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Chapter 13:

**Interactions between Resource Scarcity and Trade Policy:
The Potential Effects of Water Scarcity on China's
Agricultural Economy under the Current TRQ Regime**

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Chapter 13:**Interactions between Resource Scarcity and Trade Policy:
The Potential Effects of Water Scarcity on China's
Agricultural Economy under the Current TRQ Regime*****Introduction**

China is facing acute problems managing water resources. Falling ground-water tables and disruption of surface-water deliveries to important industrial and agricultural regions have raised concern that a more dramatic crisis is looming unless effective water conservation policies can be put into place rapidly. Water shortages are confined to a relatively limited geographic area in northern China which is a major production area for wheat, corn and cotton.¹ China is among the world's largest producers and consumers of these crops and current production levels in northern China rely heavily on supplemental irrigation. A variety of policies to improve water management and encourage conservation are being established in China but to date there is little macro-level evidence that these policies are effective. The success or failure of water management reforms could have significant implications for China's production, consumption and international trade in these commodities.

This chapter provides an overview of how water scarcity could affect China's agricultural production and trade. It provides both a detailed description of water scarcity issues in China augmented by results from modeling scenarios of water shortages in northern China under current trade policies. The chapter identifies the areas in northern China where available water resources are most overexploited, the nature of the threat to water resources for agriculture, and the crops most vulnerable to reductions in irrigation in that region. We review, and briefly comment on, the limited research on the impact of water scarcity on agricultural production and trade in China to date. To contribute to the research findings, we use the Economic Research Service (ERS) China model to examine scenarios of falling irrigation water availability in northern China and estimate the effect this will have on China's overall production,

* The views expressed are those of the authors and do not necessarily correspond to the views or policies of Economic Research Service, United States Department of Agriculture.

¹ Southern China and far northeastern China have relatively abundant water resources, except during infrequent periodic droughts.

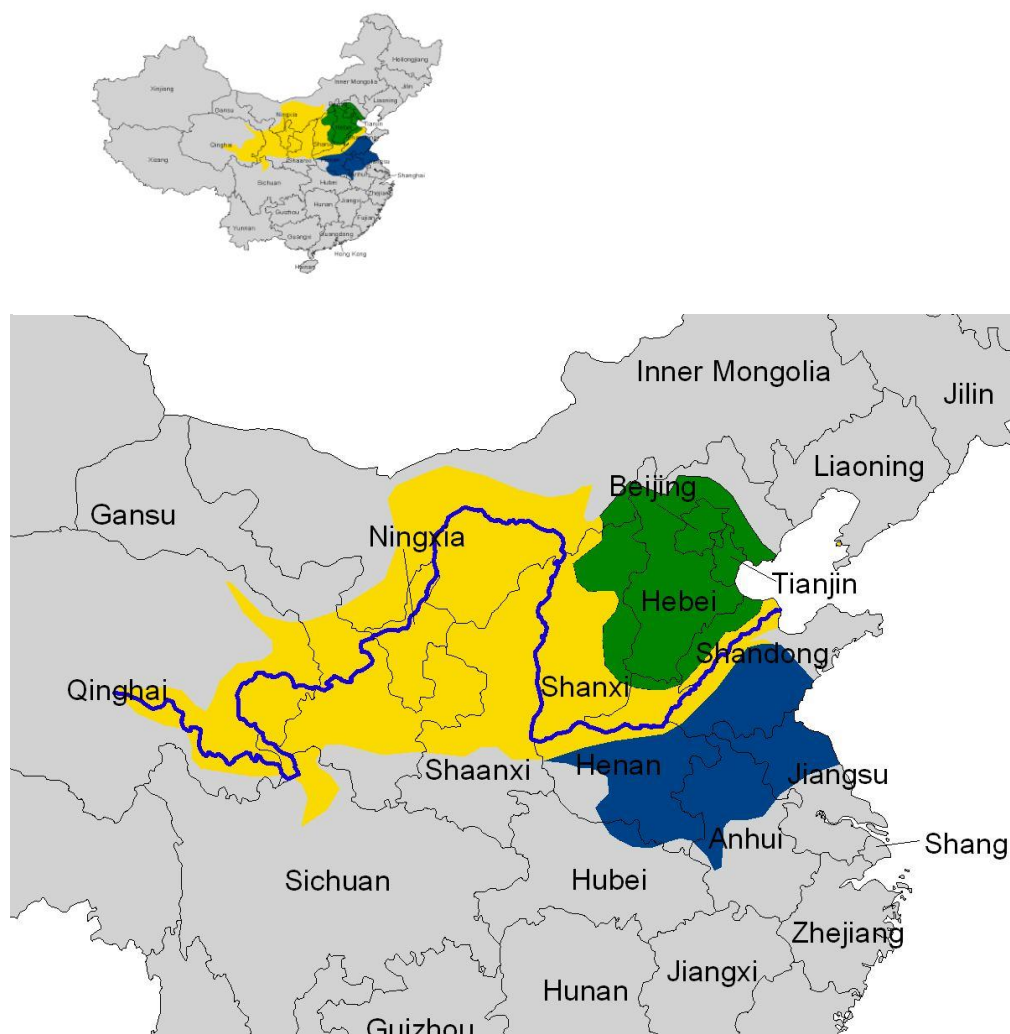
consumption and trade of wheat, corn and cotton. The ERS China model is a detailed agricultural partial equilibrium dynamic simulation model and is part of the Country-Commodity Linked System (CCLS) of 38 countries and regions used for annual United States Department of Agriculture's (USDA) Long-term projections.

Our findings indicate that China's large agricultural economy has substantial capacity to adapt to production decreases in the water-short north by increasing production in other parts of China, decreasing consumption as well as increasing imports. Under China's current trade regime of tariff-rate quotas (TRQs) for these commodities, declining production in northern China will increase prices and increase demand for imports, but the demand for imports will be partially offset by increased production in less water-stressed parts of China. Higher prices will also induce consumption decreases as China still has many low-income consumers who are price sensitive. Thus, even under scenarios of large decreases in irrigated area in the north, imports rise much less than the induced production shortfalls. The role of China's TRQ regime for imports is critical in maintaining relatively inelastic import demand that serves to drive prices up as production declines in the north yet reduce demand for imports as a means to adjust to production shortfalls.

Water Scarcity and Irrigated Agriculture in China

China, overall, is moderately well endowed with water but the water is unevenly distributed geographically. As with arable land, China's total water resources are close to those of the United States, roughly 2,800 billion cubic meters (bm³) of total exploitable water resources per year (FAO). However, having a much larger population, China's per-capita water resources are roughly 2,200 m³, about one quarter that of the United States, which is close to the world average. Still, China's overall per capita water endowment is well above water scarce endowment levels which tend to range between 1,500-1,700 m³ per capita for moderate water scarcity (Liu, 1998). Similar to the United States, China's water is disproportionately distributed: areas south of and including the Chang (Yangtze) River Basin, and in the far northeast, contain about 90% of China's water. The productive agricultural areas in northern China, however, possess only about one tenth the world levels of water per capita and are well below international standards for water scarcity on a per capita basis. Agriculture is most threatened by water scarcity in the area commonly referred to as the North China Plain, the productive grain belt centered in northern Henan and Shandong and southern Hebei Provinces.

Figure 1: Water Scarcity in China is Concentrated in the Hai, Huang (Yellow) and Huai River Basins in North China.



The river systems that supply water to the North China Plain include the Hai, Huang (Yellow), and Huai River Basins (Figure 1). These three river basins are the site of over one third of China's population and nearly one third of China's industrial production, but only hold around one tenth of China's water resources. Major field-crops in this region include wheat, corn and cotton, with the region producing roughly two-thirds, two fifths and one half of China's total production of these three crops, respectively. This area is also increasingly producing horticultural crops including apples, pears, peaches and a variety of greenhouse and field vegetables such as asparagus, onions (both round and green) and peanuts. Traditionally this region is known as an area with severe periodic floods (severe flooding in the region

occurred as late as the 1960s), but increasing water diversions for agriculture, industry and urban domestic use has greatly reduced river flows and the potential for floods. Year-to-year rainfall variability, coupled with the concentration of the region's rainfall in the late summer months (roughly 70% of rainfall in the North China Plain falls in July, August and September), leaves open the possibility of local flooding during this period despite the stresses caused by the heavy exploitation of water resources.

The Hai River Basin is an area where water shortages are most severe. The Hai River Basin, centered on Hebei Province, refers to a number of tributaries that flow into a short sea channel in Tianjin known as the Hai River (Figure 1, green area). Underlying this surface water structure is a complex set of overlapping aquifers, with varying recharge rates. Major urban areas in the Hai River Basin are drawing down the groundwater table to an extent that many have experienced land subsidence as a result.² On top of rising urban demand, irrigated area has increased over the last 40 years due to widespread establishment of tube-wells powered by electric or diesel pumps. The number of tube-wells in China grew from 150 thousand in 1965 to more than 2.3 million by the late 1970s, with most of these concentrated on the North China Plain (Shi, 2000), and this number has most likely risen dramatically since that time. The expansion of irrigation not only has allowed for higher yields, but also allows farmers to double crop, generally winter wheat followed by corn. The Hai River Basin became a major wheat-producing region as irrigated area increased. Extensive irrigation, coupled with urban and industrial demand for water, have drawn down the water tables throughout the basin at increasing rates, exceeding three meters per year in some rural regions in the 1990s (Wang and Huang, 2002). Exploitation of the groundwater is most severe in the central part of the Basin, and saltwater intrusion and poor drainage are causing salinization in the center and eastern parts of the region. Surface water is also over-exploited. Cangzhou, a downstream prefecture in Hebei Province, receives less than 10% of the surface water deliveries received in the 1970s (Lohmar and Crook, 2002). Similar examples of overexploited surface water resources can be found throughout the basin.

Water resources in the Yellow River Basin also show signs of over-exploitation. The Yellow River meanders from its headwaters on the edge of the Tibetan Plateau in Qinghai Autonomous Region, turns north through the steppe and desert provinces and autonomous regions of Gansu,

² In addition to Beijing (population 13 million) and Tianjin (population 9 million), there are three other cities with urban populations over 1 million and five with urban populations between 500,000 and 1 million in the basin.

Ningxia and Inner Mongolia, turns south along the Shaanxi and Shanxi Provincial border, then turns east again and towards the ocean through northern Henan and Shandong Provinces (Figure 1, in yellow). A few large upstream irrigation districts in Gansu, Ningxia and Inner Mongolia developed over the last few decades now draw off large amounts of water to irrigate agricultural areas that are substantially less productive than downstream areas. Upstream areas increasingly exploit their access to water for industrial development as well. Since the early-1970s, water in the Yellow River has often been drawn off to such an extent that the river did not flow into the ocean for part of the year. In 1997 and 1998, over-exploitation was particularly acute, the river did not reach the ocean for over 220 days in both years, and the dry stretch reached as far as 700 kilometers inland (Liu, 1998; Liu, 1999). When this happens, farmers in the productive downstream provinces of Shandong and Henan are denied surface water for part of the irrigation season. Since 1999, however, the river has been more tightly managed so that it does not run dry, but downstream sluice gates leading to irrigation districts may be abruptly closed when the river flow reaches a minimum threshold in those areas (this minimum threshold is often referred to as environmental flow).

The Huai River Basin also suffers from poor drainage and acute pollution, in addition to over-exploitation and water shortages during dry periods. For roughly 700 years prior to 1857, the Yellow River flowed to the East China Sea through this region, and built up large deposits of silt, ultimately causing it to change course for its current route through Shandong to the north. However, the silt deposits left by the Yellow River obstructed the drainage from the tributaries that remained primarily the Huai River, but also the many smaller rivers and tributaries in the basin. Thus, much of the drainage in this region does not flow directly into the ocean. Instead the main water flow is into Hongze Lake, where it then is diverted south to the Yangtze River. In the past few decades, a man-made channel has been built to divert some Huai River water directly to the East China Sea, and some gets diverted to the former Grand Canal, which serves to bring water from the Yangtze to more arid northern Jiangsu (and will ultimately comprise the eastern route of China's South-North water transfer program). Because of the siltation, drainage as well as water shortages are a problem in this basin, and periodic floods still occur after incidences of severe rainfall. However, even in normal years, water resources in this region are heavily taxed by the large population and extensive irrigation, and surface water sources may dry-up or become unusable for irrigation.

Irrigation in this region allows farmers to not only increase yields but also plant two crops a year. Precipitation on the North China Plain is unevenly distributed throughout the year, with 70% of the rainfall arriving in the three-month period from July-September. Single season corn and summer sown cotton can be grown in this period without supplemental irrigation. With irrigation, however, farmers can grow a second crop in the spring, usually winter wheat, and still realize satisfactory yields. Winter wheat is irrigated roughly 4-5 times, once in the fall after planting, then 3-4 times in the spring when rainfall is low, and is harvested in June. If rainfall is still low after planting corn in late June, and if water is available, farmers may also irrigate corn or whatever second crop they choose to grow, to get the seedlings started, but the bulk of corn production occurs during the period with adequate rainfall. Spring-sown cotton in the North China Plain also relies on supplemental irrigation in the spring, but can withstand a dry spell before the rainy season.

Understanding these features of China's water issues is important for understanding how water scarcity may affect China's agricultural economy. Water scarcity in China is extremely localized. Most of China has sufficient water, and some of China has too much water so that flooding and drainage issues take priority over conservation. But in areas in and around the North China Plain, water resources are scarce on both a per capita and per land basis. Largely because of the regional aspect of water scarcity in China, increasingly stressed water resources affects some crops more than others. For example, China's overall production of rice and soybeans is less sensitive to water stress because only a small percentage of those crops are produced in water-stressed regions. But major shares of China's wheat, corn, and cotton crops are produced in the regions facing water scarcity, thus are more exposed to a deterioration of the water availability for agriculture. Moreover, even among these crops there are important differences, with some crops being more or less vulnerable to disruptions in supplemental irrigation than others. Since the primary growing season for winter wheat is in the spring, and the primary rainfall season is in the late summer (July-September), wheat relies heavily on supplemental irrigation. Other crops, such as corn and cotton, grow primarily during the late-summer, intensive-rainfall, months and are less sensitive to supplemental irrigation unless there are droughts, which occur with some frequency in the region.

Estimation of the Implications for Agriculture

There are a few published estimates of how water shortages will affect agricultural production in China (Table 1). Modeling approaches vary in these estimates and include a hydro-climatic approach (Heilig et al., 2000), a hydrological-economic approach with varying water prices (Rosegrant and Cai, 2002), extrapolation of water use and water efficiency trends (Yang and Zender, 2000), and results from a simulation model using econometrically estimated parameters (Huang et al., 2007). In addition, the results vary widely, even within the same study. For example, Heilig et al. predict that at current levels of water use efficiency, China's grain production will fall short of projected demand by 156 million metric tonnes (mmt) in 2025, but that with increased efficiency, grain production can exceed projected demand by 22 mmt in that year. Rosegrant and Cai's (2002) results show a more moderate effect. They predict that China will import 47.2 mmt of grain in 2025 as a baseline and this figure rises to 56.7 mmt under a scenario where water prices are tripled. Under a scenario where water use efficiency increases in addition to the higher water prices, imports fall back to below the baseline, to 46.3 mmt. Huang et al. find that with prices rising to level 50% greater than the current marginal value of water in agriculture, wheat production in north China will fall by nearly 20 mmt.

While these studies provide insight into how China's agricultural sector may respond to water shortages, there are a number of shortcomings with the analysis. A primary shortcoming with most previous work is that they often take China as a whole (Heilig et al., 2000; Rosegrant and Cai, 2002), but water scarcity is very much a regional phenomenon. Moreover, most studies provide long-term projections (more than 20 years) of China's agricultural supply and demand which have been unreliable in the past. For example, projections made in past decades predicted that China would import corn, and none predicted that China would still be exporting corn in 2007.

Table 1: Previous Studies into the Effects of Water Scarcity on China's Agricultural Trade

Reference	Modeling Approach	Conclusions
Brown and Heilwell (1998)	Cites modeling sponsored by the US National Intelligence Council	China imports 175 mmt grain by 2025, and over 200 mmt by 2030
Heilig, Fischer and Van Velthuizen (2000)	Use hydro-climatic model to show that agricultural production is sustainable at current levels and with current technology, but will not keep up with increases in demand.	Find China will produce roughly 156 mmt less than estimated demand in 2025 with current irrigation levels, but has a maximum production potential of 22 mmt above the estimated demand in 2025 if irrigation is expanded.
Yang and Zender (2001)	Extrapolate from current trends of water use and increases in water use efficiency.	Recommends China import 10 mmt of wheat to relieve over-exploitation of water
Rosegrant and Cai (2002)	Use hydrological-economic model linked to IFPRI's IMPACT model to estimate how changes in water prices and water use efficiency in China affect international trade.	Find that China will import 56.7 mmt of grain in 2025 if water prices are tripled, 9.5 mmt higher than the baseline of 47.2 mmt (without raising water prices). Imports fall to 46.3 mmt if water use efficiency increases and water prices rise.

An additional, and related, shortcoming in some of these studies is that they aggregate grains, concealing different trends in food grains, feed grains and other crops. Rising incomes and urbanization are generating more diversified diets in China, increasing the consumption of livestock products, while decreasing per capita consumption of food grains like rice and wheat. Thus, demand for feed grains such as corn is expected to rise dramatically over the next few decades as China's per capita consumption of livestock products increases with income. Corn, however, is less threatened by unreliable irrigation because it is grown in the rainy season, while wheat relies heavily on supplemental irrigation. In addition, studies have not addressed the effects of water scarcity on cotton, also an important crop in north China. Demand for cotton in China has increased dramatically after the Multi-Fiber Arrangement (MFA) ended at the end of year 2004, but cotton is rarely considered in estimates of water scarcity and agricultural trade.

In our model, we add parameters to address some of these issues described above. In order to see how regional water scarcity might affect China's overall agricultural economy, we estimated the effects of a decrease in irrigated area in northern China using the China model that is incorporated into the ERS CCLS. The CCLS is a partial equilibrium model of the world agricultural economy used to provide the annual USDA Long-term projections. The model solves for international supply and demand for 24 commodities in 38 countries and regions, and a major part of the CCLS is a model of China's agricultural economy. Using the China model allows us to determine how international markets for each crop are affected by water shortage scenarios. The China model is disaggregated into six regions. We focus on the northern region which includes five agricultural provinces (Hebei, Henan, Shandong, Shanxi, Shaanxi and Inner Mongolia) and two metropolitan centers (Beijing and Tianjin). This region is where agricultural production is most threatened by water scarcity.

The scenarios focus on wheat, corn and cotton production in northern China. We make assumptions regarding the difference between irrigated and non-irrigated yields for these three crops during an average rainfall year in northern China. These assumptions are based on interviews carried out by the authors over the last 5 years, as well as econometric findings from data collected in this region by the Chinese Academy of Sciences (CAS).³ We used findings

³ The assumptions on irrigated and non-irrigated yields, as well as on irrigated area by crop in this region, are derived from a five-year collaboration between USDA-ERS, China's Ministry of Water Resources, the Center for Chinese Agricultural Policy (CCAP), the Australian Bureau of Agricultural and Resource Economics, and the *China's Agricultural Trade: Issues and Prospects*

from survey work in Northern China, also conducted by CAS, on the irrigated area by crop to calculate an adjusted weighted average of the yields that matches the yields for each crop used in the base year of the 2007 USDA Long-term projections.

Using the modified model, we estimated a series of scenarios by reducing the amount of irrigated land in northern China over the projection period. The 4 scenarios estimated the effects of a decline in total irrigated land in northern China of 10, 20, 30 and 40% over the 10-year projection period. These scenarios are intended to approximate the effect of a reduction in water allocated to agriculture over the period, and estimate how agriculture will change in the region if water for irrigation is reduced. The model provides estimates of total irrigated crop production in northern China, total non-irrigated crop production in northern China, production in other regions of China, price changes, consumption, imports and exports. By comparing the results of these scenarios to the 2007 USDA Long-term projections for year 2015/2016, we estimate how falling irrigation in northern China might affect China's broader agricultural economy.

The 2007 USDA Long-term projections were generated based on policies currently in place. The forecasts assume the continuation of China's TRQ import regime for the three commodities. China's TRQ regime was adopted upon WTO accession in 2001 and sets a share of each quota aside for non state-trading enterprises, with the remainder of the TRQ under the control of China's state-owned import-export companies (heretofore, state-trading enterprises). For example, for wheat the TRQ amount is 9.8 mmt, but 90% of this is set-aside for state-trading enterprises. This unique TRQ regime is modelled by assuming differing import elasticities for state and non-state shares. For the non-state share of the TRQ, the import response to domestic price changes is more elastic than the import response for the state-share of the TRQ. We also assume the non-state and state shares of the TRQ are filled sequentially. As prices increase, imports occur first with the more-elastic non-state share. When the non-state share of the TRQ fills, import demand becomes less elastic as state enterprises begin to import. Once the TRQ fills, imports face higher over-quota tariffs of 40% for corn and cotton and 65% for wheat, compared to in-quota tariffs of just 1% for the three commodities (Lohmar et. al, 2002).⁴

University of California at Davis. CCAP conducted extensive fieldwork and data collection in this region, and USDA-ERS received access to these data as part of our participation in the collaboration.

⁴ Recently, China has been importing cotton at level above the TRQ but charging a sliding scale tariff rather than the above quota tariff of 40%. The sliding scale tariff starts at 5%, and goes higher as imports increase.

We provide important insights into how water scarcity might affect China's overall agricultural economy by modeling how production changes in one region affect another region in China. We find that water scarcity may induce significant production declines in northern China, but the effects of these declines will be partially offset by supply response in other regions, reducing the demand for imports. This happens, at least in part, because of China's TRQ regime and the extent to which it discourages imports.⁵

Results

The results from the modeling indicate that production declines in northern China due to reduced irrigation may raise domestic prices and induce increased production in other regions of China under the TRQ regime. Higher prices would also reduce consumption of these commodities. The extent to which water scarcity in China results in higher domestic prices depends on China's import policies, which dampens import response and cause prices to rise more than under less restrictive import regimes.

Wheat: Because of the reliance on supplemental irrigation in northern China, wheat is the crop that is most affected by declining access to irrigation. Figure 2 shows the effect of four different scenarios on production in northern China, production in other parts of China, national consumption and net imports of wheat. Model results were produced for scenarios in which irrigated area falls 10, 20, 30 and 40%. The production of wheat in northern China falls by only 2.1 mmt when irrigated area falls by 10% (about 2.3% of China's total wheat production estimated by USDA Long-term projections for the crop year 2015/6). However, production falls by nearly 18.3 mmt when irrigated area falls by 40%. For the most part, we anticipate that farmers will simply go out of wheat production when they lose access to irrigation, but some (very few) farmers will maintain rain-fed wheat production when irrigation access is lost.

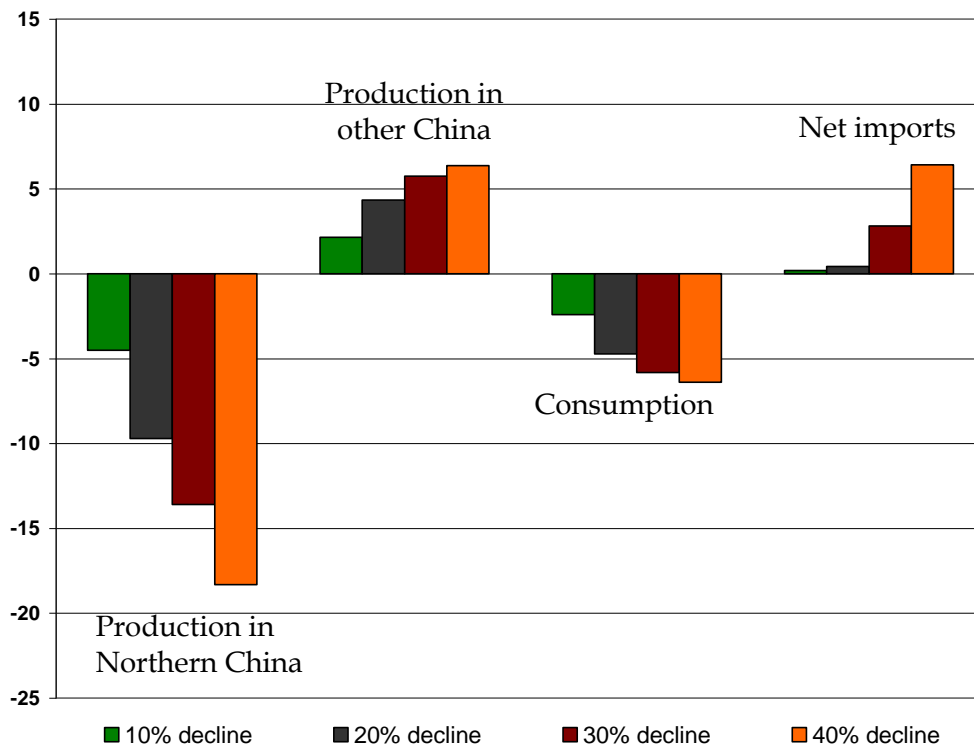
The production shortfalls in northern China cause prices to rise and this, in turn, causes wheat production in other regions to increase. Thus, the total decline in wheat production in China is smaller than the decline in the North China Plain and adjacent water scarce regions. For example, when irrigated area declines by 10% in northern China, the production in the north falls by 4.5 mmt, but production in other parts of China increases by 2.1 mmt, resulting in China's total wheat production falling by only 2.4 mmt (Figure 2). With the larger 40% fall in irrigated area, production in the north falls by 18.3 mmt, but increases in other areas by 6.4

⁵ Subsequent research will examine the welfare effects of increasing water scarcity under China's TRQ, and compare to scenarios with more liberal trade regimes.

mmt, resulting in a total production decline of 11.9 mmt. The areas that increase production are largely in the water-abundant Yangtze River Basin, and likely represent farm households moving from a rice-rice double cropping system to a wheat-rice double crop as the wheat/rice price ratio rises. Wheat quality in these areas is lower than the wheat produced in the North China Plain, and thus is not a perfect substitute for the wheat production declines in the north, and these quality issues imply that the model results may understate the demand for wheat imports.

Figure 2: Wheat - Effects of a 10, 20, 30 and 40% Decline in Irrigated Acreage in Northern China on the Production, Consumption and Trade of Wheat.

(million metric tons)



Consumers in China also respond to the higher prices by consuming less wheat. For wheat, the consumption response is nearly the same magnitude (but different direction) as the supply response of producers in other regions. For example, when irrigation falls by 10% in northern China, prices rise and total consumption declines by 2.4 mmt. Thus the entire impact of a fall in wheat production due to a 10% decline in irrigated area in northern China is absorbed domestically, with producers in other areas increasing production by 2.1 mmt, and *China's Agricultural Trade: Issues and Prospects*

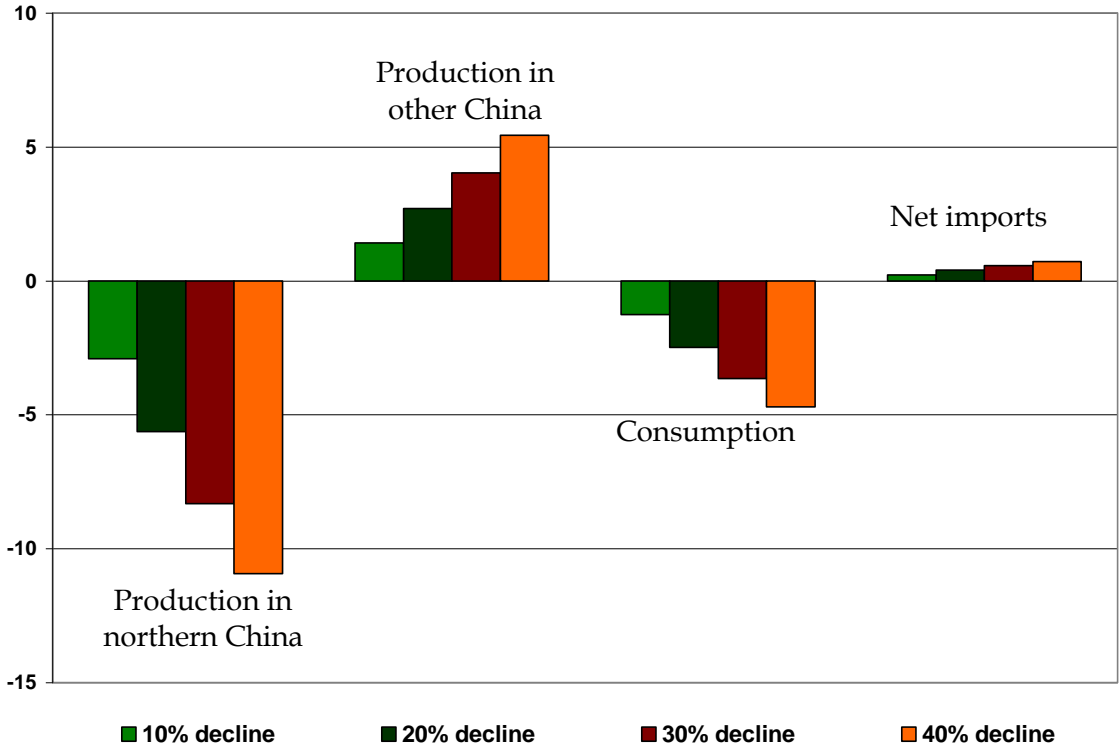
consumers decreasing consumption by 2.4 mmt, and together these offset the 4.5 mmt production decline in northern China. Larger irrigated area declines in northern China, however, bring about much larger production declines and the combined effects of production and consumption do not cover these declines. When production in north China falls by 18.3 mmt under the scenario of 40% decline in irrigated acreage, consumption falls by 6.4 mmt. This again is about the same as the rise in production in other regions (also rounded to 6.4 mmt) but together only comprise 12.8 mmt. The remaining shortfall is made up by (net) imports, which increase by 6.4 mmt as well.

The responses of producers in other regions, consumers and imports are due largely to restrictive trade policies that impede imports and allow domestic prices to rise well above the prices on international markets. Wheat has the most restrictive import policies of the three crops we address, with 90% of the TRQ set aside for state-trading enterprises. But the 2007 USDA Long-term projections for China's wheat imports in 2015/16 are 3.28 mmt, above the non-state share of the TRQ, so any additional imports due to water scarcity occur at the more restrictive state-trading portion of the TRQ. This causes prices for wheat to rise fairly rapidly as irrigated acreage declines in northern China, and this explains why producers in other regions increase production and consumers reduce consumption of wheat. When irrigated acreage in northern China declines by 10%, wheat prices will rise by 19.2% above the baseline projections. When irrigation in northern China declines by 40%, wheat prices will rise by 62.5% above the baseline prices.

Corn: The response of the corn market is similar to wheat, but not as pronounced (Figure 3). Like wheat, corn production declines in northern China as irrigated land becomes scarce, but to a lesser extent. Moreover, as with wheat, production in other regions in China rises, consumption declines, and these changes dampen China's overall import response. In the scenario representing the smallest impact, a 10% fall in irrigated area, corn production in northern China declines by 2.9 mmt, but, similar to wheat, the response of consumers and producers in other areas results in a non-significant change in imports. Under this scenario, production in other regions increases by 1.4 mmt and consumption falls by 1.3 mmt, leaving the remaining 200,000 mt to net imports, roughly half coming from a reduction in exports.

Figure 3: Corn - Effects of a 10, 20, 30 and 40% Decline in Irrigated Acreage in Northern China on the Production, Consumption and Trade of Corn.

(million metric tons)



Consumption and production of corn are very responsive to the price changes induced by the production shortfall in northern China. This leaves corn imports much less responsive to large production shortfalls on the North China Plain. When irrigated acreage decreases by 40%, corn production in northern China decreases by 10.9 mmt, but producers in other areas increase production by 5.4 mmt, and consumption declines by 4.9 mmt, so net imports are only 700,000 mt above baseline predictions when water scarcity in northern China is most acute.

Not only does corn production decrease less than wheat, but prices rise less as well. The lower price response of domestic corn that results from larger regional domestic production shocks is largely due to the price-responsiveness of consumption and production. Corn prices rise by 6.7% under the "10% decline in irrigated area" scenario, and rise by 23.8% under the assumption, "irrigated acreage falls by 40% in northern China", far less than the 19.2% and 62.5% rise in wheat prices under those scenarios. This is because there are very productive regions in the far northeast that can move into corn production as prices rise (generally by *China's Agricultural Trade: Issues and Prospects*

replacing soybeans or japonica rice with corn). Also, the demand for livestock products, the primary user of corn in China, is more price elastic than the demand for staple grains such as wheat, so the livestock market shrinks somewhat as corn prices rise and this reduces demand for corn. Livestock producers also likely find substitutes for corn in their feed rations for meat production as prices rise.

Cotton: As with wheat and corn, increasing water scarcity induces a decline in cotton production in northern China (Figure 4). But unlike the other two commodities, this decline is matched largely by imports. As irrigated area falls by 10% in northern China, cotton production in the region falls by 255,600 mt. This induces a price increase of only 2.6%, causing consumption to fall by only 76,000 mt. Moreover, since there is little capacity to expand cotton production in China, production outside of northern China increases by only 15,600 mt. Thus net imports take up most of the gap by increasing 164,000 mt. Looking at the more severe scenario of a 40% decline in irrigated area, we find the same pattern: production in the north falls by 989,000 mt, inducing prices to rise 10.1%, production in other regions to increase by 69,000 mt, consumption to fall by 285,000 mt, and net imports to rise by 634,400 mt.

China's cotton market relies more heavily on imports than corn or wheat and is protected less, resulting in a larger import response as production falls in northern China. In recent years, China has allowed cotton imports well beyond the TRQ to enter the country at sliding-scale tariffs that are lower than the stated above-quota tariff of 40%. This is because the demand for cotton in China surged after the end of the MFA in 2004, allowing China's exports of textiles to boom.

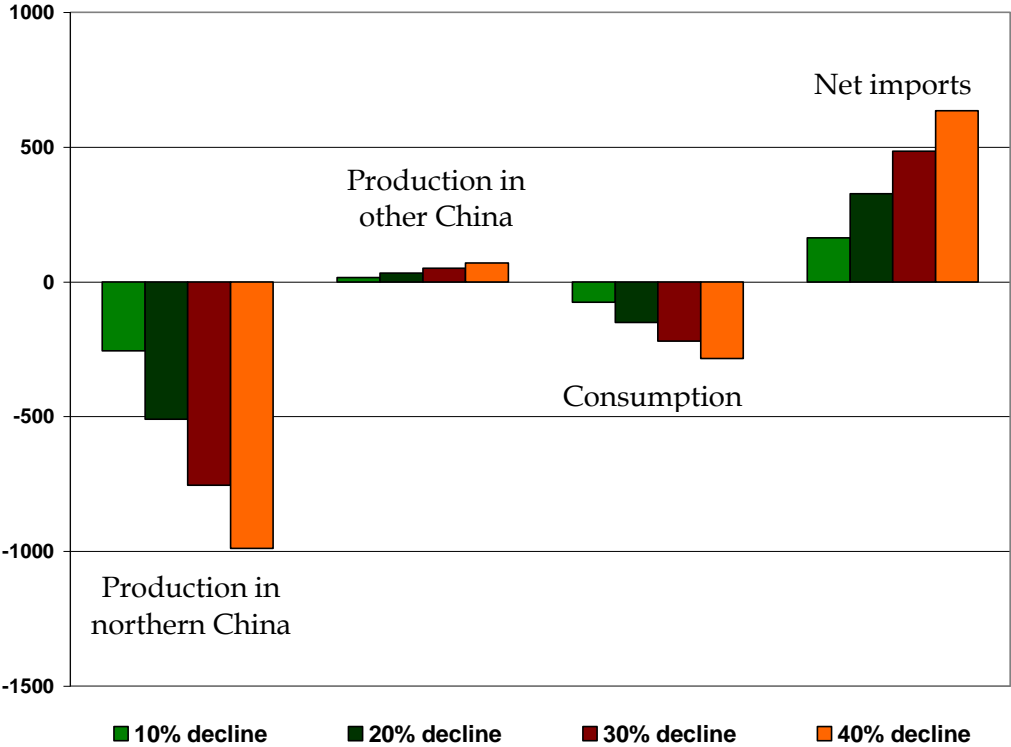
Other Crops: The effects on the wheat, corn and cotton markets from scenarios of declining irrigation in northern China have second-order spillover effects in other markets. For example, rice production declines under these scenarios, about 742,000 mt in the "40% decline" scenario. The decline in rice production is likely due to producers in water-abundant areas substituting wheat and corn for rice when the prices for these commodities rise. Still, the decline is small compared to China's overall rice crop, only 0.5% of total estimated rice production in 2015/16.

Livestock markets are also affected under these scenarios, likely due to rising corn prices. Under the severe "40% decline" scenario, pork production declines 1.4% and poultry production declines 4.4%. The decline in livestock production also induces a decline in soybean production and imports, by 2.7% and 1.0% respectively. The decline in soybean production also

may be due to expanding corn production in the northeast region.

Figure 4: Cotton - Effects of a 10, 20, 30 and 40% Decline in Irrigated Acreage in Northern China on the Production, Consumption and Trade of Cotton.

(thousand metric tons)



Caveats: These scenario results provide a snapshot of how China’s agricultural economy might adapt to declining water availability for agriculture in and around the productive North China Plain. However, there are important caveats that should be stated. One is that the nature of the modeling does not take into account the possibility of increased water use efficiency in agriculture. It is unclear exactly how increased water use efficiency might affect the water scarcity problems in north China, particularly in areas using groundwater. Some argue that water tables are continuing, and will continue, to fall even as water is used more efficiently in agriculture (Kendy et al., 2003), while others argue that there is substantial capacity to use water more effectively and curb the deterioration of water resources (Lohmar et al. 2003). The way we model declining irrigated acreage might be viewed as a “worst case scenario” for the future of irrigated agriculture in China.

A second caveat is that while these scenarios look at a sustained deterioration in water availability for agriculture in China, they do not reflect the effect of periodic droughts. Droughts in this region can last more than one year and can have devastating effects on crop production. Corn and cotton are especially vulnerable to droughts since they are often grown in rainfed areas that have no access to irrigation or less secure access to surface water irrigation that itself could be affected by a drought. In much of the region, wheat can only be grown with supplemental irrigation so is produced only where there are secure sources of water, such as ample ground water, making it less vulnerable to droughts. In areas that receive water from the Yellow River, the dry periods tend to be in the latter part of the summer growing season. Spring season flows are relatively secure as the river carries the snowmelt from the Tibetan Plateau. Thus, surface water in the basin is more secure for wheat production in the spring than it is for corn and cotton in the late summer.

Conclusion

Over-exploitation of water resources and the changes brought about to adapt to limited water resources will almost certainly induce changes in China's agricultural production patterns. Increasing urban demand for water as well as demand for environmental flows, such as those to maintain the Yellow River flows to the ocean, will limit the amount agriculture can continue to draw off the water system in the important grain producing areas of northern China. But many of these areas have seen dramatic increases in grain production due to the establishment of irrigation systems over the last 50 years. With irrigation now threatened and policy no longer focused on providing cheap irrigation to maintain grain self-sufficiency, changes in agricultural production are likely to occur. Given China's size and importance in the world food system, these changes will likely affect international markets.

China's size, however, also serves to dampen the effects of declines in production in the northern region on international markets. Because China is such a large producer and consumer of the crops affected by water shortages in the northern region, there is substantial capacity for response by domestic consumption and producers in other regions to the shortfalls in production in the north. Moreover, the magnitude of the changes on international markets depends on a variety of factors. The success and effectiveness of water policy changes currently being promoted will make a difference. Trade policy also clearly matters. With more liberalized trade policies, China's adjustment to production shortfalls in the north will more

likely be via importing "virtual water" – water embodied in crops. Under such circumstances, prices will increase less, consumers will consume more, and production in other areas will change less, resulting in an overall welfare gain.

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