**SUPPLEMENTARY INFORMATIONThe asymmetric impacts of feeding China’s monogastric livestock with food waste on food security and environment sustainability**

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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 ()" is the weighted sum of the utility () of all consumers, according to Zhu and Van Ierland 2.

(1)

where is the Negishi weight of the representative consumer in each region (=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 is written as:

(2)

where consumption goods 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. is the consumption of the rival good in region . is the elasticity of utility concerning the consumption of rival good in region , i.e., the expenditure share of consumption good in consumption of rival goods in region , and .

## *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:

(3)

where is the production of sector in region . is the technological parameter of the production of sector in region . , , and are capital, labour, cropland, and pasture land inputs for production in region , respectively. , , , , , , , , , , , and 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 in region , respectively. , , , , , , and 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 in region , respectively. (0<<1) is the cost share of food waste for the production of sector in region . (=1, 2, 3, …, 16) is the cost share of each factor and intermediate input for production, an*d* *.* (=1, 2, 3, …, 7) is the cost share of each food waste input for production, an*d* *.*

When emissions are outputs of the production process, the emissions intensities of greenhouse gases (GHGs) (, kg CO2 equivalent USD-1), acidification pollutants (, kg NH3 equivalent USD-1), and eutrophication pollutants (EP, , kg N equivalent USD-1) from producer in region are calculated as:

(4)

(5)

(6)

where is the emissions of GHGs (=CO2, CH4, and N2O emissions) from producer in region in the base run. is the emissions of acidification pollutants (=NH3, NOx, and SO2 emissions) from producer in region in the base run. is the emissions of eutrophication pollutants (= N and P losses) from producer in region in the base run. is the production of producer in region 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 are calculated as follows:

for emissions of GHGs = CO2, CH4, and N2O emissions

(7)

for emissions of acidification pollutants = NH3, NOx, and SO2 emissions

(8)

for emissions of eutrophication pollutants = N and P losses

(9)

where , , and are the total emissions of GHGs, acidification and eutrophication pollutants from producer in region , respectively. , , and 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 are as follows:

(10)

(11)

(12)

(13)

(14)

(15)

where , , , , , and are cereals used for monogastric livestock, ruminant livestock, compound feed, cereal bran, alcoholic pulp, and other food production in region , respectively. , , , , and are cereals used for monogastric livestock, ruminant livestock, compound feed, oil cake, and other food production in region , respectively. , , , and are vegetables & fruits used for monogastric livestock, ruminant livestock, compound feed, and other food production in region , respectively. , , , and are roots & tubers used for monogastric livestock, ruminant livestock, compound feed, and other food production in region , respectively. , , , and are sugar crops used for monogastric livestock, ruminant livestock, compound feed, and other food production in region , respectively. , , , and are other non-food crops used for monogastric livestock, ruminant livestock, compound feed, and other food production in region , respectively. , , , , , and are the shadow prices of cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops in region , respectively.

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

(16)

(17)

(18)

where , , and are cereal bran, alcoholic pulp, and oil cake used for monogastric livestock production in region , respectively. ,, and are the shadow prices of cereal bran, alcoholic pulp, and oil cake in region .

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

(19)

where and are compound feed used in monogastric livestock and ruminant livestock production in region , respectively. is the shadow price of compound feed in region .

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

(20)

where is the shadow price of good in region .

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

(21)

(22)

where , , , , and are the nitrogen fertiliser used for cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops production in region , respectively. , , , , and are the phosphorus fertiliser used for cereal grains, oilseeds & pulses, vegetables & fruits, roots & tubers, and other non-food crops production in region , respectively. and are the shadow prices of nitrogen fertiliser and phosphorus fertiliser in region , respectively.

For trade balance of all goods:

(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:

(24)

(25)

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

(26)

for sector = ruminant livestock

(27)

where , , and are the factor endowments (i.e., capital, labour, cropland, pasture land) supply in region , respectively. , , , and are the shadow prices of capital, labour, cropland, and pasture land in region , 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:

(39)

(40)

(41)

where , , and are the total emissions of GHGs, acidification and eutrophication pollutants from all producers in region , respectively. , , and are the permitted level of the total emissions of GHGs, acidification and eutrophication pollutants in region , 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. , , and are the shadow prices of the emissions of GHGs, acidification and eutrophication pollutants in region , 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:

(31)

(32)

(33)

(34)

(35)

(36)

(37)

where , , , , , , and 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. , , , , , , and 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:

(38)

(39)

(40)

(41)

(42)

(43)

(44)

where , , , , , , and 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. , , , , , , and 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 holds such that the expenditure must be equal to the income:

(45)

where consumption goods 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. is the total expenditure on the consumption goods in region . , , , , , , and 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 . The Negishi weight () in the welfare function (equation 1) will be chosen such that the budget constraints hold for each representative consumer in region .

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:

(46)

where is the income from exports. , , , , , , and are the income from food waste recycling service in region . , , , , , , and are the income from food waste collection service in region .

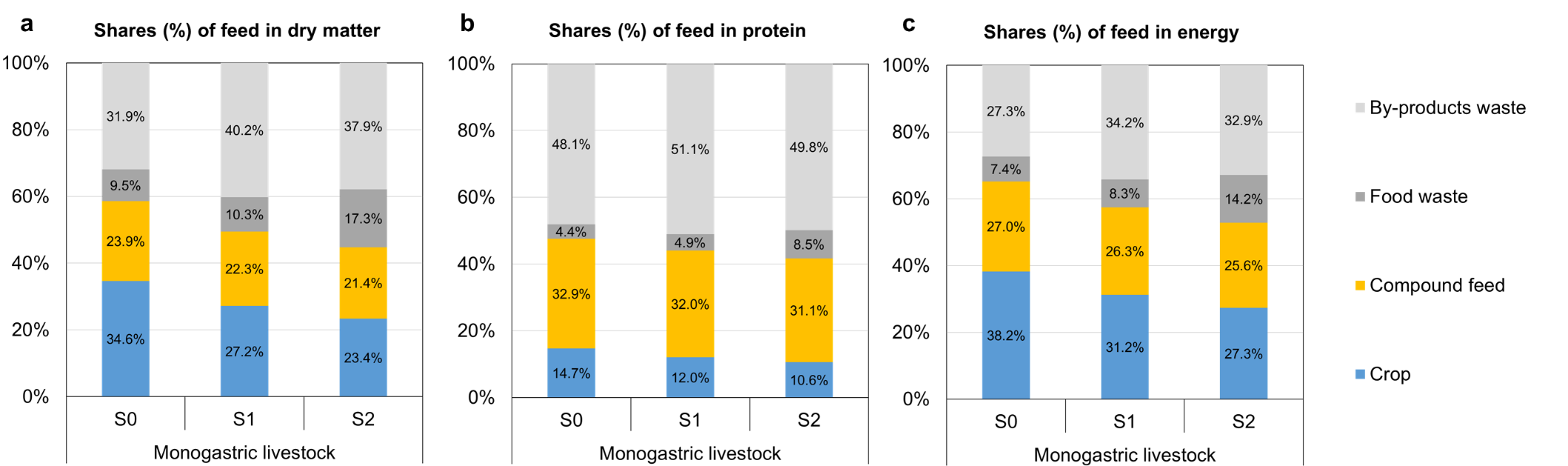
The producers' profits are specified as follows:

(47)

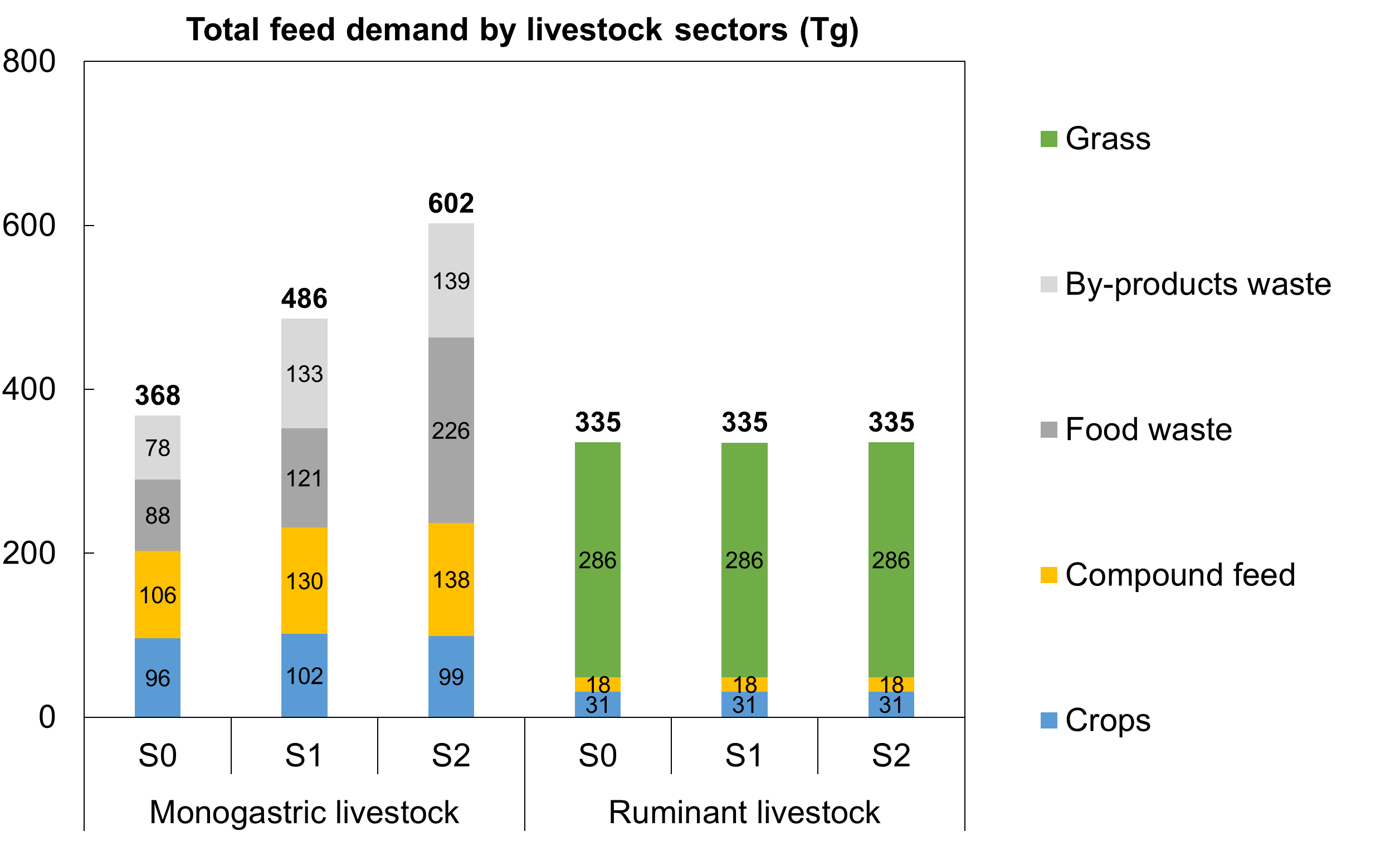
## *Model calibration*

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)).

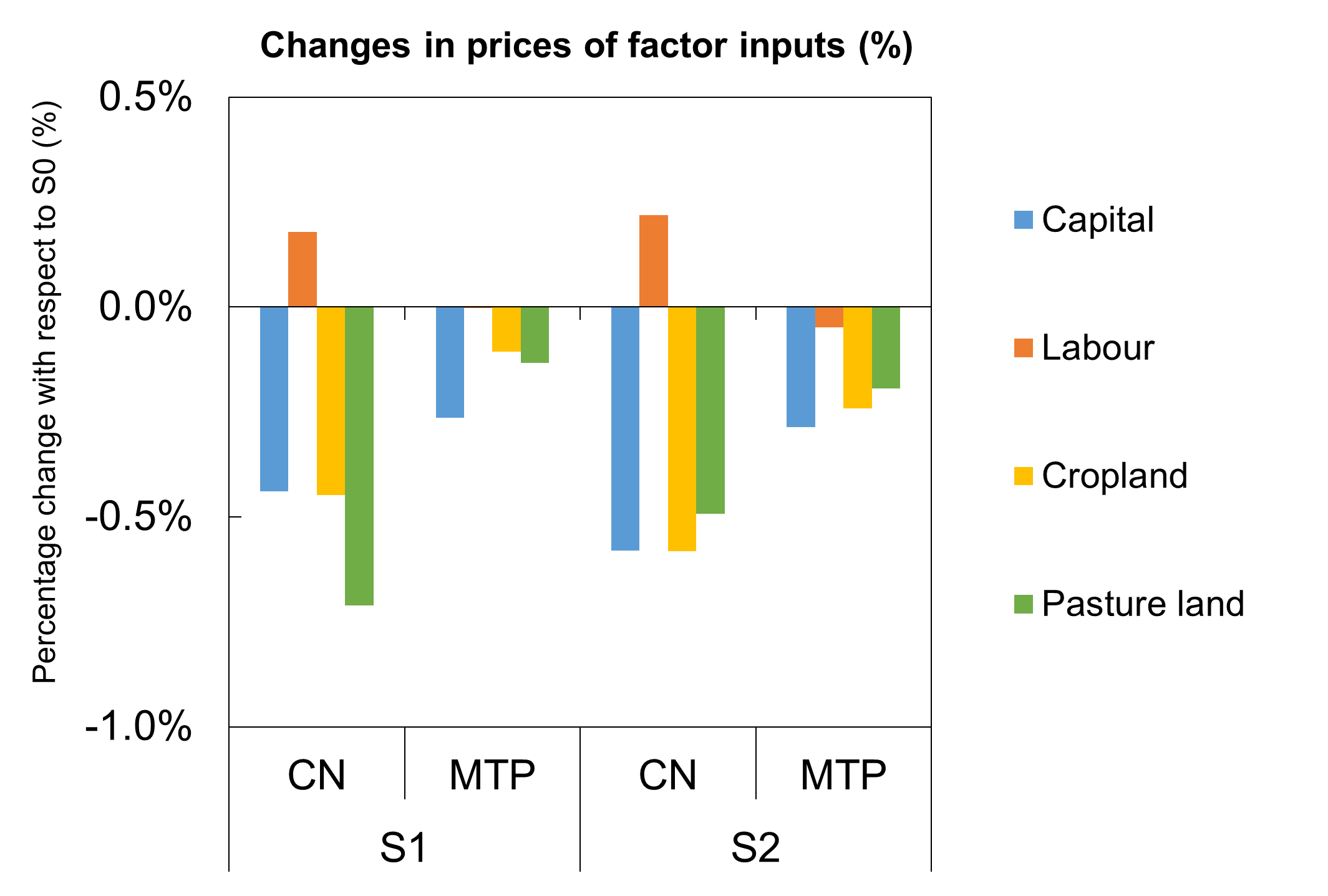
# Supplementary Figures



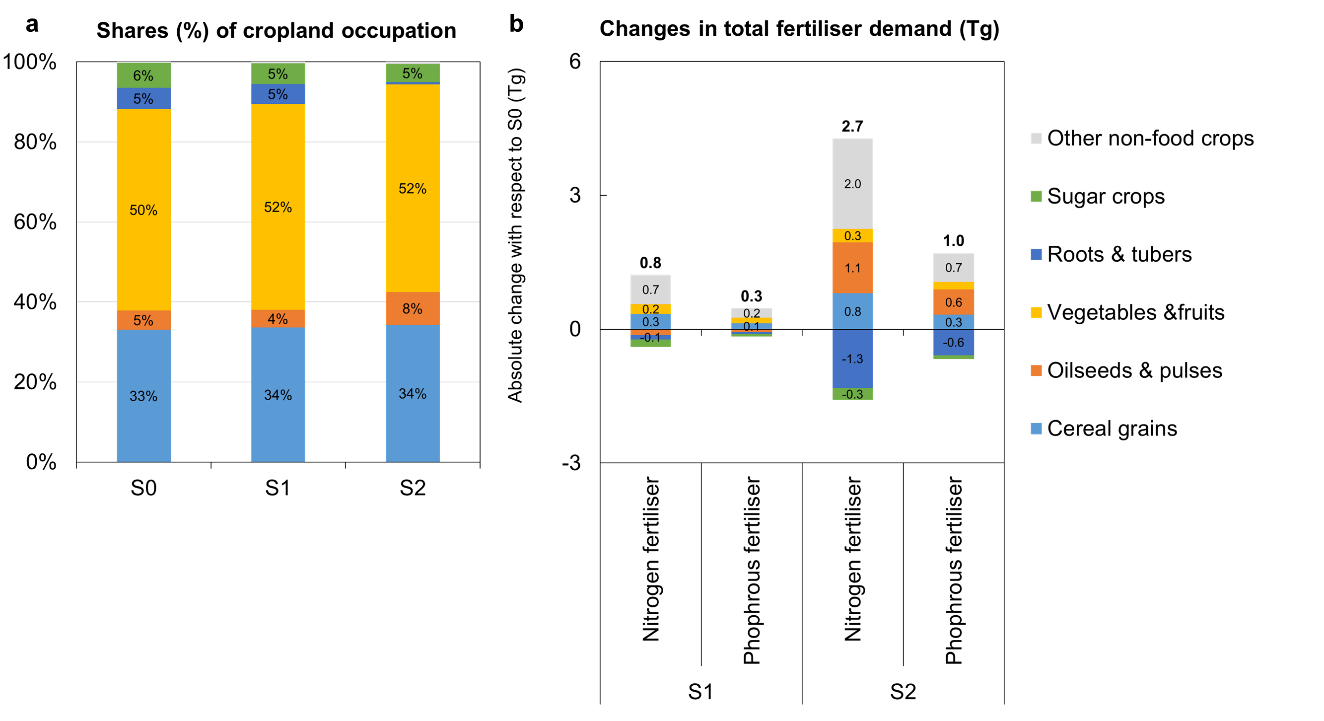
## Supplementary Fig. 1 | Percentage shares (%) for each feed type of changes in feed in (a) dry matter, (b) protein, and (c) energy within total feed use for per kg of monogastric livestock production in scenarios.



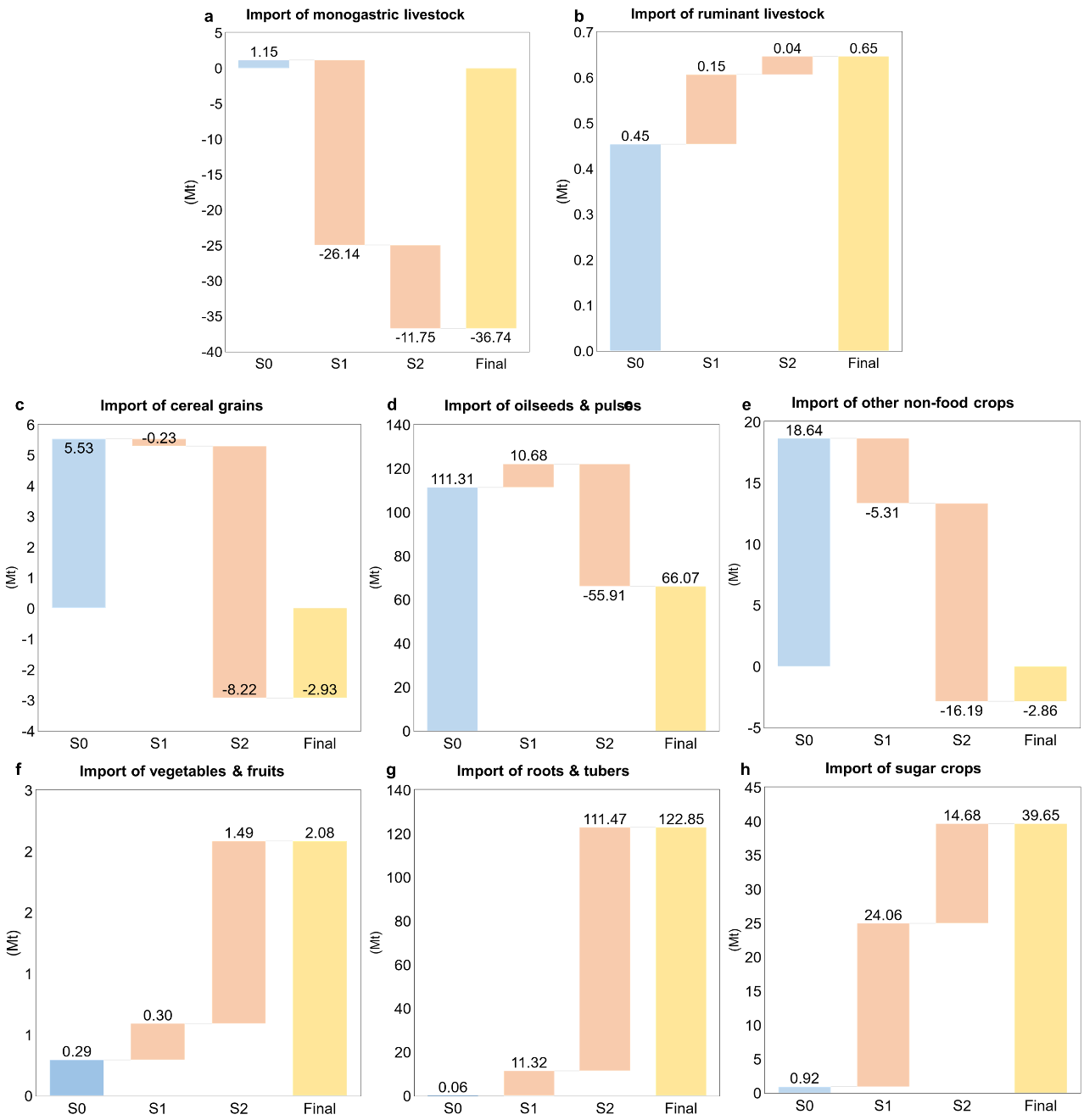
## Supplementary Fig. 2 | Total feed demand (Tg) by livestock sectors in China in scenarios.



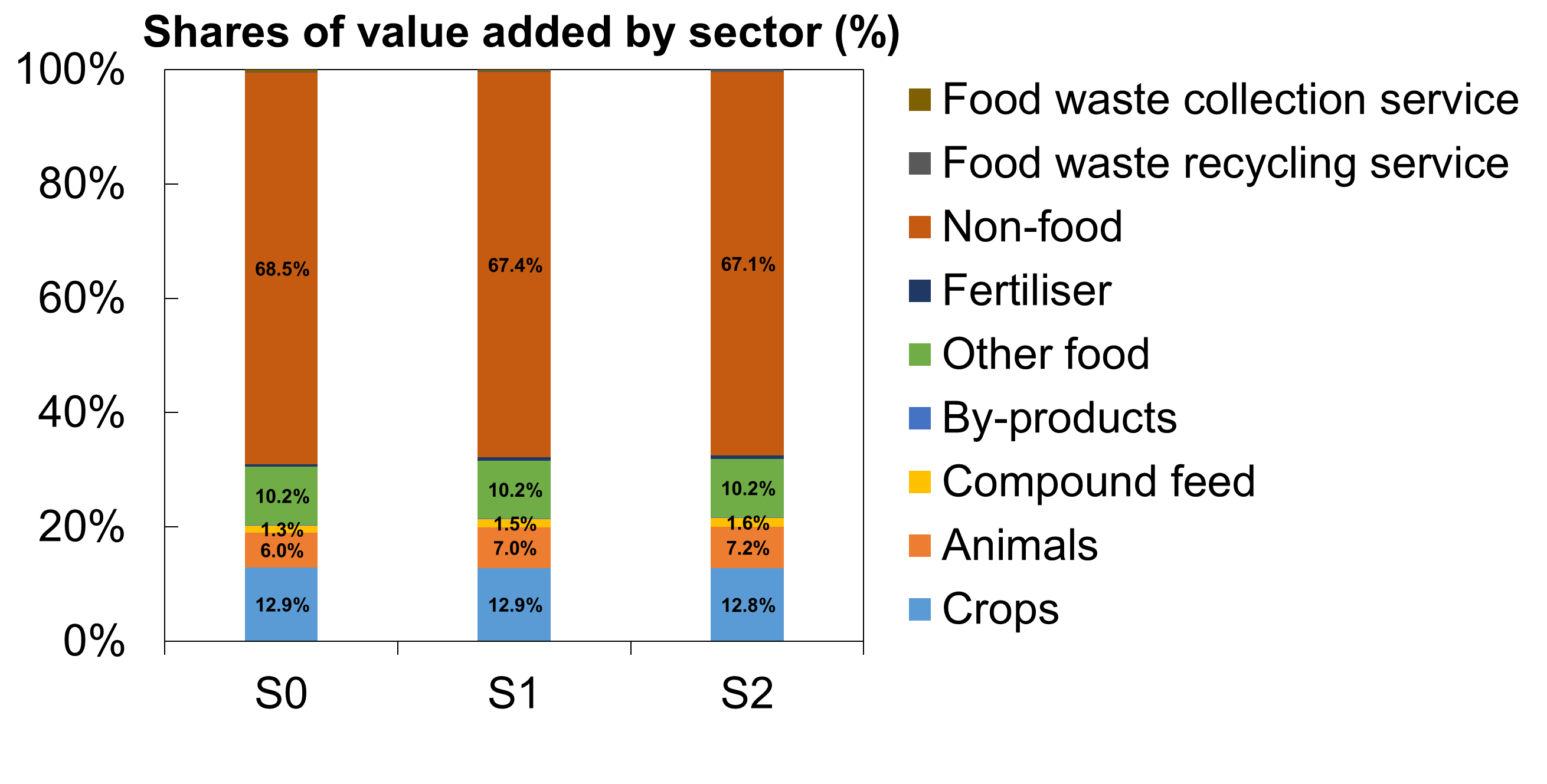
## Supplementary Fig. 3 | Percentage changes (%) in prices of factor inputs in China (CN) and China’s main food and feed trading partners (MTP) in scenarios with respect to S0.



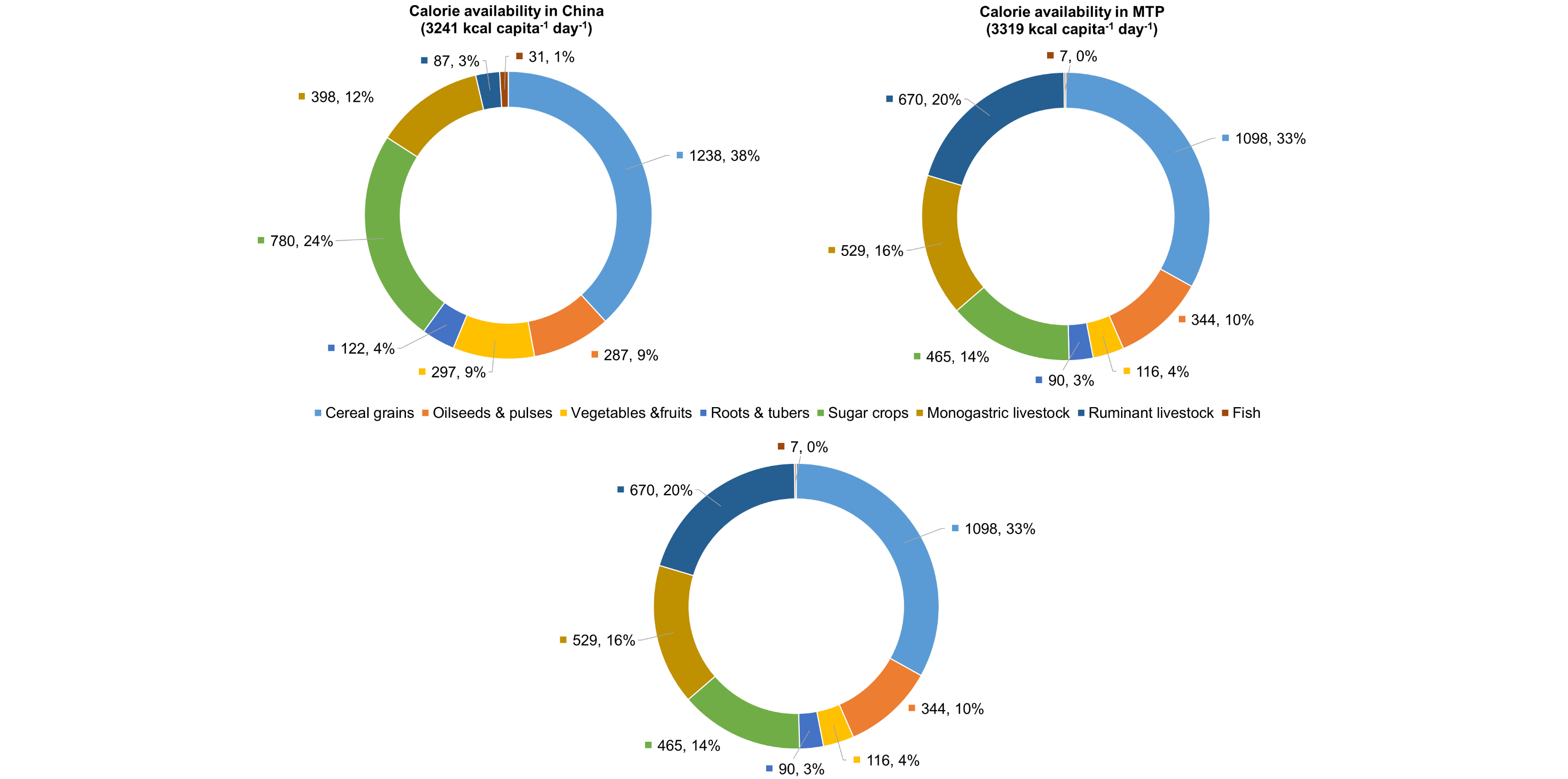
## Supplementary Fig. 4 | (a) Percentage shares (%) for each crop of changes in total cropland occupation in scenarios. (b) Absolute changes (Tg) in total fertiliser demand by crops in China in scenarios with respect to S0.



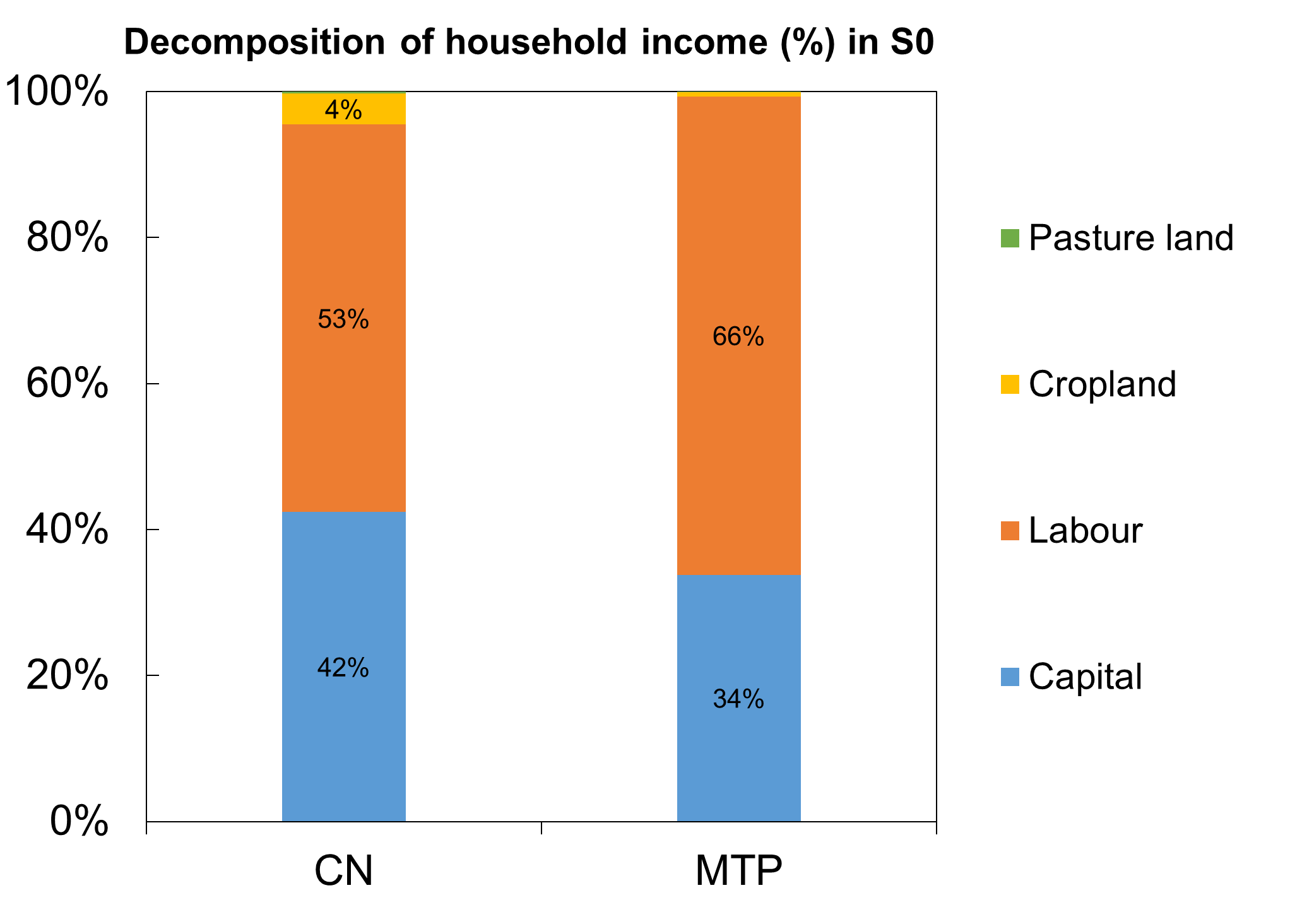
## Supplementary Fig. 5 | Absolute changes (Tg) in China’s imports of (a) monogastric livestock, (b) ruminant livestock, (c) cereal grains, (d) oilseeds &pulses, (e) other non-food crops, (f) vegetables & fruits, (g) roots & tubers, and (h) sugar crops. The lengths of orange bars indicate the absolute 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.



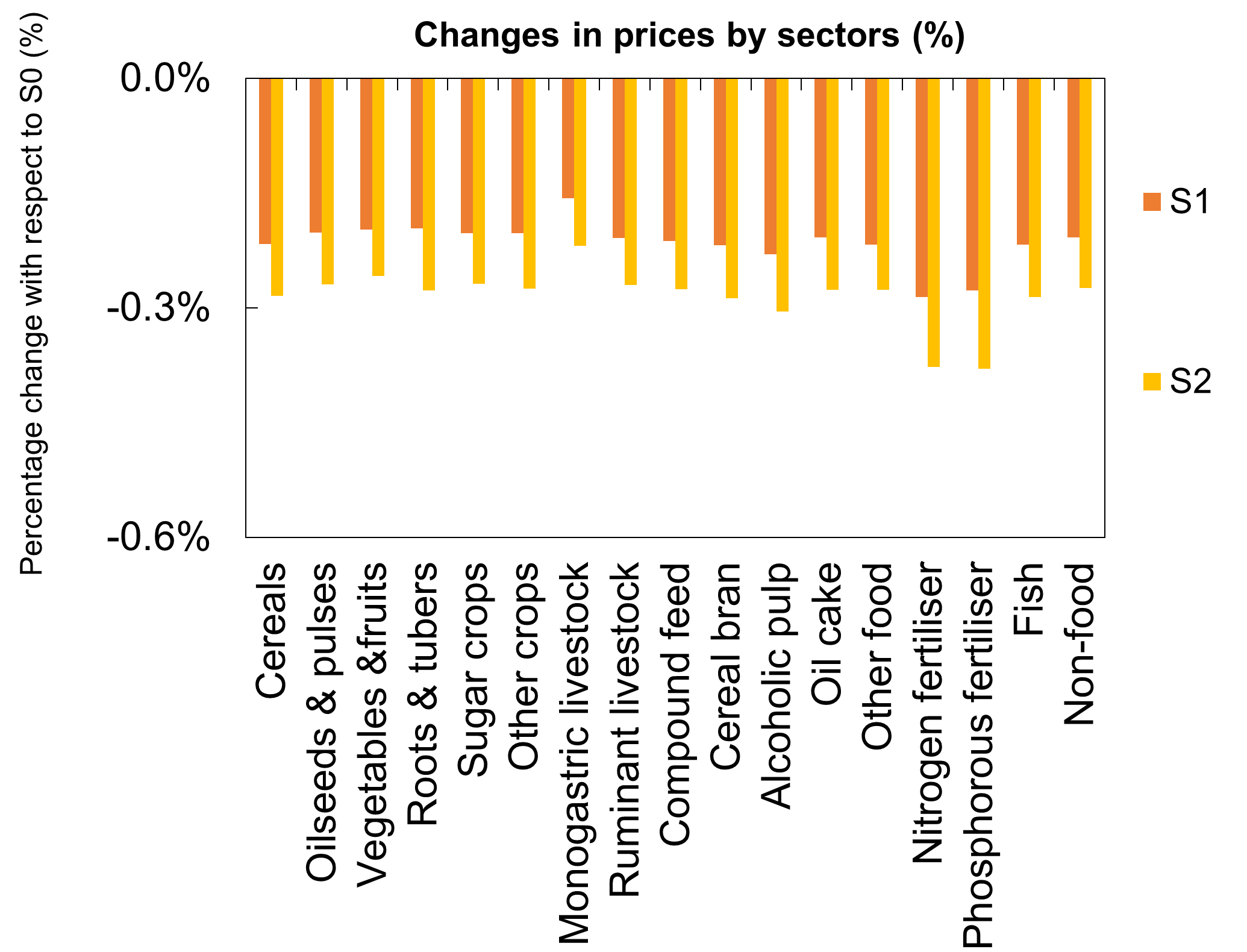
## Supplementary Fig. 7 | Calorie availability per capita per day by food types in China and China’s main food and feed trading partners (MTP) in S0.



## 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.



## 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 ofcereal 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.

## 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% |

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 |
| 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 |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 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 | |  | |  | |  | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  | |  | |  | |  | |  | |
| 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 CO2 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 NH3 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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