogastric livestock, ruminant livestock, compound feed, by-products (i.e., cereal bran, alcoholic pulp, and oil cake), and other food production. By-products (i.e., cereal bran, alcoholic pulp, and oil cake) and compound feed are produced for intermediate use for monogastric livestock and ruminant livestock production. Monogastric livestock, ruminant livestock, fish, other food, and non-food are used for direct consumption. Nitrogen fertiliser and phosphorus fertiliser are used for cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops production but not for consumption. We note C for consumption, XNET for net export (exports minus imports), and Y for production. Variables with a bar stand for exogenous ones.

The balance equations for cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops in region i are as follows:

$$C_{i,cer} + CER_{i,oap} + CER_{i,ctl} + CER_{i,cof} + CER_{i,bran} + CER_{i,pulp} + CER_{i,otf} + XNET_{i,cer} \leq Y_{i,cer} \qquad (p_{i,cer})$$

(10)

$$C_{i,osd} + OSD_{i,oap} + OSD_{i,ctl} + OSD_{i,cof} + OSD_{i,cake} + OSD_{i,otf} + XNET_{i,osd} \leq Y_{i,osd} \qquad (p_{i,osd})$$

(11)

$$C_{i,vf} + VF_{i,oap} + VF_{i,ctl} + VF_{i,cof} + VF_{i,otf} + XNET_{i,vf} \leq Y_{i,vf} \qquad (p_{i,vf})$$

(12)

$$C_{i,rt} + RT_{i,oap} + RT_{i,ctl} + RT_{i,cof} + RT_{i,otf} + XNET_{i,rt} \leq Y_{i,rt} \qquad (p_{i,rt})$$

(13)

$$C_{i,sgr} + SGR_{i,oap} + SGR_{i,ctl} + SGR_{i,cof} + SGR_{i,otf} + XNET_{i,sgr} \leq Y_{i,sgr} \qquad (p_{i,sgr})$$

(14)

$$C_{i,ocr} + OCR_{i,oap} + OCR_{i,ctl} + OCR_{i,cof} + OCR_{i,otf} + XNET_{i,vf} \leq Y_{i,ocr} \qquad (p_{i,ocr})$$

(15)

where $CER_{i,oap}$, $CER_{i,ctl}$, $CER_{i,cof}$, $CER_{i,bran}$, $CER_{i,pulp}$, and $CER_{i,otf}$ are cereals used for monogastric livestock, ruminant livestock, compound feed, cereal bran, alcoholic pulp, and other food production in region i, respectively. $OSD_{i,oap}$, $OSD_{i,ctl}$, $OSD_{i,cof}$, $OSD_{i,bran}$, and $OSD_{i,otf}$ are cereals used for monogastric livestock, ruminant livestock, compound feed, oil cake, and other food production in region i, respectively. $VF_{i,oap}$, $VF_{i,ctl}$, $VF_{i,cof}$, and $VF_{i,otf}$ are vegetables & fruits used for monogastric livestock, ruminant livestock, compound feed, and other food production in region i, respectively. $RT_{i,oap}$, $RT_{i,ctl}$, $RT_{i,cof}$, and $RT_{i,otf}$ are roots & tubers used for monogastric livestock, ruminant livestock, compound feed, and other food production in region i, respectively. $SGR_{i,oap}$, $SGR_{i,ctl}$, $SGR_{i,cof}$, and $SGR_{i,otf}$ are sugar crops used for monogastric livestock, ruminant livestock, compound feed, and other food production in region i, respectively. $OCR_{i,oap}$, $OCR_{i,ctl}$, $OTC_{i,cof}$, and $OTC_{i,otf}$ are other non-food crops used for monogastric livestock, ruminant livestock, compound feed, and other food production in region i, respectively. $p_{i,cer}$, $p_{i,osd}$, $p_{i,vf}$, $p_{i,rt}$, $p_{i,sgr}$, and $p_{i,ocr}$ are the shadow prices of cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops in region i, respectively.

The balance equation for by-products (i.e., cereal bran, alcoholic pulp, and oil cake) in region i is as follows:

$$BRAN_{i,oap} + XNET_{i,bran} \leq Y_{i,bran} \qquad (p_{i,bran}) \tag{16}$$

$$PULP_{i,oap} + XNET_{i,pulp} \leq Y_{i,pulp} \qquad (p_{i,pulp}) \tag{17}$$

$$CAKE_{i,oap} + XNET_{i,cake} \leq Y_{i,cake} \qquad (p_{i,cake}) \tag{18}$$

where $BRAN_{i,oap}$, $PULP_{i,oap}$, and $CAKE_{i,oap}$ are cereal bran, alcoholic pulp, and oil cake used for monogastric livestock production in region i, respectively. $p_{i,bran}$, $p_{i,pulp}$, and $p_{i,cake}$ are the shadow prices of cereal bran, alcoholic pulp, and oil cake in region i.

The balance equation for compound feed in region i is as follows:

$$COF_{i,oap} + COF_{i,ctl} + XNET_{i,cof} \leq Y_{i,cof} \qquad (p_{i,cof}) \tag{19}$$

where $COF_{i,oap}$ and $COF_{i,ctl}$ are compound feed used in monogastric livestock and ruminant livestock production in region i, respectively. $p_{i,cof}$ is the shadow price of compound feed in region i.

The balance equation for monogastric livestock, ruminant livestock, fish, other food, and non-food in region i is as follows:

$$C_{i,j} + XNET_{i,j} \leq Y_{i,j} \qquad (p_{i,j}) \tag{20}$$

where $p_{i,j}$ is the shadow price of good j in region i.

The balance equation for nitrogen and phosphorus fertiliser in region i is as follows:

$$NFE_{i,cer} + NFE_{i,osd} + NFE_{i,vf} + NFE_{i,rt} + NFE_{i,sgr} + NFE_{i,ocr} + XNET_{i,nfe} \leq Y_{i,nfe} \qquad (p_{i,nfe}) \tag{21}$$

$$PFE_{i,cer} + PFE_{i,osd} + PFE_{i,vf} + PFE_{i,rt} + PFE_{i,sgr} + PFE_{i,ocr} + XNET_{i,pfe} \leq Y_{i,pfe} \qquad (p_{i,pfe}) \tag{22}$$

where $NFE_{i,cer}$, $NFE_{i,osd}$, $NFE_{i,vf}$, $NFE_{i,rt}$, $NFE_{i,sgr}$ and $NFE_{i,ocr}$ are the nitrogen fertiliser used for cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops production in region i, respectively. $PFE_{i,cer}$, $PFE_{i,osd}$, $PFE_{i,vf}$, $PFE_{i,rt}$, $PFE_{i,sgr}$ and

$PFE_{i,ocr}$ are the phosphorus fertiliser used for cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops production in region i, respectively. $p_{i,nfe}$ and $p_{i,pfe}$ are the shadow prices of nitrogen fertiliser and phosphorus fertiliser in region i, respectively.

For trade balance of all goods:

$$\sum_i XNET_{i,j} = 0 \qquad (p_j) \tag{23}$$

In the applied model, we assume that factor endowments (i.e., capital, labour, cropland, and pasture land) are mobile between different sectors but immobile among the two regions. For the balance equations of production factor inputs:

$$\sum_j KL_{i,j} \leq \overline{KL_i} \qquad (r_i) \tag{24}$$

$$\sum_j LB_{i,j} \leq \overline{LB_i} \qquad (w_i) \tag{25}$$

$$\sum_j LD1_{i,j} \leq \overline{LD1_i} \qquad (k1_i)$$

for sector j = cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops

(26)

$$\sum_j LD2_{i,j} \leq \overline{LD2_i} \qquad (k2_i)$$

for sector j = ruminant livestock

(27)

where $\overline{KL_i}$, $\overline{LB_i}$, $\overline{LD1_i}$ and $\overline{LD2_i}$ are the factor endowments (i.e., capital, labour, cropland, pasture land) supply in region i, respectively. r_i, w_i, $k1_i$, and $k2_i$ are the shadow prices of capital, labour, cropland, and pasture land in region i, respectively.

If an emission permit system is implemented to control the total emissions of GHGs, acidification and eutrophication pollutants from all producers, then the following relationship holds:

$$\sum_j EMG^+_{i,j} \leq \overline{TMG^+_i} \qquad (p_{eg,i}) \tag{28}$$

$$\sum_j EMA^+_{i,j} \leq \overline{TMA^+_i} \qquad (p_{ea,i}) \tag{29}$$

$$\sum_j EME^+_{i,j} \leq \overline{TME^+_i} \qquad (p_{ee,i}) \tag{30}$$

where TMG^+_i, TMA^+_i, and TME^+_i are the total emissions of GHGs, acidification and eutrophication pollutants from all producers in region i, respectively. $\overline{TMG^+_i}$, $\overline{TMA^+_i}$, and $\overline{TME^+_i}$ are the permitted level of the total emissions of GHGs, acidification and eutrophication pollutants in region i, respectively. Emissions should not be above a certain level for the regeneration of the environment. For benchmarking, the permitted emission level is the total emission level in the base year. For an environmental policy study, the permitted emission level can be an exogenous emission permit determined by the ecological limit. $p_{eg,i}$, $p_{ea,i}$, and $p_{ee,i}$ are the shadow prices of the emissions of GHGs, acidification and eutrophication pollutants in region i, respectively.

Monogastric livestock's total demand for food waste recycling service must be equal to or less than the total supply of food waste recycling service, then the following relationship holds:

$$CERW_{i,oap} \leq \overline{CERW_{i,oap}} \qquad (p_{i,cerw1}) \tag{31}$$

$$OSDW_{i,oap} \leq \overline{OSDW_{i,oap}} \qquad (p_{i,osdw1}) \tag{32}$$

$$VFW_{i,oap} \leq \overline{VFW_{i,oap}} \qquad (p_{i,vfw1}) \tag{33}$$

$$RTW_{i,oap} \leq \overline{RTW_{i,oap}} \qquad (p_{i,rtw1}) \tag{34}$$

$$BRANW_{i,oap} \leq \overline{BRANW_{i,oap}} \qquad (p_{i,branw1}) \tag{35}$$

$$PULPW_{i,oap} \leq \overline{PULPW_{i,oap}} \qquad (p_{i,pulpw1}) \tag{36}$$

$$CAKEW_{i,oap} \leq \overline{CAKEW_{i,oap}} \qquad (p_{i,cakew1}) \tag{37}$$

where $\overline{CERW_{i,oap}}$, $\overline{OSDW_{i,oap}}$, $\overline{VFW_{i,oap}}$, $\overline{RTW_{i,oap}}$, $\overline{BRANW_{i,oap}}$, $\overline{PULPW_{i,oap}}$, and $\overline{CAKEW_{i,oap}}$ are the total supply of food waste (i.e., cereal grains waste, oilseeds & pulses waste, vegetables & fruits waste, roots & tubers waste, cereal bran waste, alcoholic pup waste, and oil cake waste) recycling service. $p_{i,cerw1}$, $p_{i,osdw1}$, $p_{i,vfw1}$, $p_{i,rtw1}$, $p_{i,branw1}$, $p_{i,pulpw1}$, and $p_{i,cakew1}$ are the shadow prices of food waste (i.e., cereal grains waste, oilseeds & pulses waste, vegetables & fruits waste, roots & tubers waste, cereal bran waste, alcoholic pup waste, and oil cake waste) recycling service.

Consumer's total demand for food waste collection service must be equal to or less than the total supply of food waste collection service, then the following relationship holds:

$$C_{i,cerw} \leq \overline{C_{i,cerw}} \qquad (p_{i,cerw2}) \tag{38}$$

$$C_{i,osdw} \leq \overline{C_{i,osdw}} \qquad (p_{i,osdw2}) \tag{39}$$

$$C_{i,vfw} \leq \overline{C_{i,vfw}} \qquad (p_{i,vfw2}) \tag{40}$$

$$C_{i,rtw} \leq \overline{C_{i,rtw}} \qquad (p_{i,rtw2}) \tag{41}$$

$$C_{i,branw} \leq \overline{C_{i,branw}} \qquad (p_{i,branw2}) \tag{42}$$

$$C_{i,pulpw} \leq \overline{C_{i,pulpw}} \qquad (p_{i,pulpw2}) \tag{43}$$

$$C_{i,cakew} \leq \overline{C_{i,cakew}} \qquad (p_{i,cakew2}) \tag{44}$$

where $C_{i,cerw}$, $C_{i,osdw}$, $C_{i,vfw}$, $C_{i,rtw}$, $C_{i,branw}$, $C_{i,pulpw}$, and $C_{i,cakew}$ are the total supply of food waste (i.e., cereal grains waste, oilseeds & pulses waste, vegetables & fruits waste, roots & tubers waste, cereal bran waste, alcoholic pup waste, and oil cake waste) collection service. $p_{i,cerw2}$, $p_{i,osdw2}$, $p_{i,vfw2}$, $p_{i,rtw2}$, $p_{i,branw2}$, $p_{i,pulpw2}$, and $p_{i,cakew2}$ are the shadow prices of food waste (i.e., cereal grains waste, oilseeds & pulses waste, vegetables & fruits waste, roots & tubers waste, cereal bran waste, alcoholic pup waste, and oil cake waste) collection service.

Budget constraint

The budget constraint for a consumer i holds such that the expenditure must be equal to the income:

$$\sum_s(p_{i,s}C_{i,s}) + \sum_j(p_j XNET_{i,j}) + p_{i,cerw2}C_{i,cerw} + p_{i,osdw2}C_{i,osdw} + p_{i,vfw2}C_{i,vfw} + p_{i,rtw2}C_{i,rtw} + p_{i,branw2}C_{i,branw} + p_{i,pulpw2}C_{i,pulpw} + p_{i,cakew2}C_{i,cakew} = h_i \tag{45}$$

where consumption goods s refers to cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, sugar crops, other non-food crops, monogastric livestock, ruminant livestock, other food, fish, and non-food. $\sum_s(p_{i,s}C_{i,s})$ is the total expenditure on the consumption goods in region i. $p_{i,cerw2}C_{i,cerw}$, $p_{i,osdw2}C_{i,osdw}$, $p_{i,vfw2}C_{i,vfw}$, $p_{i,rtw2}C_{i,rtw}$, $p_{i,branw2}C_{i,branw}$, $p_{i,pulpw2}C_{i,pulpw}$, and $p_{i,cakew2}C_{i,cakew}$ are the payments to the food waste (i.e., cereal grains waste, oilseeds & pulses waste, vegetables & fruits waste, roots & tubers waste, cereal bran waste, alcoholic pup waste, and oil cake waste) collection service in region i. The Negishi weight (α_i) in the welfare function (equation 1) will be chosen such that the budget constraints hold for each representative consumer in region i.

Consumer's income is the sum of the remuneration of initial endowments employed in production and payments to the food waste collection service sector. Since goods are tradable, the consumer's income should exclude the export part. Thus, the consumer's income is:

$$h_i = r_i\overline{KL_i} + w_i\overline{LB_i} + k1_i\overline{LD1_i} + k2_i\overline{LD2_i} - \sum_j(p_jXNET_{i,j}) + p_{i,cerw1}CERW_{i,oap} + p_{i,osdw1}OSDW_{i,oap} + p_{i,vfw1}VFW_{i,oap} + p_{i,rtw1}RTW_{i,oap} + p_{i,branw1}BRANW_{i,oap} + p_{i,pulpw1}PULPW_{i,oap} + p_{i,cakew1}CAKEW_{i,oap} + p_{i,cerw2}C_{i,cerw} + p_{i,osdw2}C_{i,osdw} + p_{i,vfw2}C_{i,vfw} + p_{i,rtw2}C_{i,rtw} + p_{i,branw2}C_{i,branw} + p_{i,pulpw2}C_{i,pulpw} + p_{i,cakew2}C_{i,cakew} \quad (46)$$

where $\sum_j(p_jXNET_{i,j})$ is the income from exports. $p_{i,cerw1}CERW_{i,oap}$, $p_{i,osdw1}OSDW_{i,oap}$, $p_{i,vfw1}VFW_{i,oap}$, $p_{i,rtw1}RTW_{i,oap}$, $p_{i,branw1}BRANW_{i,oap}$, $p_{i,pulpw1}PULPW_{i,oap}$, and $p_{i,cakew1}CAKEW_{i,oap}$ are the income from food waste recycling service in region i. $p_{i,cerw2}C_{i,cerw}$, $p_{i,osdw2}C_{i,osdw}$, $p_{i,vfw2}C_{i,vfw}$, $p_{i,rtw2}C_{i,rtw}$, $p_{i,branw2}C_{i,branw}$, $p_{i,pulpw2}C_{i,pulpw}$, and $p_{i,cakew2}C_{i,cakew}$ are the income from food waste collection service in region i.

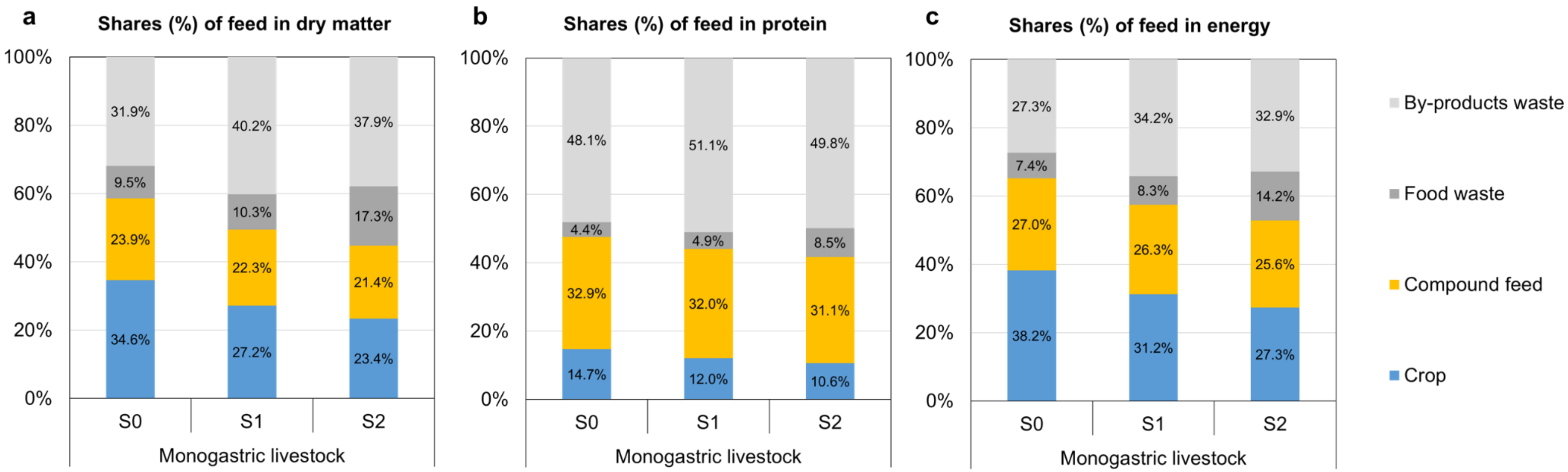
The producers' profits are specified as follows:

$$PROF_{i,j} = p_jY_{i,j} - r_iKL_{i,j} - w_iLB_{i,j} - k1_iLD1_{i,j} - k2_iLD2_{i,j} - p_{cer}CER_{i,j} - p_{osd}OSD_{i,j} - p_{vf}VF_{i,j} - p_{rt}RT_{i,j} - p_{sgr}SGR_{i,j} - p_{ocr}OCR_{i,j} - p_{cof}COF_{i,j} - p_{bran}BRAN_{i,j} - p_{pulp}PULP_{i,j} - p_{cake}CAKE_{i,j} - p_{nfe}NFE_{i,j} - p_{pfe}PFE_{i,j} - p_{i,cerw1}CERW_{i,oap} - p_{i,osdw1}OSDW_{i,oap} - p_{i,vfw1}VFW_{i,oap} - p_{i,rtw1}RTW_{i,oap} - p_{i,branw1}BRANW_{i,oap} - p_{i,pulpw1}PULPW_{i,oap} - p_{i,cakew1}CAKEW_{i,oap} \quad (47)$$

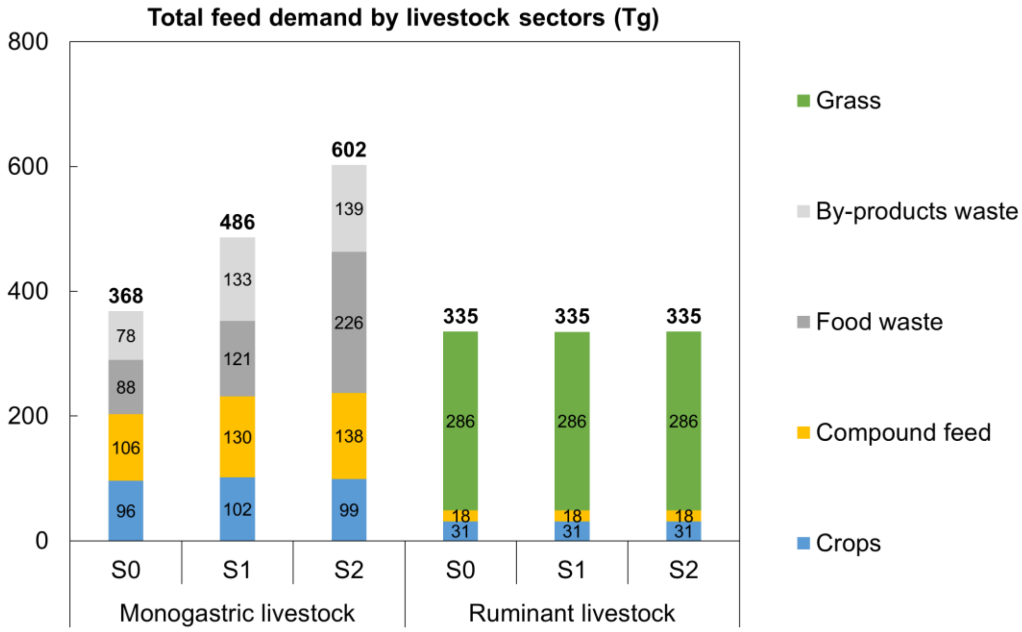
Model calibration

As in the literature on AGE models, we followed the Harberger convention [4] to calibrate the model using the base year SAMs. It means that the prices of all goods and factors are set to one, and the quantities of consumption and production goods equal the monetary value of the base year SAMs [5]. We calibrate the parameters in production and utility functions based on the cost shares of inputs in total production output and expenditure shares of consumption goods in total expenditure. In order to calibrate food waste-related parameters and add food waste (i.e., cereal grains waste, oilseeds & pulses waste, vegetables & fruits waste, roots & tubers waste, cereal bran waste, alcoholic pup waste, and oil cake waste) into the SAMs (see Supplementary Tables 10-11), our model treats food waste recycling service as feed input for monogastric livestock production (see equation (3)), and assumes that consumer buys food waste collection service for consumption (see equation (45)).

Supplementary Figures



Supplementary Fig. 1 | Percentage shares (%) for each feed type of changes in feed in (a) dry matter, (b) protein, and (c) energy within total feed use for per kg of monogastric livestock production in scenarios.



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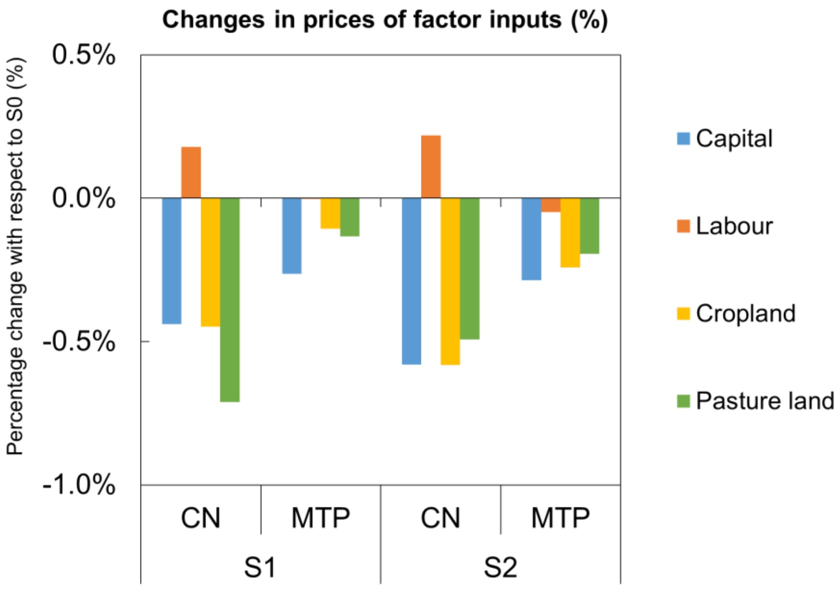
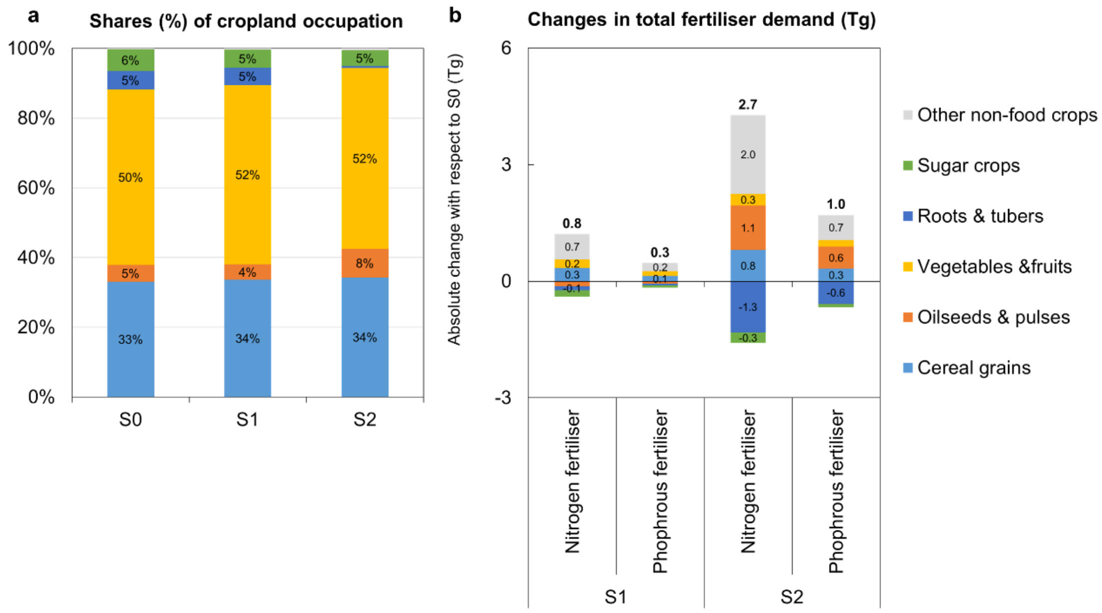
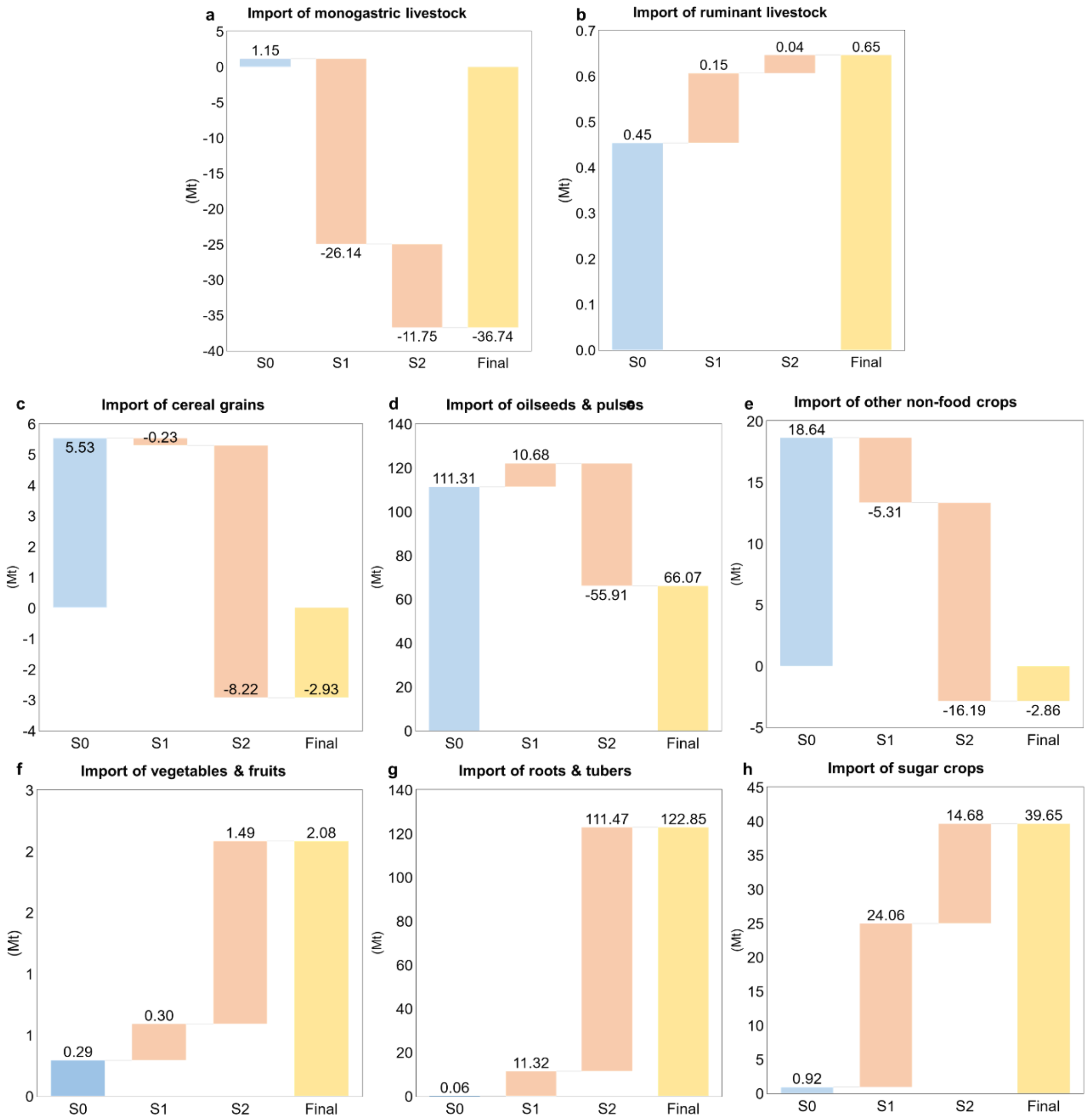
373 Supplementary Fig. 2 | Total feed demand (Tg) by livestock sectors in China in scenarios.



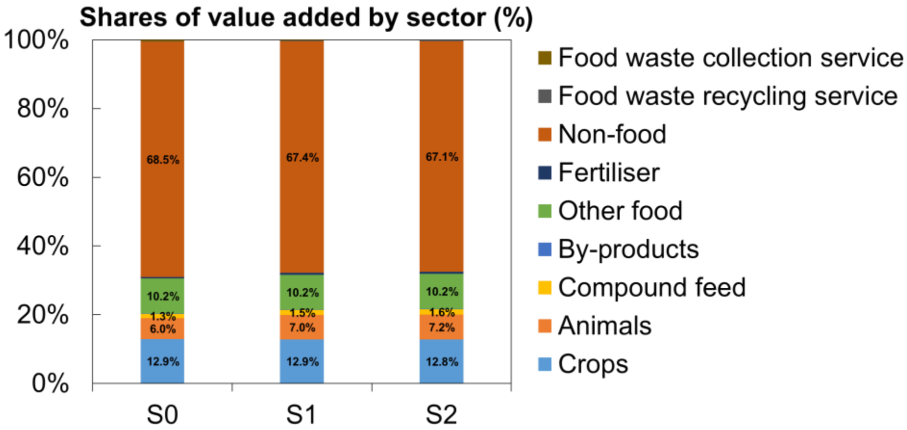
Supplementary Fig. 3 | Percentage changes (%) in prices of factor inputs in China (CN) and China's main food and feed trading partners (MTP) in scenarios with respect to S0.



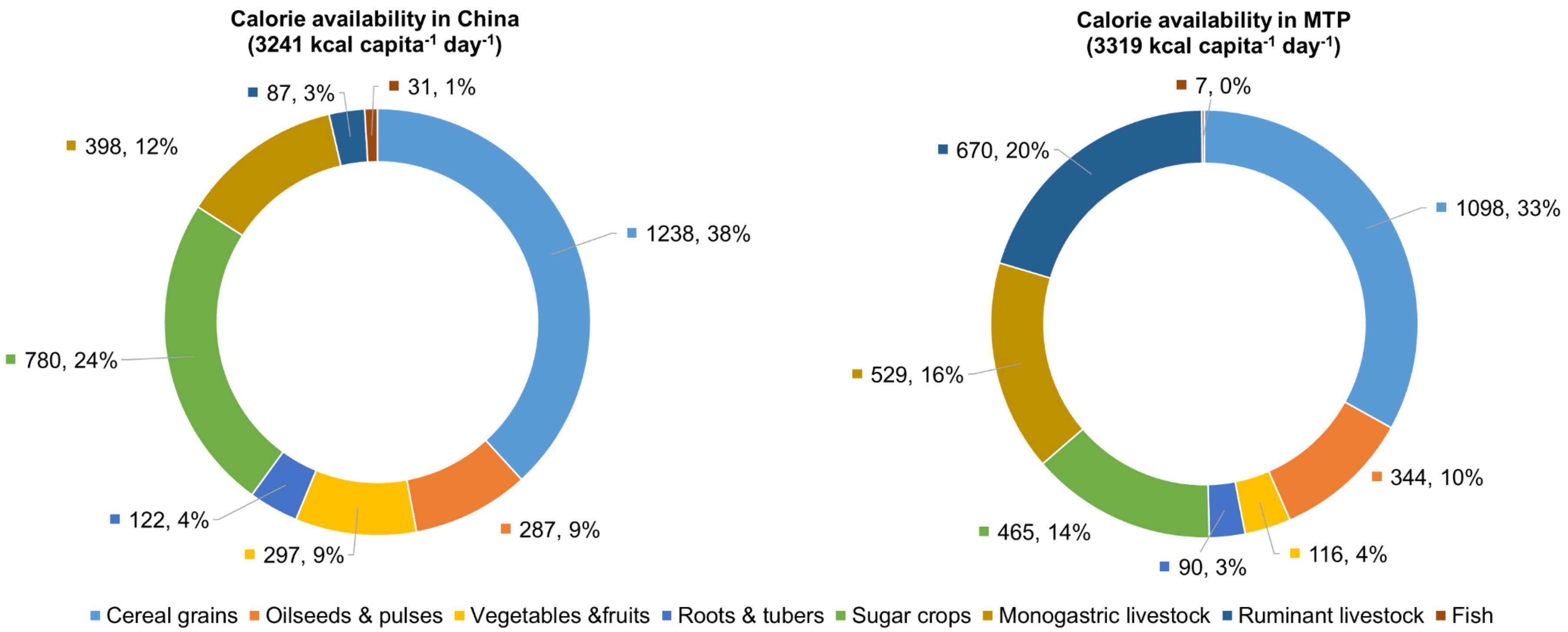
Supplementary Fig. 4 | (a) Percentage shares (%) for each crop of changes in total cropland occupation in scenarios. (b) Absolute changes (Tg) in total fertiliser demand by crops in China in scenarios with respect to S0.



Supplementary Fig. 5 | Absolute changes (Tg) in China's imports of (a) monogastric livestock, (b) ruminant livestock, (c) cereal grains, (d) oilseeds &pulses, (e) other non-food crops, (f) vegetables & fruits, (g) roots & tubers, and (h) sugar crops. The lengths of orange bars indicate the absolute change in each scenario compared with the previous scenario. The length of the final bar is the value for S2.



Supplementary Fig. 6 | Shares (%) of value-added by sector in Chinese GDP in scenarios.



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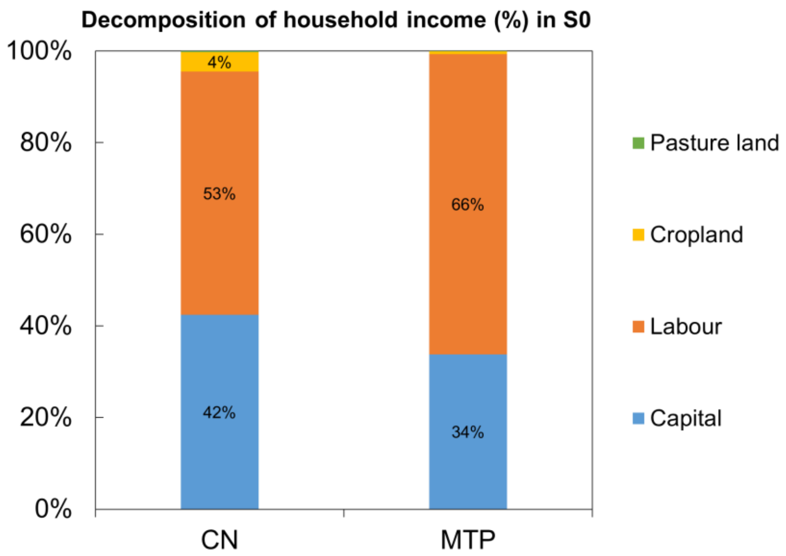
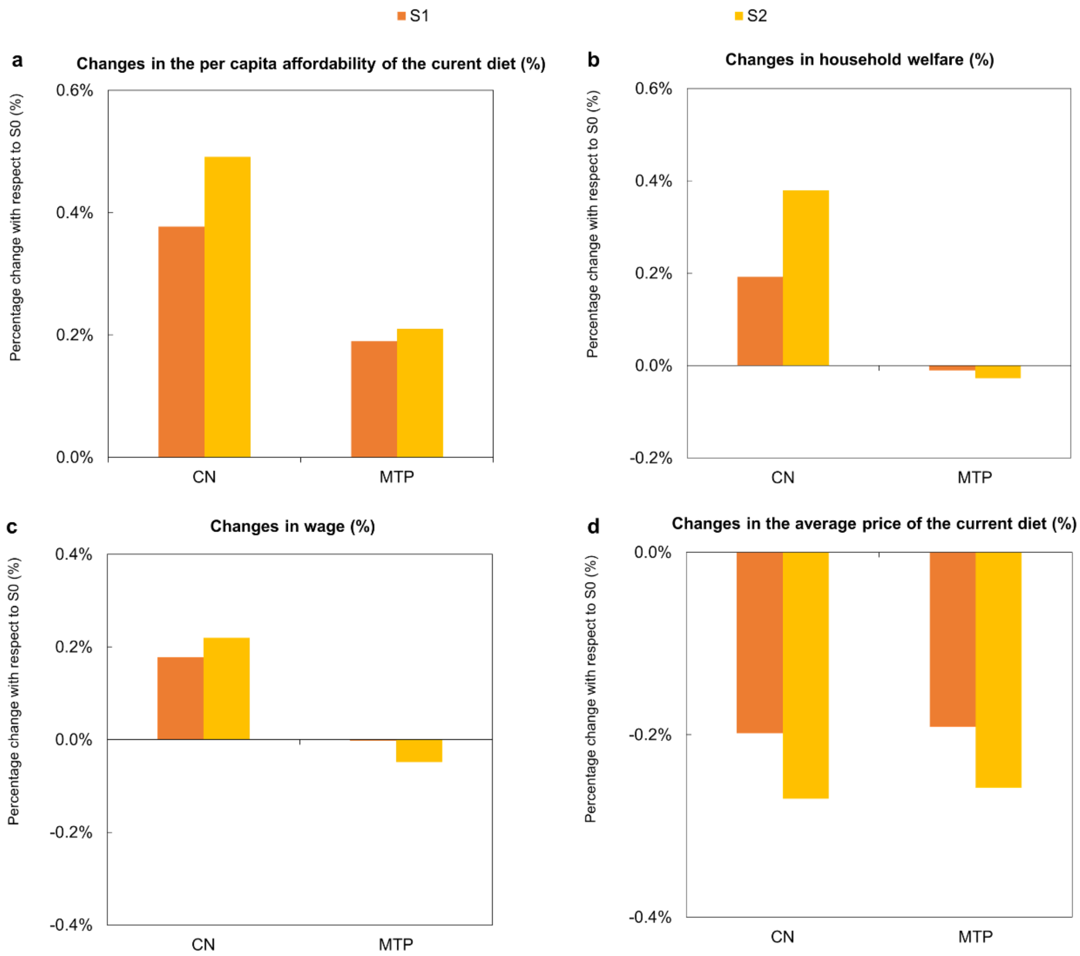
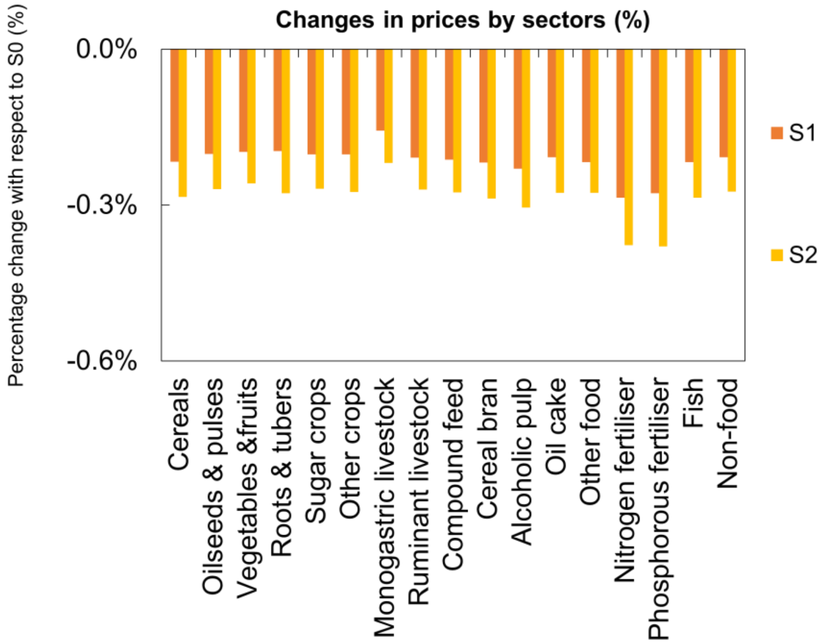
390 Supplementary Fig. 7 | Calorie availability per capita per day by food types in China and China's main food and feed trading partners (MTP) in S0.



Supplementary Fig. 8 | Decomposition of household income in China and China's main food and feed trading partners (MTP) in S0.



Supplementary Fig. 9 | Percentage changes (%) in (a) per capita affordability of the current diet, (b) household welfare, (c) wage, and (d) the average price of the current diet in China (CN) and China's main food and feed trading partners (MTP) in scenarios with respect to S0.



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399 Supplementary Fig. 10 | Percentage changes (%) in prices by sectors in scenarios with respect to S0.

Supplementary Tables

Supplementary Table 1 | Physical quantities (Tg) for each product or service in China (CN) and its main food and feed trading partners (MTP) in S0.

	CN	MTP
Cereal grains [a]	521.33	595.93
Oilseeds &pulses [a]	74.04	255.65
Vegetables &fruits [a]	572.24	116.39
Roots &tubers [a]	133.14	54.76
Sugar crops [a]	133.61	792.67
Other non-food crops [a]	24.98	19.27
Monogastric livestock [a]	103.15	18.65
Ruminant livestock [a]	52.53	46.28
Fish [b]	12.51	0.66
Compound feed [c]	128.00	103.10
Cereal bran [d]	11.37	12.01
Alcoholic pulp [d]	3.41	76.09
Oil cake [d]	58.06	84.02
Grass [e]	286.22	0.00
Nitrogen fertiliser [a]	39.60	13.65
Phosphorous fertiliser [a]	17.43	3.13

[a] Physical quantities of cereal grains, oilseeds &pulses, vegetables &fruits, roots &tubers, sugar crops, other non-food crops, monogastric livestock, ruminant livestock, nitrogen fertiliser, and phosphorous fertiliser were obtained from FAO [6]. Here physical quantities of cereal grains waste, oilseeds &pulses waste, vegetables &fruits waste, and roots &tubers waste were excluded and presented in Table A3.

[b] Fish production data was derived from FAO [7].

[c] Compound feed production data was calculated according to the weighted averages of feeding crops included in the compound feed at the national level.

[d] Physical quantities of cereal bran, alcoholic pulp, and oil cake were estimated from the consumption of corresponding food products and specific technical conversion factors [8]. Here, physical quantities of cereal bran, alcoholic pulp, and oil cake only include quantities recycled as feed for monogastric livestock, and quantities collected as waste for landfill and incineration are excluded and presented in Table A3.

[e] Grass from natural grassland was derived from Miao and Zhang [9]. Here, grass refers to grass from natural grassland where ruminant livestock is grazing for feed, and grass from remaining grassland is not included. We do not present grass production data in MTP due to data unavailability.

Supplementary Table 2 | Physical quantities (Tg) of food waste and food processing by-products and their utilisation in the baseline (S0) for China.

	Total (Tg)	Used as feed (%)	Unused biomass (%) [c]
Cereals waste	36.09	39% [a]	Landfill (40%) & incineration (21%)
Vegetables & fruits waste	175.01	39% [a]	Landfill (40%) & incineration (21%)
Roots & tubers waste	13.32	39% [a]	Landfill (40%) & incineration (21%)
Oil seeds & pulses waste	1.27	39% [a]	Landfill (40%) & incineration (21%)
Cereal bran	31.34	36% [b]	Landfill (42%) & incineration (22%)
Alcoholic pulp	42.34	16% [b]	Landfill (55%) & incineration (29%)
Oil cake	84.66	72% [b]	Landfill (18%) & incineration (10%)

[a] In China, quantitative empirical data on food waste recycled as feed for monogastric livestock was not available. We infer that the practices of feeding food waste to monogastric livestock in Japan and South Korea are rather similar to those in China, following Fang, et al. [10]. Thus, we assumed that a similar proportion (39%, the mean of values in Japan and South Korea [11]) of food waste was being used as feed in China in 2014 in S0.

[b] The utilisation rates of by-products recycled as feed in China in 2014 in S0 were based on Fang, et al. [10].

[c] The current whereabouts of unused biomass were based on Kaza, et al. [12].

Supplementary Table 3 | Physical quantities (Tg) of food waste and by-product waste to food waste recycling service and food waste collection service in China in S0.

		Physical quantity (Tg)	
	Total (Tg)	Food waste recycling service [a]	Food waste collection service [a]
Cereal grains waste [b]	36.09	14.08	22.02
Vegetables & fruits waste [b]	175.01	67.76	107.25
Roots & tubers waste [b]	13.32	5.20	8.13
Oilseeds & pulses waste [b]	1.27	0.50	0.78
Cereal bran waste [c]	19.97	0.00	19.97
Alcoholic pulp waste [c]	38.94	0.00	38.94
Oil cake waste [c]	26.59	0.00	26.59
Total	311.19	87.53	223.66

[a] Physical quantities of food waste recycling service and food waste collection service refer to how much food waste is recycled as feed for monogastric livestock production and how much food waste is collected for landfill and incineration.

[b] Physical quantities of food waste (i.e., cereal grains waste, vegetables & fruits waste, roots & tubers waste, and oilseeds & pulses waste) were quantified separately for each type of food product using data on food consumption and China-specific food loss and waste fractions [13] following the FAO methodology [14]. In China, quantitative empirical data on food waste used as feed for monogastric livestock was not available. We infer that the practices of feeding food waste to monogastric livestock in Japan and South Korea are rather similar to those in China, following Fang, et al. [10]. Thus, we assumed that a similar proportion (39%, the mean of values in Japan and South Korea [11]) of food waste was being used as feed in China in 2014 in S0, and the remaining food waste was collected for landfill and incineration.

[c] Physical quantities of by-product waste (i.e., cereal bran waste, alcoholic pulp waste, and oil cake waste) collected for landfill and incineration were estimated by detracting physical quantities of by-products recycled as feed for monogastric livestock (36%, 16%, 72% of total physical quantities of by-products according to Fang, et al. [10]) from total physical quantities of by-products.

Supplementary Table 4 | Prices of food waste recycling service and food waste collection service in China. [a]

	Food waste treatment	Price [b] (dollar ton^{-1})	Weighted price [c] (dollar ton^{-1})
Food waste recycling service	Recycling waste as feed	54	54
Food waste collection service	Collection	40	82
	Landfill	31	
	Incineration	64	

[a] Food waste recycling service refers to recycling food waste as feed for monogastric livestock production, and food waste collection service means collecting food waste for landfill and incineration.

[b] The process of recycling food waste involves sorting, shredding, thermal treatment, fermentation, hydrolysis, and extrusion to create animal feed, as outlined by Alsaleh and Aleisa [15]. Excluding the food waste recycled as feed, 66% of the remaining food waste in China in 2014 was collected for landfill, while 34% was incinerated, according to Kaza, et al. [12] and Bhada-Tata and Hoornweg [16]. Collection includes pick up, transfer, and transport to final disposal site for food waste. By multiplying the quantity of food waste with the price of food waste treatment, we can calculate the value of food waste generation. The prices of food waste recycling service and food waste collection service are obtained from Alsaleh and Aleisa [15], Kaza, et al. [12] and Bhada-Tata and Hoornweg [16]. Since the value of food waste generation needs to be taken from the 'wtr' demand of consumers and monogastric producers, we further checked whether or not the value of food waste generation is more than 80% of the initial demand of "wtr". If it is higher than 80% of the 'wtr' demand, the value of food waste generation is scaled down.

[c] The weighted price of food waste collection service = collection price (40 $/t) + 66%*landfill price (31$/t)+34%*incineration price (64$/t)=82$/t.

463 Supplementary Table 5 | The economic and mass allocation of main and by-products. [a]

	Main and by-products	By-product group	Economic share (%)	Mass share (%)
Cereal flour production [a]	Cereal flour	-	93%	86%
	Cereal bran	Cereal bran	7%	14%
Maize ethanol production [b]	Maize ethanol	-	83%	49%
	Distillers' grain from maize ethanol	Alcoholic pulp	17%	51%
Barley beer production [b]	Barley beer	-	98%	82%
	Brewers' grain from barley beer	Alcoholic pulp	2%	18%
Liquor production [b]	Liquor	-	97%	25%
	Distillers' grain from liquor	Alcoholic pulp	3%	75%
Vegetable oil production [c]	Soybean oil	-	44%	23%
	Soybean oil cake	Oil cake	56%	77%
	Other oil	-	66%	43%
	Other oil cake	Oil cake	34%	57%

464 [a] Data source: Haque, et al. [17], Mackenzie, et al. [18], Nyhan, et al. [19], and Pourmehdi and Kheiralipour [20]

Supplementary Table 6 | Food availability (kcal $capita^{-1}$ day^{-1}) and the additional number of population (million people) to be fed as the current diet in China (CN) and China's main food and feed trading partners (MTP) in scenarios.

		Food availability (kcal $capita^{-1}$ day^{-1})	Additional number of people to be fed as the current diet (million people)
S0	CN	3241.0	0
	MTP	3319.3	0
S1	CN	3247.1	2.6
	MTP	3318.8	-0.1
S2	CN	3253.1	5.2
	MTP	3318.4	-0.2

Supplementary Table 7 | Estimated mean dry matter (DM, %), crude protein (CP, %), and energy (MJ kg DM^{-})contents of feed sub-groups in China (CN) and its main food and feed trading partners (MTP). [a]

	Dry matter (DM, %)		Crude protein (CP, %)		Energy (MJ kg DM^{-1})	
	CN	MTP	CN	MTP	CN	MTP
Cereal grains	89	89	11	10	18.25	18.82
Oilseeds &pulses	74	86	22	32	19.72	19.78
Vegetables &fruits	10	10	19	19	13.80	13.80
Roots &tubers	29	29	5	5	21.54	21.54
Sugar crops	69	69	16	16	19.68	19.68
Compound feed	48	70	34	23	18.61	19.36
Cereal bran	89	89	16	16	12.24	12.24
Alcoholic pulp	75	75	27	27	12.84	12.84
Oil cake	89	89	46	47	14.69	14.94
Grass	27	27	12	12	11.20	11.20
Cereal grains waste	87	-	10	-	14.25	-
Vegetables & fruits waste	10	-	17	-	10.45	-
Roots & tubers waste	26	-	8	-	12.15	-
Oilseeds & pulses waste	94	-	15	-	14.70	-
Cereal bran waste	89	-	16	-	12.24	-
Alcoholic pulp waste	75	-	27	-	12.84	-
Oil cake waste	89	-	46	-	14.69	-

[a] The values were weighted averages of feed types included in the groups at the national level. Data were sourced from the NUFER database [21], MITERRA-EUROPE database [22], NRC [23], NRC [24], NRC [25], NRC [26], and China Feed–database Information Network Centre((http://www.chinafeeddata.org.cn/).

Supplementary Table 8 | Physical quantities of feed demand (Tg) by livestock sectors in China in scenarios.

Feed demand	Monogastric livestock (Tg)			Ruminant livestock (Tg)		
	S0	S1	S2	S0	S1	S2
Cereal grains	77.66	79.18	76.05	24.51	24.47	24.50
Oilseeds & pulses	3.15	3.31	3.24	0.74	0.73	0.74
Vegetables &fruits	11.84	15.33	17.12	3.17	3.17	3.17
Roots & tubers	2.75	2.97	2.93	0.74	0.74	0.74
Sugar crops	0.78	0.77	0.72	2.13	2.13	2.13
Compound feed	106.45	129.83	139.33	17.63	17.59	17.62
Cereal bran	11.08	12.36	12.52	-	-	-
Alcoholic pulp	6.67	7.05	7.01	-	-	-
Oil cake	59.83	28.51	34.79	-	-	-
Cereal grains waste	14.08	19.49	36.09	-	-	-
Vegetables & fruits waste	67.76	93.82	175.01	-	-	-
Roots & tubers waste	5.20	7.19	13.32	-	-	-
Oilseeds and pulses waste	0.50	0.69	1.27	-	-	-
Cereal bran waste	-	19.97	19.97	-	-	-
Alcoholic pulp waste	-	38.94	38.94	-	-	-
Oil cake waste	-	26.59	26.59	-	-	-
Grass	-	-	-	286.22	286.22	286.22
Total (Tg)	368	486	605	335	335	335

Supplementary Table 9 | Sectoral aggregation scheme.

Aggregated sectors	GTAP original sectors
Cereal grains	"Paddy rice (pdr)", "Processed rice (pcr)", "Wheat (wht)", and "Cereals grains nec (gro)" sectors
Oilseeds & pulses	"Oil seeds (osd)" sector, and pulses split from the original "Vegetables& fruits (v_f)" sector
Vegetables & fruits	"Vegetables, fruits, nuts (v_f)" sector after splitting out pulses, and roots & tubers
Roots &tubers	Split from the original "Vegetables& fruits (v_f)" sector
Sugar crops	"Sugar cane & Sugar beet (c_b)" and Sugar (sgr)" sectors
Other non-food crops	"Plant-based fibers (pfb)", and "Crops nec (ocr)" sectors
Monogastric livestock	"Animal products nec (oap)" and "Meat products nec (omt)" sectors
Ruminant livestock	"Cattle, sheep, goats, horses (ctl)", "Meat: cattle, sheep, goats, horses (cmt)", "Raw milk (rmk)", "Wool, silk-worm cocoons (wol)", and "Dairy products (mil)" sectors
Compound feed [a]	Split from the original "Food products nec (ofd)" sector
Cereal bran [a]	Split from the original "Food products nec (ofd)" sector
Alcoholic pulp [a]	Distiller's grains from maize ethanol production split from the original "Food products nec (ofd)" sector; Distiller's grains from liquor production and brewer's grains from barley beer production split from the original "Beverages and Tobacco products (b_t)" sector
Oil cake [a]	Split from the original "Vegetable oils and fats (vol)" sector
Other food [a]	"Food products nec (ofd)" sector after splitting out splitting out compound feed, cereal bran, and distiller's grains from maize ethanol production; "Beverages and Tobacco products (b_t)" sector after splitting out distiller's grains from liquor production and brewer's grains from barley beer production; Vegetable oils and fats (vol)" sector after splitting out oil cake
Nitrogen fertiliser [b]	Split from the original "Manufacture of chemicals and chemical products (chm)" sector
Phosphorous fertiliser [b]	Split from the original "Manufacture of chemicals and chemical products (chm)" sector
Food waste recycling service [c]	Split from the original "Waste and water (wtr)" sector
Food waste collection service [c]	Split from the original "Waste and water (wtr)" sector
Fish	"Fishing (Fsh)" sector

Aggregated sectors	GTAP original sectors
Non-food	"Manufacture of chemicals and chemical products (chm)" sector after splitting out nitrogen fertiliser and phosphorous fertiliser; "Waste and water (wtr)" sector after splitting out food waste recycling service and food waste collection service; "Forestry (frs)", "Fishing (fsh)", "Coal (coa)", "Oil (oil)", "Gas (gas)", "Minerals nec (oxt)", "Petroleum, coal products (p_c)", "Electricity (ely)", "Gas manufacture, distribution (gdt)", "Textiles （tex)", "Wearing apparel (wap)", "Leather products (lea)", "Wood products (lum)", "Paper products, publishing (ppp)", "Manufacture of pharmaceuticals, medicinal chemical and botanical products (bph)", "Manufacture of rubber and plastics products (rpp)", "Mineral products nec (nmm)", "Ferrous metal (i_s)", "Metal nec (nfm)", "Metal products (fmp)", Electronic equipment (ele)", "Manufacture of electrical equipment (eeq)", "Manufacture of machinery and equipment n.e.c. (ome)", "Motor vehicles and parts (mvh)", "Transport equipment nec (otn)", "Manufactures nec (omf)", "Construction (cns)", "Wholesale and retail trade; repair of motor vehicles and motorcycles (trd)", "Accommodation, Food and service activities (afs)", "Land transport and transport via pipelines (otp)", "Warehousing and support activities (whs)", "Sea transport (wtp)", "Air transport （atp)", "Communication (cmn)", "Financial services nec (ofi)", "Insurance (ins)", "Real estate activities (rsa)", "Other Business Services nec (obs)", "Recreation & other services (ros)", "Other Services (Government) (osg)", "Education (edu)", "Human health and social work (hht)", "Dwellings: ownership of dwellings (imputed rents of houses occupied by owners) (dwe)" sectors

[a] Compound feed was split from the "Food products nec (ofd)" sector in the original GTAP database. The substance flow from "Food products nec (ofd)" to monogastric livestock and ruminant livestock was compound feed. Cereal bran and distiller's grains from maize ethanol production were taken from the newly-splitted sector of compound feed according to the shares of economic values of cereal bran and distiller's grains from maize ethanol production in the total economic value of compound feed. Economic values of cereal bran and distiller's grains from maize ethanol production were calculated by multiplying the physical quantity (in tons) and the corresponding price (dollar per ton). Distiller's grains from liquor production and brewer's grains from barley beer production were split from the "Beverages and Tobacco products (b_t)" sector in the original GTAP database. The substance flow from "Beverages and Tobacco products (b_t)" to monogastric livestock were distillers' grains from liquor production and brewers' grains from barley beer production. Oil cake was split from the "Vegetable oils and fats (vol)" sector in the original GTAP database. The substance flow from the "Vegetable oils and fats (vol)" sector to monogastric livestock was oil cake.

[b] The nitrogen and phosphorus fertilisers were taken from the original 'Manufacture of chemicals and chemical products' sector following the method of Sturm [27] and Bartelings, et al. [28].

[c] Food waste recycling service and food waste collection service were split from the "Waste and water ("wtr") sector in the original GTAP database according to the shares of economic values of food waste recycling service and food waste collection service in the total economic value of "Waste and water ("wtr") sector. The economic values of food waste recycling service and food waste collection service were calculated by multiplying the physical quantity (in tons) and the corresponding price (dollar per ton). Since the value of food waste generation needs to be taken from the 'wtr' demand of consumers and mongastric producers, we further checked

whether or not the value of food waste generation is more than 80% of the initial demand of "wtr". If it is higher than 80% of the 'wtr' demand, the value of food waste generation are scaled down.

Supplementary Table 10 | The social accounting matrix in the base year of 2014 for China (million $).[a]

	cer	osd	vf	rt	sgr	ocr	oap	ctl	cof	bran	pulp	cake	otf	nfe	pfe	fsh	nf	CONS	XNET	TOT
cer	0	0	0	0	0	0	29229	9055	11363	1372	67	0	81831	0	0	0	0	61825	-2016	192727
osd	0	0	0	0	0	0	1002	230	8312	0	0	182	42993	0	0	0	0	5092	-34661	23150
vf	0	0	0	0	0	0	5685	1495	18959	0	0	0	98059	0	0	0	0	145756	-139	269815
rt	0	0	0	0	0	0	595	157	1986	0	0	0	10270	0	0	0	0	15265	-15	28259
sgr	0	0	0	0	0	0	192	515	1280	0	0	0	6619	0	0	0	0	24553	-903	32256
ocr	0	0	0	0	0	0	664	262	197	0	0	0	1021	0	0	0	0	1282	-1465	1963
oap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176874	-3205	173669
ctl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63546	-484	63062
cof	0	0	0	0	0	0	45882	7458	0	0	0	0	0	0	0	0	0	0	854	54194
bran	0	0	0	0	0	0	3371	0	0	0	0	0	0	0	0	0	0	0	27	3398
pulp	0	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0	-398	402
cake	0	0	0	0	0	0	215	0	0	0	0	0	0	0	0	0	0	0	-10	205
otf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	432109	714	432823
nfe	7396	521	3479	471	313	621	0	0	0	0	0	0	0	0	0	0	0	0	-78	12721
pfe	2412	211	1542	169	83	163	0	0	0	0	0	0	0	0	0	0	0	0	-28	4551
fsh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15571	2154	17725
nf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2547713	352518	2900231
LAD1	53323	7694	80962	8445	9849	396	0	0	0	0	0	0	0	0	0	0	0	-160670	0	0
LAD2	0	0	0	0	0	0	0	10240	0	0	0	0	0	0	0	0	0	-10240	0	0
LAB	94995	11819	148120	15450	17556	631	62255	24592	6707	959	155	8	89845	4413	1579	9208	1531587	-2019880	0	0
CAP	34602	2905	35711	3725	4455	151	23777	9057	5390	1067	180	15	102185	8308	2972	8517	1368643	-1611662	0	0
TRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312868	-312868	
TOT	192727	23150	269815	28259	32256	1963	173669	63062	54194	3398	402	205	432823	12721	4551	17725	2900231			

	cer	osd	vf	rt	sgr	ocr	oap	ctl	cof	bran	pulp	cake	otf	nfe	pfe	fsh	nf	CONS	XNET	TOT
cerw	0	0	0	0	0	0	754	0	0	0	0	0	0	0	0	0	0	1808		
vfw	0	0	0	0	0	0	3631	0	0	0	0	0	0	0	0	0	0	8806		
rtw	0	0	0	0	0	0	278	0	0	0	0	0	0	0	0	0	0	667		
osdw	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	64		
branw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1639		
pulpw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3197		
cakew	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2184		

[a] Data source: GTAP [29]. cer=cereal grains. osd= oilseeds & pulses. vf=vegetables & fruits. rt= roots & tubers. sgr=sugar crops. ocr=other non-food crops. oap=monogastric livestock. ctl=ruminant livestock. cof=compound feed. bran=cereal bran. pulp=alcoholic pulp. cake=oil cake. otf=other food. nfe=nitrogen fertiliser. pfe=phosphorous fertiliser. fsh=fish. nf=non-food. CONS=consumption. XNET=net export. TOT=total. LAD1=cropland. LAD2=pasture land. LAB=labour. CAP=capital. TRA=trade. cerw=cereal grains waste. osdw= oilseeds & pulses waste. vfw=vegetables & fruits waste. rtw= roots & tubers waste. branw=cereal bran waste. pulpw=alcoholic pulp waste. cakew=oil cake waste.

Supplementary Table 11 | The social accounting matrix in the base year of 2014 for China's main food and feed trading partners (MTP) (million $).[a]

	cer	osd	vf	rt	sgr	ocr	oap	ctl	cof	bran	pulp	cake	otf	nfe	pfe	fsh	nf	CONS	XNET	TOT
cer	0	0	0	0	0	0	3794	34288	4450	1023	414	0	32927	0	0	0	0	16597	2016	95511
osd	0	0	0	0	0	0	69	301	3307	0	0	2009	17059	0	0	0	0	1938	34661	59344
vf	0	0	0	0	0	0	354	1110	8351	0	0	0	43966	0	0	0	0	50755	139	104675
rt	0	0	0	0	0	0	37	116	875	0	0	0	4605	0	0	0	0	5316	15	10963
sgr	0	0	0	0	0	0	58	1037	1598	0	0	0	7759	0	0	0	0	16038	903	27392
ocr	0	0	0	0	0	0	130	413	943	0	0	0	4929	0	0	0	0	13124	1465	21003
oap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97851	3205	101056
ctl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	214439	484	214923
cof	0	0	0	0	0	0	30067	32726	0	0	0	0	0	0	0	0	0	0	-854	61939
bran	0	0	0	0	0	0	4229	0	0	0	0	0	0	0	0	0	0	0	-27	4203
pulp	0	0	0	0	0	0	4967	0	0	0	0	0	0	0	0	0	0	0	398	5365
cake	0	0	0	0	0	0	2383	0	0	0	0	0	0	0	0	0	0	0	10	2393
otf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	514821	-714	514107
nfe	2528	940	131	38	255	685	0	0	0	0	0	0	0	0	0	0	0	0	78	4655
pfe	1547	1164	87	47	92	231	0	0	0	0	0	0	0	0	0	0	0	0	28	3195
fsh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6983	-2154	4828
nf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13043344	-352518	12690826
LAD1	22886	13940	25013	2605	2260	5474	0	0	0	0	0	0	0	0	0	0	0	-72178	0	0
LAD2	0	0	0	0	0	0	0	15132	0	0	0	0	0	0	0	0	0	-15132	0	0
LAB	31115	17269	34446	3585	14182	5957	35369	71060	23869	1730	2795	231	203920	2038	1461	1581	8508850	-8959458	0	0
CAP	37435	26030	44998	4688	10603	8655	19600	58739	18547	1450	2155	153	198941	2618	1734	3247	4181976	-4621570	0	0
TRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-312868	312868	
TOT	95511	59344	104675	10963	27392	21003	101056	214923	61939	4203	5365	2393	514107	4655	3195	4828	12690826			

	cer	osd	vf	rt	sgr	ocr	oap	ctl	cof	bran	pulp	cake	otf	nfe	pfe	fsh	nf	CONS	XNET	TOT
cerw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
vfw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
rtw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
osdw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
branw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
pulpw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
cakew	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

[a] Data source: GTAP [29]. cer=cereal grains. osd= oilseeds & pulses. vf=vegetables & fruits. rt= roots & tubers. sgr=sugar crops. ocr=other non-food crops. oap=monogastric livestock. ctl=ruminant livestock. cof=compound feed. bran=cereal bran. pulp=alcoholic pulp. cake=oil cake. otf=other food. nfe=nitrogen fertiliser. pfe=phosphorous fertiliser. fsh=fish. nf=non-food. CONS=consumption. XNET=net export. TOT=total. LAD1=cropland. LAD2=pasture land. LAB=labour. CAP=capital. TRA=trade. cerw=cereal grains waste. osdw= oilseeds & pulses waste. vfw=vegetables & fruits waste. rtw= roots & tubers waste. branw=cereal bran waste. pulpw=alcoholic pulp waste. cakew=oil cake waste.

Supplementary Table 12 | Total emissions of greenhouse gases (Tg CO_2 equivalents) in China (CN) and its main food and feed trading partners (MTP).[a]

	CN	MTP
Cereal grains	276.61	118.98
Oilseeds &pulses	8.33	9.88
Vegetables &fruits	54.88	3.34
Roots &tubers	7.46	0.82
Sugar crops	4.58	6.33
Other crops	15.55	20.73
Monogastric livestock	79.37	63.77
Ruminant livestock	245.04	700.30
Compound feed	25.39	16.03
Cereal bran	0.00752	0.00288
Alcoholic pulp	0.0001148	0.0000318
Oil cake	0.01580	0.01422
Other food	204.54	130.82
Nitrogen fertiliser	324.09	80.29
Phosphrous fertiliser	24.53	9.06
Fish	0.00	0.00
Non-food	10238.21	6825.11
Food waste recycling service	16.37	0.00
Food waste collection service	221.98	0.00
Total	11746.93	7985.49

[a] Data source: Climate Analysis Indicators Tool (CAIT) [30]. Emissions related to N fertiliser production were allocated to the N fertiliser sector, while emissions related to N fertiliser application were distributed to the crop sectors. The data on N and P fertiliser use by crop types and countries were derived from Ludemann, et al. [31]. Emissions of by-products (i.e., cereal bran, alcoholic pulp, oil cake) were derived from Mackenzie, et al. [18]. Emissions of food waste recycling service and food waste collection service were obtained from Alsaleh and Aleisa [15], Hong, et al. [32], and Hong, et al. [33]

Supplementary Table 13 | Total emissions of acidification pollutants (Tg NH_3 equivalents) in China (CN) and its main food and feed trading partners (MTP).[a]

	CN	MTP
Cereal grains	3.94	0.94
Oilseeds &pulses	0.29	0.15
Vegetables &fruits	1.89	0.05
Roots &tubers	0.26	0.01
Sugar crops	0.16	0.09
Other crops	0.54	0.34
Monogastric livestock	5.22	2.88
Ruminant livestock	2.21	1.05
Compound feed	0.04	0.02
Cereal bran	0.000328	0.000126
Alcoholic pulp	0.00000067	0.00000019
Oil cake	0.00080	0.00073
Other food	0.35	0.16
Nitrogen fertiliser	0.0009	0.0035
Phosphrous fertiliser	0.0007	0.0029
Fish	0.00	0.00
Non-food	18.10	8.21
Food waste recycling service	0.06	0.00
Food waste collection service	0.56	0.00
Total	33.61	13.92

[a] Data source: Liu, et al. [34], Huang, et al. [35], and Dahiya, et al. [36]. Emissions of by-products (i.e., cereal bran, alcoholic pulp, oil cake) were derived from Mackenzie, et al. [18]. Emissions of food waste recycling service and food waste collection service were obtained from Alsaleh and Aleisa [15], Hong, et al. [32], and Hong, et al. [33]

Supplementary Table 14 | Total emissions of eutrophication pollutants (Tg N equivalents) in China (CN) and its main food and feed trading partners (MTP).[a]

	CN	MTP
Cereal grains	1.04	0.06
Oilseeds &pulses	0.15	0.05
Vegetables &fruits	0.88	0.04
Roots &tubers	0.12	0.01
Sugar crops	0.02	0.01
Other crops	0.01	0.01
Monogastric livestock	0.58	0.38
Ruminant livestock	1.63	2.02
Compound feed	0.17	0.07
Cereal bran	0.0000147	0.0000056
Alcoholic pulp	0.00000029	0.00000008
Oil cake	0.000037	0.000034
Other food	1.35	0.56
Nitrogen fertiliser	0.0002	0.0007
Phosphrous fertiliser	0.0002	0.0009
Fish	0.00	0.00
Non-food	3.66	2.40
Food waste recycling service	0.0303	0.0000
Food waste collection service	0.2790	0.0000
Total	9.92	5.61

[a] Data source: Hamilton, et al. [37]. Emissions of by-products (i.e., cereal bran, alcoholic pulp, oil cake) were derived from Mackenzie, et al. [18]. Emissions of food waste recycling service and food waste collection service were obtained from Alsaleh and Aleisa [15], Hong, et al. [32], and Hong, et al. [33]

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