Supplementary Information for: Water resources transfers through Chinese inter-provincial and foreign food trade

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The following supplementary information (SI Appendix) covers two main sections. The first section describes the materials and methods used to construct China's virtual water trade network. The second section presents in further details the results described in the printed version of the paper: "Water resources transfers through Chinese inter-provincial and foreign food trade", and includes additional tables and figures.

1 Building China's Virtual Water Trade network

In the Chinese virtual water trade (VWT) network, each node represents a province, and the rest of the world (ROW) is represented by a 32^{nd} node. Each link between a pair of nodes is directed by the direction of trade and weighted by the volume of virtual water involved in the traded commodities. We used two main pieces of information to construct the VWT network for year 2005: China's detailed inter-provincial and international food trade, and the virtual water content of each commodity in all provinces and other nations. We built China's VWT network by multiplying the traded volume of a specific commodity by the virtual water content of this commodity in the province (or foreign nation) of export:

$$VWT_{i,j,x}^{loc} = VWC_{i,x} \cdot T_{i,j,x}^{loc} \tag{1}$$

$$VWT_{i,j,x}^{for} = VWC_{ROW,x} \cdot T_{i,j,x}^{for} \tag{2}$$

where: $VWT_{i,j,x}^{loc}$ and $VWT_{i,j,x}^{for}$ (kg_{water}) are the volume of virtual water exported from province i to province j through trade of commodity x produced locally and abroad (i.e. in the ROW), respectively. $T_{i,j,x}^{loc}$ and $T_{i,j,x}^{for}$ ($kg_{product}$) are the volume of commodity x, produced locally and abroad, respectively, and exported from i to j. $VWC_{i,x}$ ($kg_{water}/kg_{product}$) and $VWC_{ROW,x}$ are the virtual water content of commodity x produced in province i and in the ROW, respectively.

In this study, we analyze individual commodity networks and the aggregated VWT network, built by summing the VWT from all selected commodities.

1.1 Food trade model

The inter-regional trade of agricultural products was obtained from the CHINAGRO general equilibrium welfare model (*Fischer et al.*, 2007) for the 4 major crops (corn, rice, soybean and wheat) and 3 livestock products (ruminant, pork and poultry) between 8 regions of China. Several commodities are grouped by base product (rice bran and milled riced are aggregated to rice, wheat bran and wheat flour to wheat, and soybean oil and cakes to soy). CHINAGRO conducted its analysis within a modeling framework that (i) represents the consumer, producer and government decisions in the various regions, (ii) accounts for transportation costs in the economy, (iii) builds the supply response on spatially explicit assessment of the resource base and its biophysical characteristics, and (iv) describes agricultural processing and supply of farm inputs. Due to this set-up, CHINAGRO is a nationwide, regionalized applied general equilibrium (AGE)-model with a great deal of geographical detail. A distinctive feature of the CHINAGRO project is that it pays due attention to the large spatial and social diversity of the country. This goal is achieved by conducting analysis at the county level, distinguishing over 2,400 of these administrative units. The model distinguishes eight regional markets, which are linked to each other and to the world market through commodity flows. Hence, this welfare model is rather large, comprising around 50,000 truly endogenous variables including prices, as well as consumption by every consumer group (including urban and rural population and three income groups) in every region, and agricultural production and input demand for every land use type (included irrigated and rainfed cropland) in every county.

1.2 Downscaling food trade to the provincial level: linear programming optimization

CHINAGRO simulates food trade between 8 Chinese regions for years 2005, 2010, 2020 and 2030. Here we analyze the VWT network in year 2005. To obtain a more detailed and more complete representation of Chinese domestic food trade, we use an optimization model to downscale the inter-regional trade to inter-provincial trade, i.e. between the 31 Chinese provinces. By doing so, we capture a significantly larger part of domestic trade flows in China, and provide insightful information to guide water-saving trade and agriculture policies.

We use a linear programming optimization procedure, aiming at minimizing the cost of inter-provincial trade (which include transaction - due to price differences - and transportation costs) under several constraints, one of which being the compatibility of optimized inter-provincial trade with inter-regional trade simulated by the CHINAGRO welfare model. The optimization procedure is as follows.
Objective: minimizing cost of inter-provincial trade,
subject to the following constraints:

- inter-provincial trade flows are positive and we impose foreign trade with 4 harbor provinces
- supply equals demand in each province, based on local production and consumption of each commodity and on net foreign and local imports
- the sum of exports from all provinces in region N to all provinces in region M equals the inter-regional export from N to M, as simulated by CHINAGRO
- net export of local goods is bounded by local production
- net export of foreign goods is either bounded by imports from abroad if these are positive, or null if no foreign import

We implement this procedure mathematically as follows:

Minimize: $TC_c = \sum_{i,j} (t^{loc}_{i,j,c} + t^{for}_{i,j,c}) \cdot tc_{i,j,c}$

subject to:

- $\forall (i,j) : t_{i,j,c} \geq 0$; $\forall i : t_{i,i,c} = 0$ and $FI_{32,i}$ for 4 harbors i (exogenous net foreign trade)
- $\forall i \in [1:31]$:
$P_{i,c} + FI_{i,c} + \sum_{j \neq i, j=1:32} (t^{loc}_{j,i,c} - t^{loc}_{i,j,c}) + \sum_{j \neq i, j=1:32} (t^{for}_{j,i,c} - t^{for}_{i,j,c}) = D^{urb}_{i,c} \cdot pop^{urb}_i + D^{rur}_{i,c} \cdot pop^{rur}_i + OU_{i,c} + \Delta S_{i,c}$
- $\forall N, M \in [1:8] : \sum_{i \in N, j \in M} t^{loc}_{i,j,c} + t^{for}_{i,j,c} = T_{N,M,c}$

- $\sum_{j \neq i, j=1:32} (t^{loc}_{i,j,c} - t^{loc}_{j,i,c}) <= P_{i,c}$
- $\sum_{j \neq i, j=1:32} (t^{for}_{i,j,c} - t^{for}_{j,i,c}) <= max(0, FI_{i,c})$

where:

- ○ t^{loc}_c and t^{for}_c (kg_{crop}) are the unknown inter-provincial trade matrix for commodity c, produced locally and abroad (foreign), respectively,
- ○ TC_c ($Yuan$) is the total cost of inter-provincial trade of commodity c,
- ○ tc ($Yuan/kg$) is the inter-provincial trade cost matrix.
- ○ Indices i, j refer to 31 provinces and indices N, M refer to 8 regions.
- ○ $P_{i,c}$, $FI_{i,c}$, $\Delta S_{i,c}$ and $OU_{i,c}$ (kg_{crop}) are respectively province i's production, net foreign import, net stock increase and other uses of commodity c.
- ○ $D^{urb}_{i,c}$ and $D^{rur}_{i,c}$ (kg_{crop}/cap) are province i's consumers demand per capita for commodity c, respectively from urban and rural area.
- ○ pop^{rur}_i and pop^{urb}_i (cap) are respectively province i's rural and urban population.
- ○ Finally, T_c (kg_{crop}) is the inter-regional trade matrix simulated by CHINAGRO, for commodity c.

The inter-provincial transport cost is obtained through a GIS based dataset of different transportation modes (rail, river, road) between the provinces capital cities (*GIS*, 2012) and the corresponding transportation costs (*NSBC*, 2006).

We solve this optimization problem for each of the 8 commodities in year 2005 using the linear programming tool embedded in MATLAB (*MATLAB*, 2010); and obtain the corresponding inter-provincial trade matrices.

1.3 Virtual Water Content estimates

Virtual water content (*VWC*, $kg_{water}/kg_{product}$) of raw crops is defined as the evapotranspiration during a cropping period divided by the crop yield:

$$VWC_{i,c} = \frac{\overline{ET}_{i,c}}{Y_{i,c}} \quad (3)$$

where $ET_{i,c,s}$ is the average evapotranspiration over the area cultivated with crop c in country i (kg_{water}/m^2) and $Y_{i,c}$ is the yield of crop c in country i (kg_{crop}/m^2).

The VWC of unprocessed livestock products (kg_{water}/kg_{meat}) is defined as the water consumption per head of livestock (including virtual water from feed, drinking and cleaning water) divided by the livestock production per head:

$$VWC_{i,l} = \frac{WC_{i,l}}{P_{i,l}} \tag{4}$$

where $WC_{i,l}$ is the water consumption per head of livestock ($kg_{water}/head$) and $P_{i,l}$ is the livestock production per head ($kg_{livestock}/head$) in country i.

WC takes into account cleaning and drinking water as well as the VWC of the feed consumed by each animal throughout its lifetime. An important part of animal feed (i.e. maize, Carbohydrate and Protein feed mixes) is traded across provinces and national boarders. Thus, we have calculated feed VWC in each province by taking into account trade flows of maize, Carbohydrate and Protein feed mixes simulated by CHINAGRO (see 1.3.2.).

To transform the VWC of raw crops into that of a processed commodity made with that crop (e.g. soybean oil), we multiplied equation 3 by $p_x c_x / r_x$, following the method of Hanasaki et al. (*Hanasaki et al.*, 2010). The price ratio p is the ratio between the price of the raw crop and that of the commodity produced from that crop. The content ratio c refers to the fraction of crop into the commodity's ingredients. The yield ratio r indicates the fraction of crop ingredient in the raw crop. The coefficients for each commodity are listed by *Konar et al.* (2011).

1.3.1 Virtual water content of crops

Virtual water content (VWC) of crops was defined as follows. The total VWC (VWCTOT kg/yr), originated from green water (VWCG) and blue water (VWCB), was expressed as

$$VWCTOT = \frac{\overline{ET}_R + \overline{ET}_I}{Y \cdot (A_R + A_I)} \tag{5}$$

$$VWCG = \frac{\overline{ET}_R}{Y \cdot (A_R + A_I)} \tag{6}$$

$$VWCB = \frac{\overline{ET}_I}{Y \cdot (A_R + A_I)} \tag{7}$$

where A_R, A_I, and Y denote harvested area of rainfed and irrigated cropland, and crop yield respectively. $\overline{ET}_R$ and $\overline{ET}_I$ are the total amount of evapotranspiration during a cropping period from rainfed and irrigated cropland respectively (kg_{water}/yr), and expressed as follows:

$$\overline{ET}_R = \sum_c \sum_{DOY=plant}^{harvest} ET_{R,c,DOY} \cdot (A_{R,c} + A_{I,c}) \tag{8}$$

$$\overline{ET}_I = \sum_c \sum_{DOY=plant}^{harvest} ET_{I,c,DOY} \cdot A_{I,c} \tag{9}$$

where $ET_{R,c,DOY}$ is daily evapotranspiration for the date DOY (day of year) of a calculating grid cell of crop c from rainfed cropland, $ET_{I,c,DOY}$ is that from irrigated land. Subscripts $plant$ and $harvest$ denote planting and harvesting date, respectively. In this study, $A_{R,c}$ and $A_{I,c}$ were derived from MIRCA2000 (*Portmann et al.*, 2010). MIRCA2000 includes harvested area for 26 crop types with the separation of irrigated and rainfed area globally circa 2000. It covers the whole globe at the spatial resolution of 5 minute. In case Y is not available (e.g. the climate is not suited for the crop), it was substituted by the national average value. $ET_{R,c}$ and $ET_{I,c}$ were simulated using the H08 hydrological model (*Hanasaki et al.*, 2008a,b) as shown in section 1.4.

1.3.2 Virtual water content of livestock

First, the VWC of feed (F_l) for livestock products l (ruminant, pork and poultry) was calculated as follows:

$$F_l = \sum_c VWC_c \cdot f_{l,c} \tag{10}$$

where VWC_c is the virtual water content of feed products c, and c designates carbohydrate feed (CH feed), protein feed (PROT feed) and maize, as defined in CHINAGRO (*Fischer et al.*, 2007). These feed products' VWC were calculated for each province taking into account the international and domestic trade simulated with CHINAGRO, and assuming the following ingredient mix: CH feed made of rice and wheat, PROT feed made of soybean cakes, rice bran and wheat bran. Then, the livestock diets from CHINAGRO are used to calculate the resulting livestock VWC. The numbers are shown below, and are derived from the proportion of national averaged feed consumption of CHINAGRO.

Ingredients of concentrated fodder:

Share (in %)	Beef	Pork	Chicken
Maize	14	48	48
Soy	19	16	16
Rice	7	17	17
Wheat	13	13	13
Others	47	6	6

Note that VWC for other ingredients was neglected, since it is considered substantially smaller than the VWC of crops. However, for raised livestock, VWC can be expressed as

$$VWC_l = a_l \cdot F_l + b_l \tag{11}$$

where a_l is per product feed consumption, and b_l is water consumption other than feed. In the case of grazed cattle, VWC_{graze} can be expressed as,

$$VWC_{graze} = a_{graze} \cdot VWC_{pasture} \tag{12}$$

Where a_{graze} is per product pasture consumption and $VWC_{pasture}$ is VWC of pasture. Water use other than the growth of pasture is neglected for grazed cattle.

1.4 H08 hydrological model

H08 is a global water resources model which deals with both natural hydrological processes and major human activities related to water use. Complete model formulations and validation results are explained by Hanasaki et al. (*Hanasaki et al.*, 2008a,b). H08 consists of six sub-models: land surface hydrology, river routing, crop growth, reservoir operation, water withdrawal, and environmental flow requirement sub models. The land surface hydrology sub model is based on a bucket type model (*Manabe*, 1969; *Robock*, 1995). A simple subsurface flow process, which is similar to the process used by *Gerten et al.* (2004), is included. The effective flow velocity is set at globally uniform 0.5 m/s. The crop growth sub model is based on SWIM model (*Krysanova et al.*, 2000). The model uses a concept of phenological crop development model based on daily accumulated heat units, Monteith's approach (*Monteith*, 1977) for potential biomass, stress factors for water, temperature, and nutrients (*Krysanova et al.*, 2000). In this simulation, the crop growth sub model is mainly used to estimate cropping period globally.

First using the land surface hydrology model, evapotranspiration from rainfed cropland ($ET_{R,c,DOY}$) was estimated globally at daily interval, assuming that all of the grid cells contained cropland. Second, using the same model, evapotranspiration from irrigated cropland ($ET_{I,c,DOY}$) was estimated similarly, assuming that all of the grid cells contained irrigated cropland. In irrigated cropland, the soil moisture is kept higher than 75% of field capacity throughout a year with unrestricted water supply. Third, using the crop growth model, planting and harvesting date of four crops was estimated globally. We assumed that all of four crops were sown in all of the grid cells (e.g. rice is sown even in arctic). We repeated simulations for 365 times by shifting planting date from January 1 to December 31. The crop growth model judges the suitability of climate condition for crop growth at a daily interval. It kills crops when and where its climate condition is not suited (e.g. rice sown on January 1 in arctic is killed). It calculates the growth of crops at daily interval. When the crop is matured, the date and crop yield is recorded. After finishing 365 simulations, the crop yield of twenty-one days running mean was calculated for each planting date, and the date that produced the maximum crop yield was assumed as planting date. The performance of this simulation has been evaluated in the work of *Hanasaki et al.* (2008b).

In each 0.5 ° by 0.5 ° grid cell, the crop-wise rainfed and irrigated harvested area (*Portmann et al.*, 2010) were fixed circa year 2000, for which detailed data is available (5 minute spatial resolution). Meteorological information is input from the GMFD (*Sheffield et al.*, 2006), with precipitation, temperature, relative humidity and radiation averaged around year 2005 (2003-2007).

To ensure consistency between the crops VWC values estimated by the H08 model and the trade volumes obtained from the CHINAGRO model, which produces province-level crop production estimates, crop yield per area sown from CHINAGRO was used as the crop yield per area (Y) in calculations of province-level crops VWC (Equation 3). Thus, each crop's yield per area sown (irrigated and rainfed cropland, *Fischer et al.* (2007)) is used to scale crop yield up to the province level.

2 Results

2.1 Virtual Water Content across China

The virtual water content (or water footprint) of each commodity varies significantly across provinces of China. Moreover, the share of different water resources, i.e. green water (rainfall) and blue water (irrigation), also changes from province to province. We analyze each sub-network (VWT network associated with trade of a specific commodity) separately and find that some major exporters use more water than others (higher crop VWC) to produce the same commodity, and sometimes even larger amounts of blue water (Tables S1-S7, Fig S1 and S2). This is the case for corn and soy production in Inner Mongolia (Tables S1 and S3), for rice production in Heilongjiang and Jilin (Table S2), and for pork in Hebei (Table S6).

2.2 Inter-provincial Virtual Water Trade from major crops and livestock in 2005

When analyzing the complete VWT network (build by summing individual commodity networks), we find that all provinces participate in the trade with considerable importance. Indeed, the range of VWT volumes associated with each province (node's strength, i.e. VW imports and exports of a province) is relatively narrow $[10^8 : 10^{10}]$ compared to the range observed in the international VWT network $[10^5 : 10^{11}]$. We still identify important exporters and importers (Tables S8, S9) and trade relationships (Table S10). When analyzing VWT networks associated with each specific commodity, we observe different patterns (Fig S3-S9), with more heterogeneity that in the complete network. This makes sense since some provinces might be specialized in one product and not produce much of others. We observe the importance of international imports of soy-based commodities, including soybean oil, and soybean cakes for animal feed (Fig S5). Virtual water flows associated with international trade and domestic trade of foreign commodities are shown on Figure S10. We also observe the very localized production of rice in a few neighboring provinces (Fig S1 and S4). Top exporters and importers are shown in Tables S8-9, and shown broken down by product in Tables S1-7. Top VWT links are also shown in Table S10.

2.3 Water savings from major crop and livestock inter-provincial trade in 2005

Considering VWT associated with the *domestic* trade of local wheat, rice, corn, soy, ruminant, pork and poultry, China inter-provincial trade leads to water savings of 2.8 km^3. As compared to a provincial autarky situation, 5.9 km^3 of rainfall water are saved, but 3.1 km^3 of irrigation water (drawn from rivers, reservoirs or subsurface aquifers) are lost (see Fig 4-a). We show the relative role of each exporting province in these national water savings and losses in Tables S12 and S13.

The trade of wheat is the most efficient, saving both blue and green water resources, 7.7 km^3 in total. Inter-provincial trade of corn shows the largest gap between green water savings (9.1 km^3) and blue water loss (8.2 km^3). This suggests that major corn exporters rely more on irrigation for corn production than their importing partners do, but use less rainfall water than these partners would. With much smaller volumes of water involved, domestic trade of poultry also saves green water (0.8 km^3) and loses blue water (0.4 km^3). The pattern is the opposite for rice trade, which saves blue water resources (2.8 km^3) while losing green water (3.7 km^3). Trade of local soy, ruminant meat, pork are inefficient for all sources of water, losing 0.006, 1.8 and 1.4 km^3 of green water, and 0.6, 0.6 and 0.9 km^3 of blue water, respectively.

Considering VWT associated with the *domestic and international* trade of local and foreign wheat, rice, corn, soy, ruminant, pork and poultry, China inter-provincial trade leads to water savings of 47 km^3. As compared to a provincial autarky situation, 28 km^3 of rainfall water and 20 km^3 of irrigation water (drawn from rivers, reservoirs or subsurface aquifers) are saved (see Fig 4-b).

Most products trade show virtually unchanged water savings and losses compared to the domestic situation, except soy trade. Indeed, the trade of soy becomes the most efficient system, saving both blue and green water resources, 41 km^3 in total.

Top water savings trade relationships are shown in Table S11.

References and Notes

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Supporting Figures and Tables

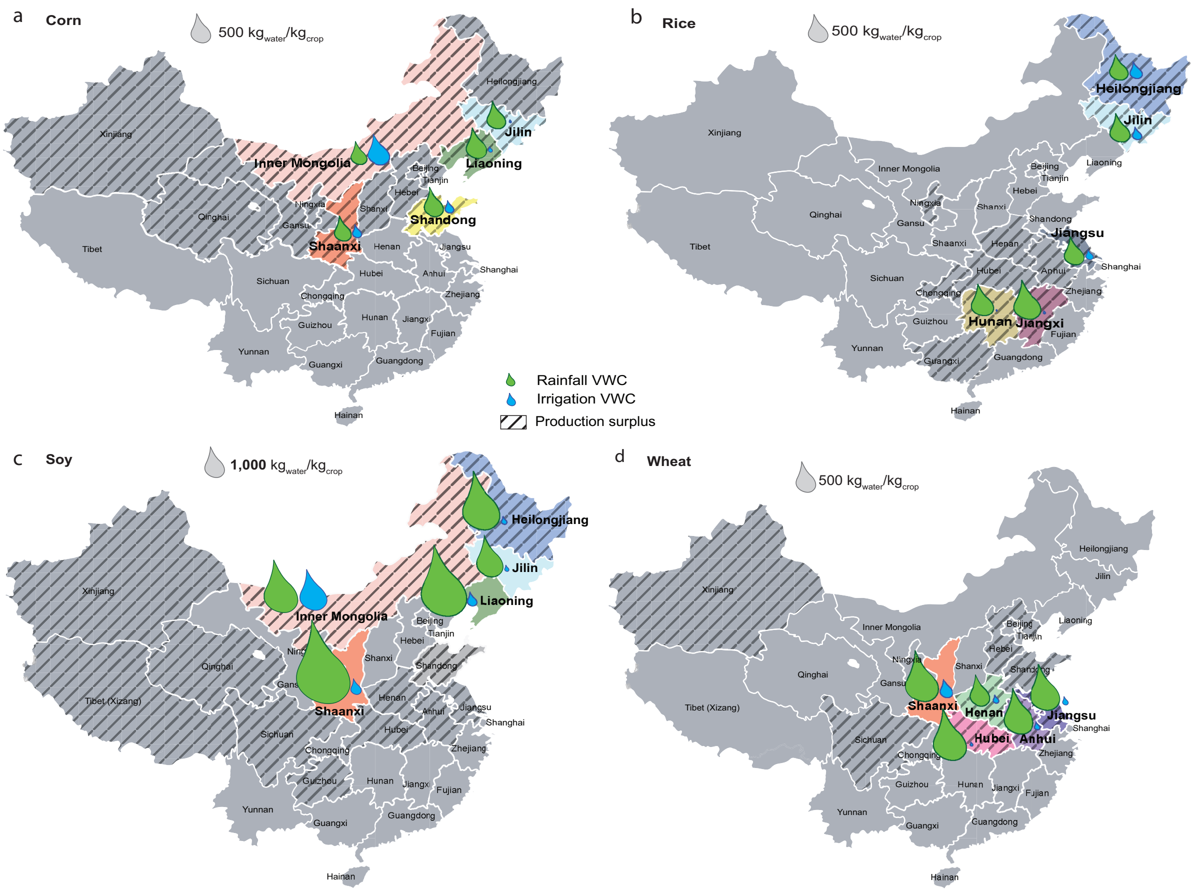

Fig. S1 Virtual Water content (VWC) of Corn, Rice, Soy and Wheat in the top 5 exporting provinces (in units of domestic commodity weight) in 2005. Blue and green drops indicate the volumes of VWC from irrigation sources and rainfall, respectively. Hatched provinces present higher local production (in weight) than consumption.

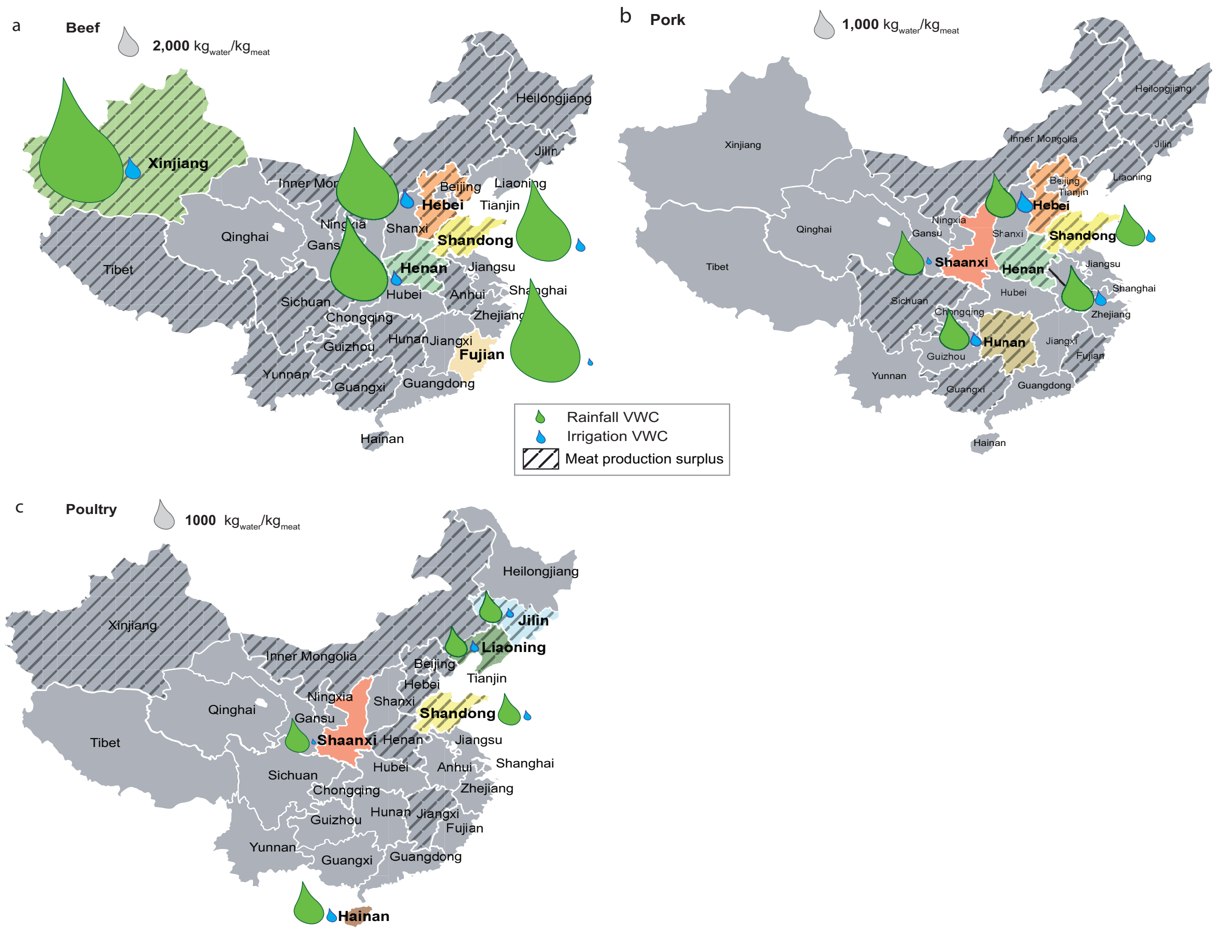

Fig. S2 Virtual Water content (VWC) of Ruminant, Poultry and Pork in the top 5 exporting provinces (in units of domestic commodity weight) in 2005. Blue and green drops indicate the volumes of VWC from irrigation sources and rainfall, respectively. Hatched provinces present higher local production (in weight) than consumption.

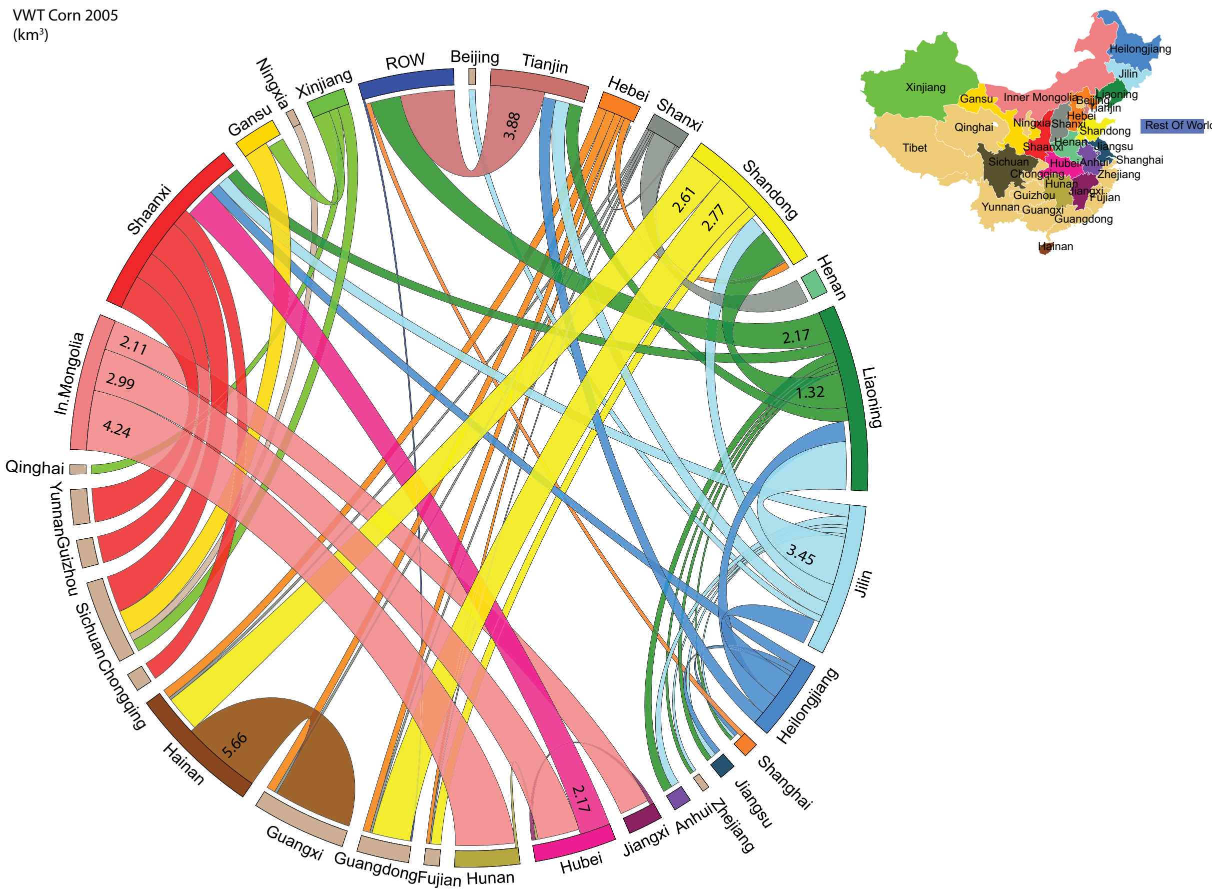

Fig. S3 VWT associated with corn.

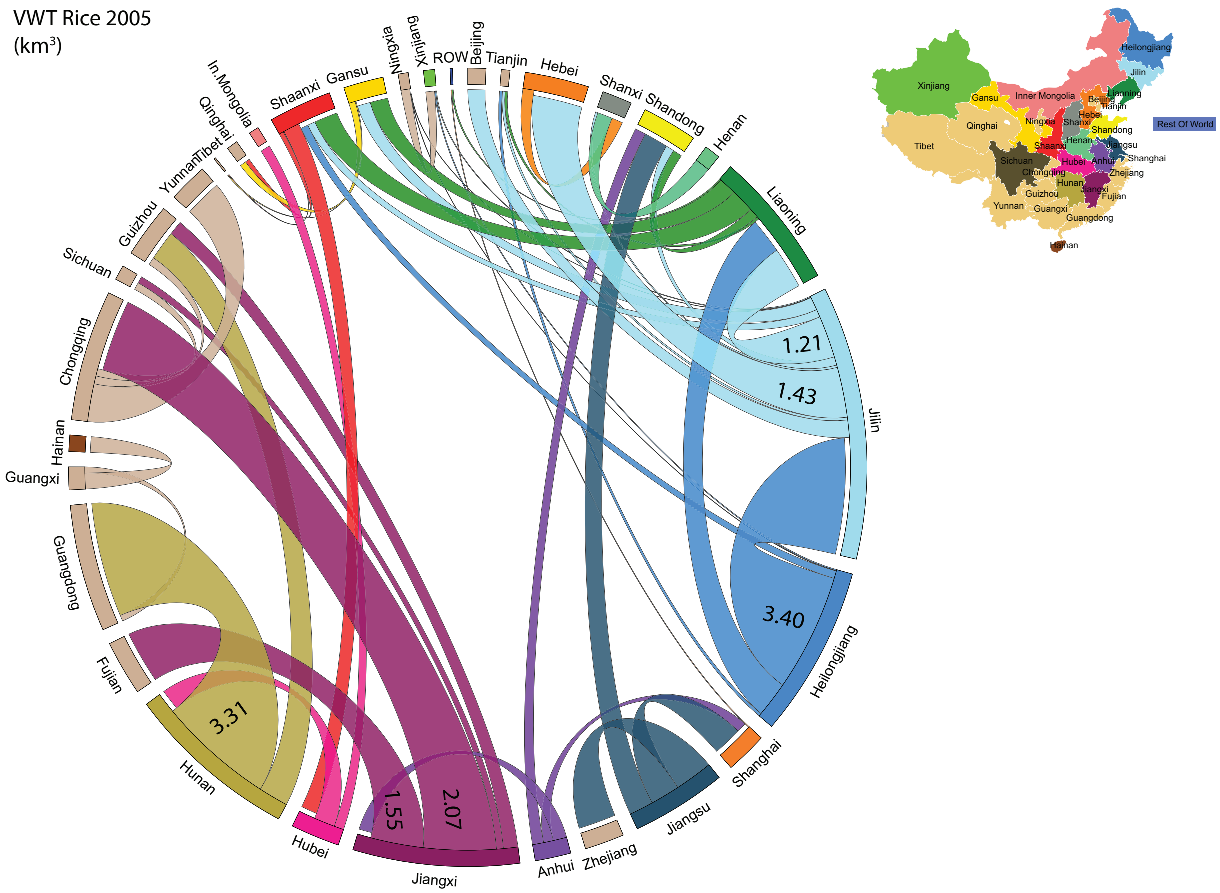

Fig. S4 VWT associated with rice.

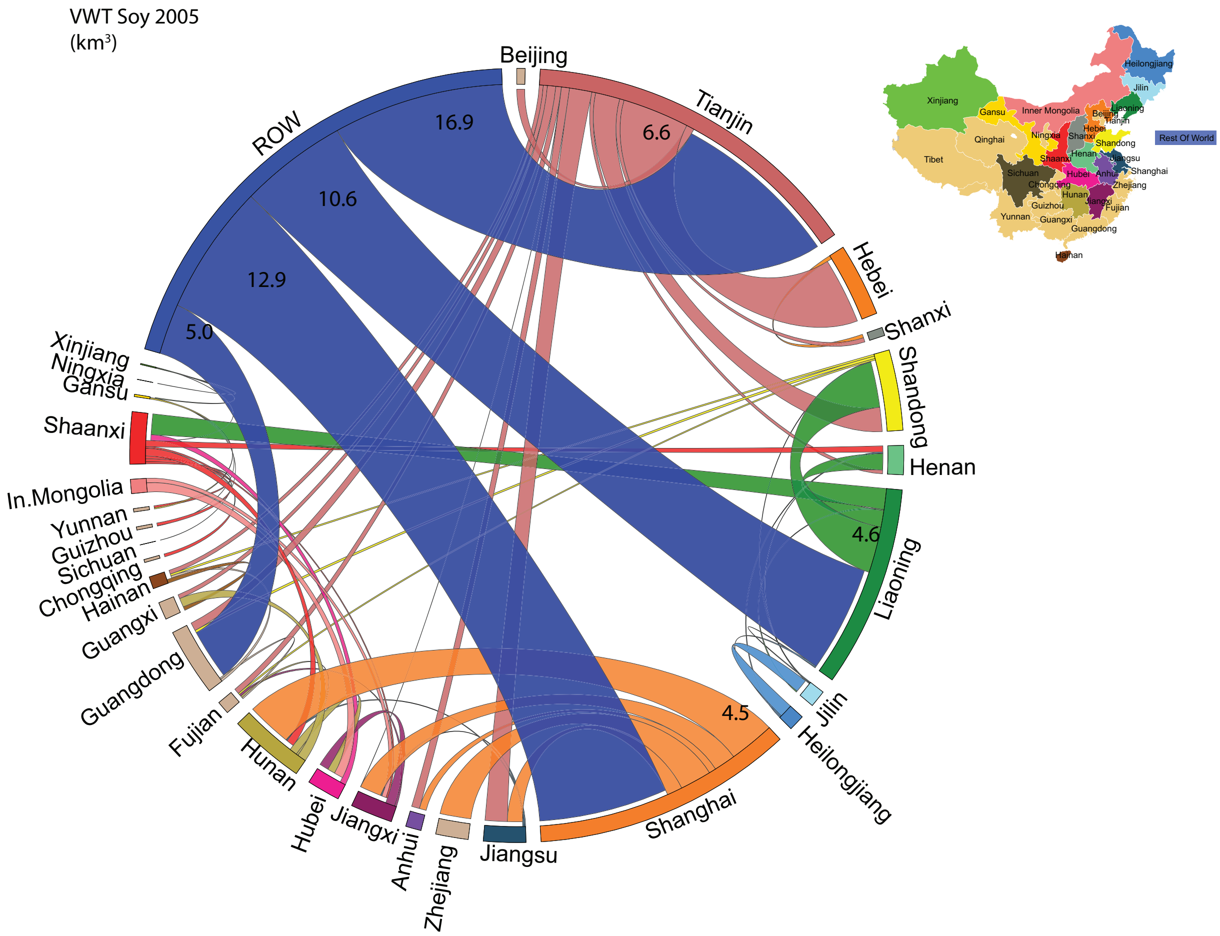

Fig. S5 VWT associated with soy.

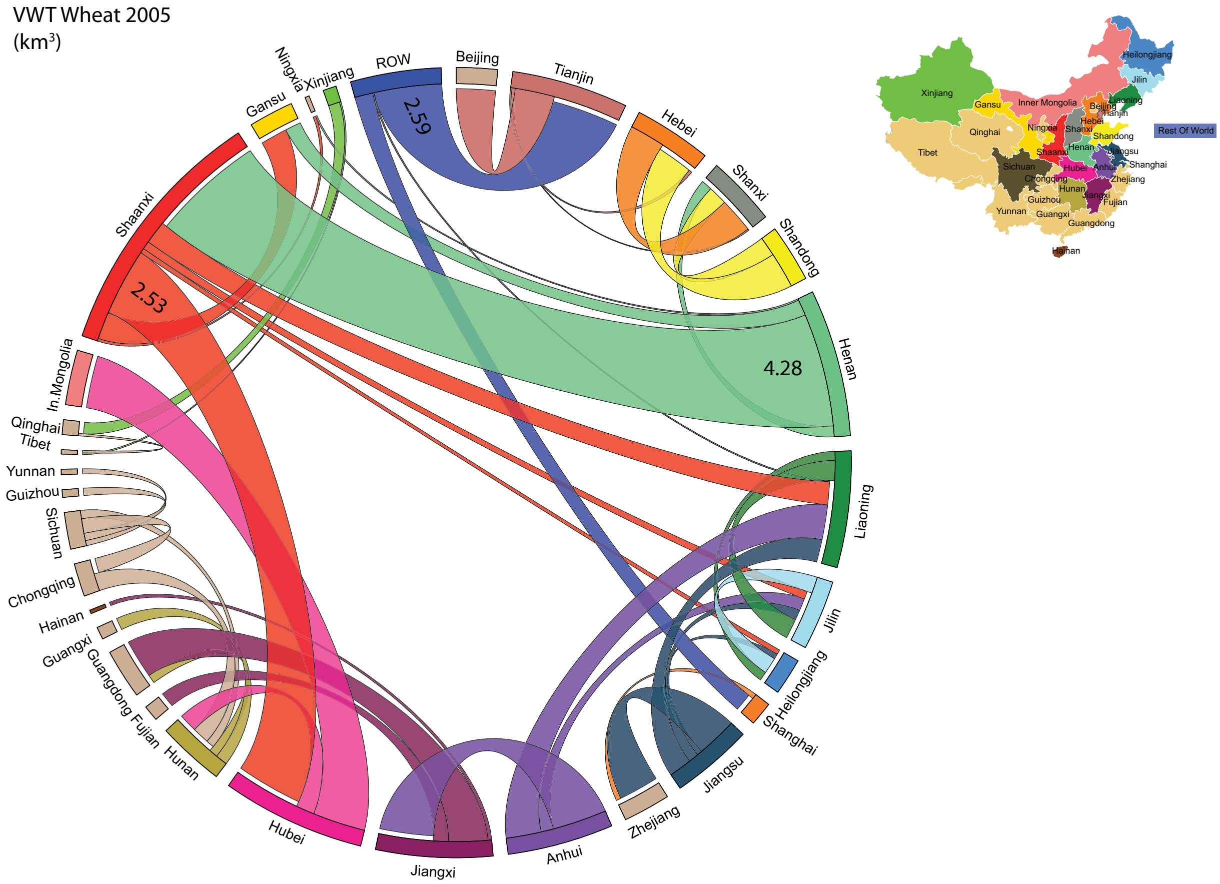

Fig. S6 VWT associated with wheat.

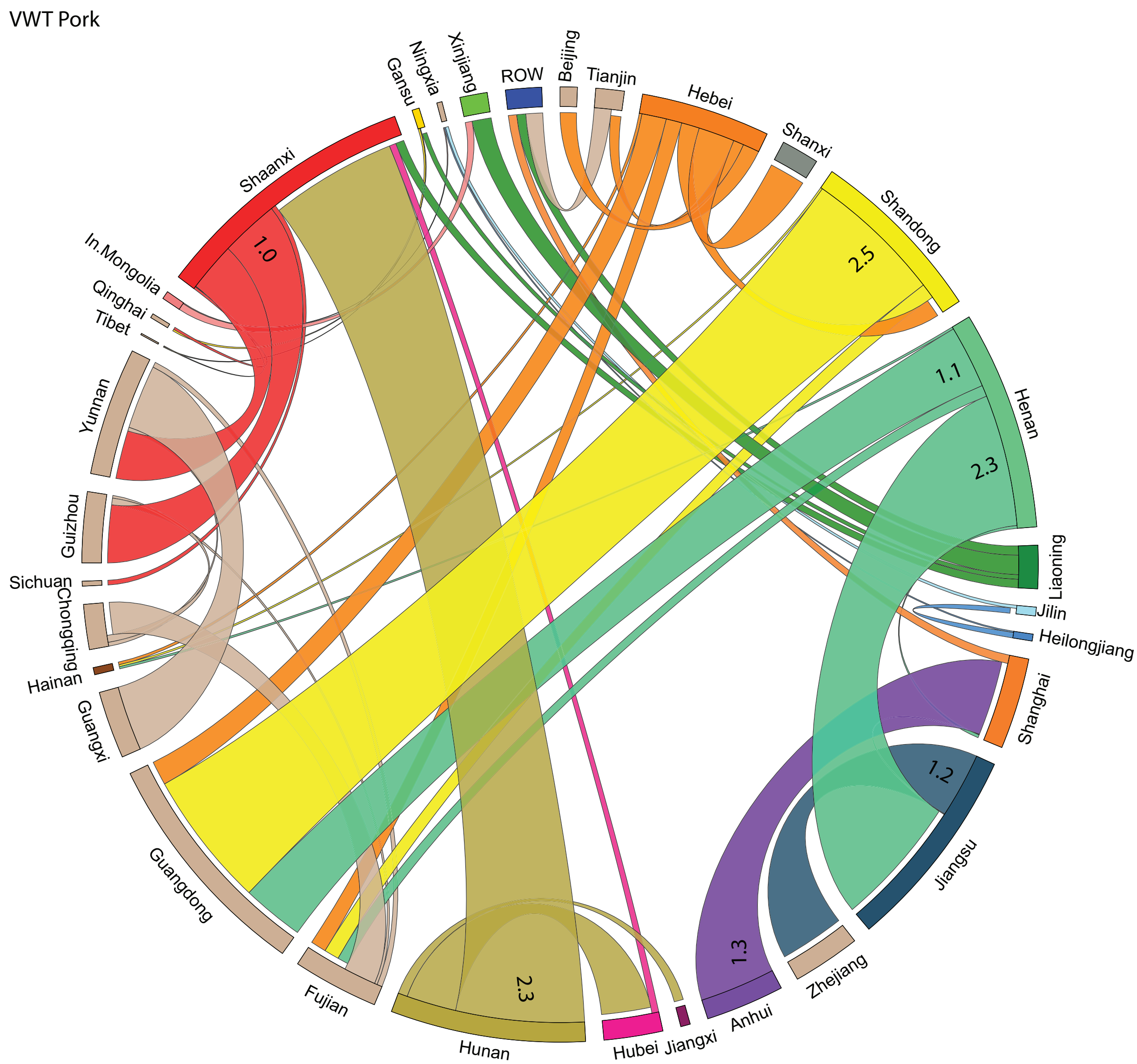

Fig. S7 VWT associated with pork.

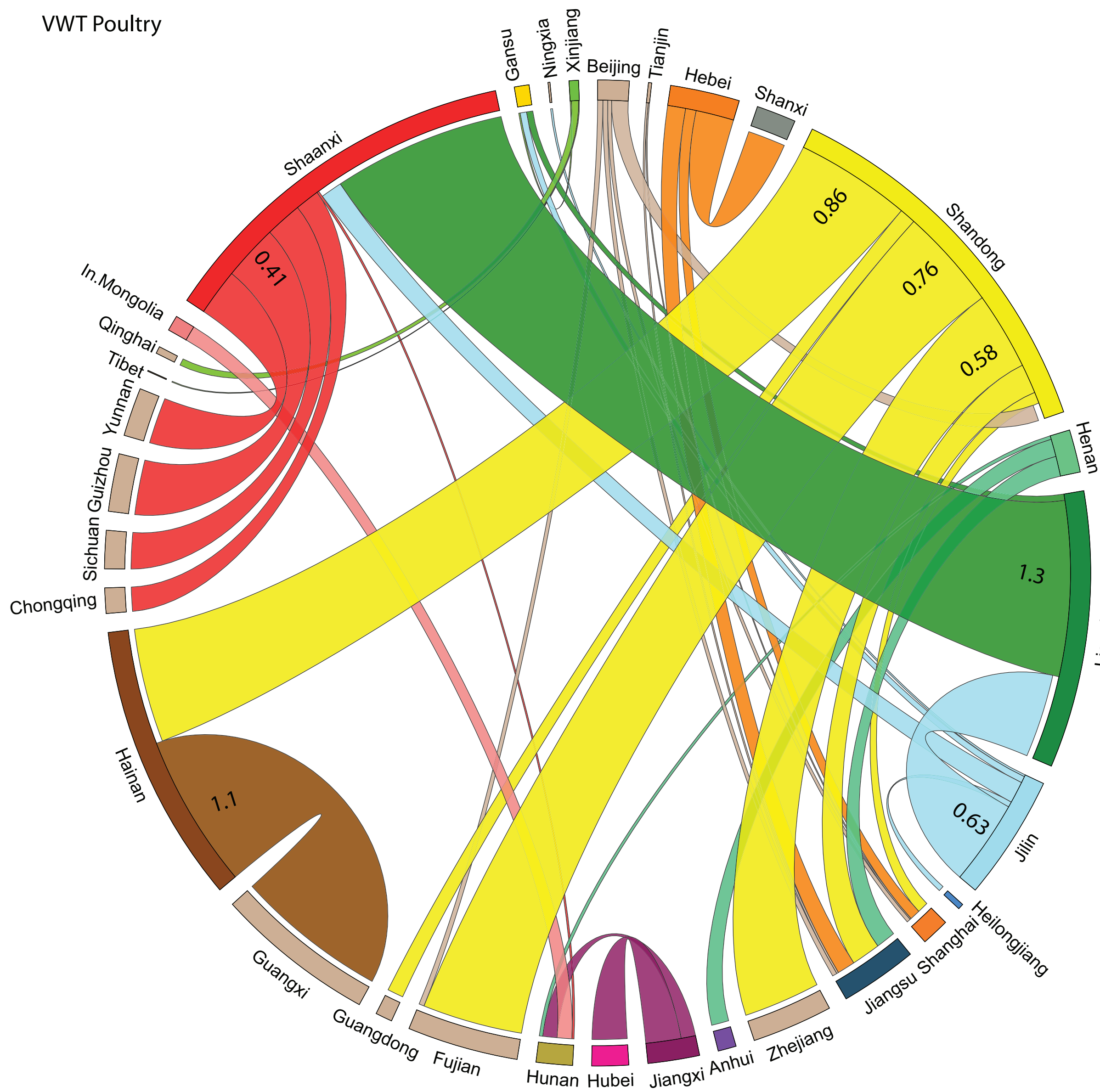

Fig. S8 VWT associated with poultry.

VWT Ruminant Meat

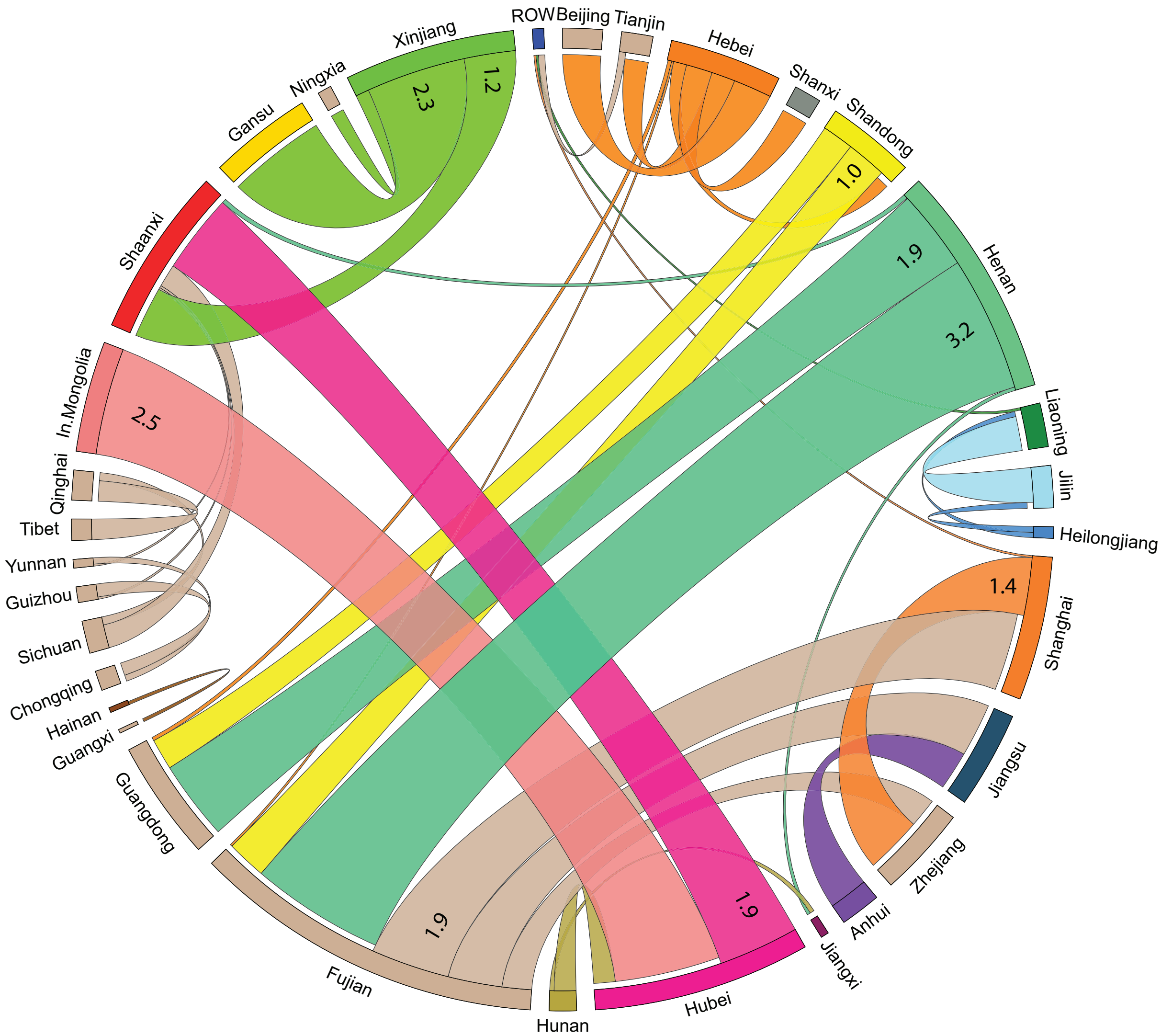

Fig. S9 VWT associated with ruminant meat.

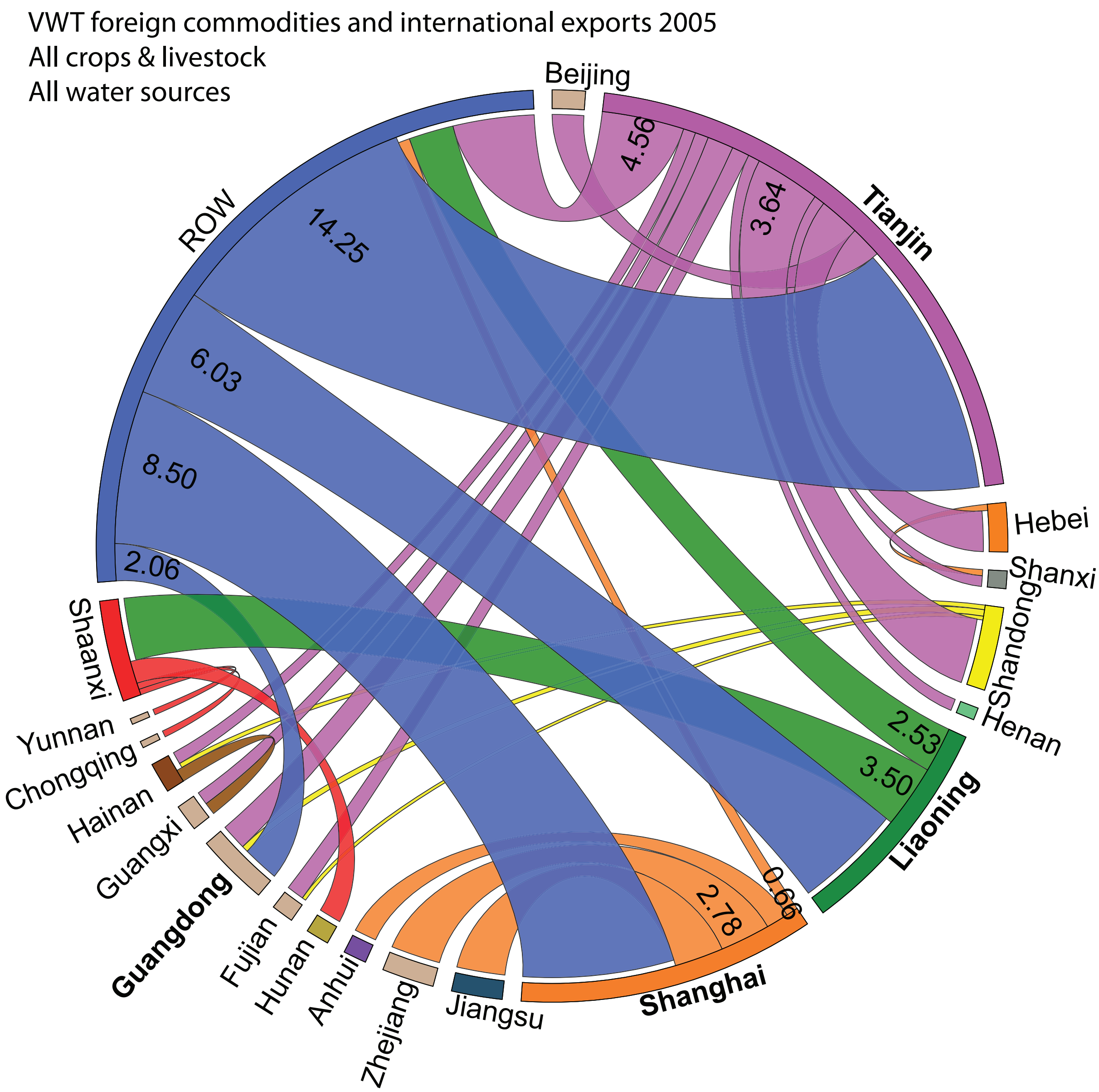

Fig. S10 VWT associated with direct international trade (exports from harbors to the ROW, imports from the ROW to harbors) as well as with *domestic re-export of foreign commodities*.

Rank	Top exporter corn	VWC (kg_{water}/kg_{crop})	green VWC	blue VWC
1	Inner Mongolia	955	405	550
2	Jilin	519	467	52
3	Shaanxi	843	598	245
4	Shandong	725	503	222
5	Liaoning	621	520	101

Table S1. Virtual water content (VWC) of corn for top corn exporting provinces (in units of domestic commodity weight), indication of green and blue water resources portions. *The blue and green VWC might not exactly sum up to total due to rounding of values.*

Rank	Top exporter rice	VWC (kg_{water}/kg_{crop})	green VWC	blue VWC
1	Heilongjiang	731	607	124
2	Hunan	703	668	35
3	Jiangxi	963	880	83
4	Jilin	519	467	52
5	Jiangsu	916	749	167

Table S2. Virtual water content of rice for top rice exporting provinces(in units of domestic commodity weight), indication of green and blue water resources portions.

Rank	Top exporter soy (domestic)	VWC (kg_{water}/kg_{crop})	green VWC	blue VWC
1	Heilongjiang	2169	1899	270
2	Inner Mongolia	3093	1714	1379
3	Liaoning	2799	2323	476
4	Shaanxi	3261	2727	534
5	Jilin	1575	1355	220

Table S3. Virtual water content of soy for top soy exporting provinces (in units of domestic commodity weight), indication of green and blue water resources portions.

Rank	Top exporter wheat	VWC (kg_{water}/kg_{crop})	green VWC	blue VWC
1	Henan	653	514	139
2	Shaanxi	1149	831	318
3	Anhui	879	743	136
4	Jiangsu	888	745	143
5	Hubei	905	837	68

Table S4. Virtual water content of wheat for top wheat exporting provinces (in units of domestic commodity weight), indication of green and blue water resources portions.

Rank	Top exporter ruminant meat	VWC (kg_{water}/kg_{meat})	green VWC	blue VWC
1	Henan	6669	5663	1006
2	Xinjiang	9868	8336	1532
3	Fujian	7404	6920	484
4	Hebei	7468	6174	1293
5	Inner Mongolia	11308	10424	884

Table S5. Virtual water content of ruminant meat for top ruminant meat exporting provinces (in units of domestic commodity weight), indication of green and blue water resources portions.

Rank	Top exporter pork	VWC (kg_{water}/kg_{meat})	green VWC	blue VWC
1	Henan	2127	1575	552
2	Hunan	1981	1465	516
3	Shandong	1882	1435	447
4	Hebei	2303	1542	763
5	Shaanxi	1794	1543	250

Table S6. Virtual water content of pork for top pork exporting provinces (in units of domestic commodity weight), indication of green and blue water resources portions.

Rank	Top exporter poultry	VWC (kg_{water}/kg_{meat})	green VWC	blue VWC
1	Shandong	1457	1107	350
2	Liaoning	1475	1077	398
3	Shaanxi	1389	1192	196
4	Hainan	1973	1484	489
5	Jilin	1462	1120	342

Table S7. Virtual water content of poultry for top exporting provinces (in units of domestic commodity weight), indication of green and blue water resources portions.

Rank	Top exporter	VWE (km^3)
1	Shaanxi	19.6
2	Liaoning	18.9
3	Tianjin	17.7
4	Shandong	15.9
5	Henan	15.1

Table S8. Top virtual water exporters (includes foreign commodities).

Rank	Top importer	VWI (km^3)
1	Shaanxi	20.6
2	Guangdong	16.7
3	Shandong	14.0
4	Hubei	13.4
5	Hunan	12.2

Table S9. Top virtual water importers (includes foreign commodities).

Rank	Top link	VWT (km^3)
1	ROW to Tianjin	19
2	ROW to Shanghai	14
3	ROW to Liaoning	11
4	Liaoning to Shaanxi	7.5
5	Hainan to Guangxi	7.3

Table S10. Most important trade relationships in terms of VWT (virtual water trade) volume (includes foreign commodities).

Rank	Top link	WS (km^3)
1	ROW to Tianjin	14
2	ROW to Liaoning	8.7
3	Tianjin to Hebei	5.0
4	Shangdong to Hainan	3.5
5	Henan to Shaanxi	3.2

Table S11. Most important trade relationships in terms of WS (water savings) volume (includes foreign commodities)).

Exporter	WS blue (m^3)
Beijing	-2.10e+07
Tianjin	1.64e+07
Hebei	-6.58e+08
Shanxi	3.51e+07
Shandong	-9.00e+08
Henan	1.28e+09
Liaoning	1.94e+09
Jilin	3.62e+09
Heilongjiang	-1.72e+08
Shanghai	-8.28e+06
Jiangsu	1.42e+08
Zhejiang	1.64e-01
Anhui	7.86e+08
Jiangxi	-3.44e+08
Hubei	3.03e+09
Hunan	-1.93e+07
Fujian	-1.53e+08
Guangdong	3.33e+07
Guangxi	2.10e+08
Hainan	-1.13e+09
Chongqing	5.90e+08
Sichuan	-1.70e+07
Guizhou	-1.63e+06
Yunnan	-8.03e+06
Tibet	4.26e+07
Qinghai	-2.80e+07
InnerMongolia	-5.38e+09
Shaanxi	-2.66e+09
Gansu	-1.16e+09
Ningxia	-4.02e+08
Xinjiang	-1.81e+09

Table S12. Blue water savings associated with domestic exports of local goods, by exporting province, for all crops and livestock commodities.

Exporter	WS green (m^3)
Beijing	1.03e+07
Tianjin	-1.81e+07
Hebei	9.43e+08
Shanxi	7.83e+08
Shandong	1.74e+09
Henan	2.58e+09
Liaoning	2.97e+08
Jilin	1.35e+09
Heilongjiang	-6.22e+08
Shanghai	-1.35e+08
Jiangsu	6.65e+08
Zhejiang	5.93e-03
Anhui	3.73e+08
Jiangxi	-2.07e+09
Hubei	-9.12e+08
Hunan	-3.46e+09
Fujian	3.81e+08
Guangdong	1.56e+08
Guangxi	7.77e+06
Hainan	-1.43e+09
Chongqing	4.50e+05
Sichuan	9.51e+08
Guizhou	-5.54e+07
Yunnan	-4.95e+07
Tibet	-1.85e+08
Qinghai	1.44e+07
InnerMongolia	2.22e+09
Shaanxi	1.46e+09
Gansu	6.90e+08
Ningxia	2.68e+08
Xinjiang	-2.00e+07

Table S13. Green water savings associated with domestic exports of local goods, by exporting province, for all crops and livestock commodities.