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In the 1990s, prior to its accession to the World Trade Organization, China dramatically reduced market distortions in agriculture. We use a panel of 6,770 rural households from 1989 to 2000 to ask whether agricultural market liberalization affected rural household food security as measured by the share of calories from non-staples. Given that not all households may be able to take advantage of new market opportunities, we focus on the distributional effect of market liberalization. Unlike most previous research on the effects of liberalization, we consider the effects of liberalization on both farm and off-farm income. We find that liberalization primarily improves household food security by increasing off-farm income, and the effects vary greatly by initial food security status and producer types. While many households benefit from liberalization, some food-insecure households producing import-competing products have lower food security as a result of agricultural market liberalization.

Key words: Agricultural market liberalization, household food security, off-farm income, rural China, trade liberalization.

JEL codes: Q17, Q18.

Recent World Trade Organization (WTO) disputes have brought China's agricultural trade policy back into the spotlight. In November 2008, China issued the nation's first Outline of Mid- and Long-term Plan for National Food Security (China Central People's Government 2008), in which they stipulate that the country will seek to stabilize the area sown to grain, and achieve more than 95% grain self-sufficiency. Trade restrictions are argued to support implementing this plan because increased imports of grains and soybeans will lower prices, causing grains and soybeans farmers to leave farming, thereby generating food insecurity (Wong and Huang 2012). Others suggest that China may not have a comparative advantage in grain or soybean production, and switching to higher-value agriculture or working off-farm could increase the incomes of both rich and poor farmers (Zhu, Hare, and Zhong 2010). In this article, we evaluate the effect of past agricultural market liberalization on rural Chinese household food security as a measure of household welfare. Because market liberalization is likely to differ in its effect across households, we explore the distributional effect of liberalization on rural household food security.

Prior to its accession to the WTO in 2001, China substantially reformed its agricultural markets, prices, and trade. From 1992 to 1998, the average agricultural import tariff rate fell from 42% to 24%, and domestic agricultural policy reforms dramatically decreased market distortions (MOFTEC 2001; Huang et al. 2009). The government lowered

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the mandatory amount of grain that farmers had to sell to the government (grains quota) and reduced the price disparity between in-quota versus out-of-quota sales, fully eliminating the grains quota around 2000. The government also decentralized much of the agricultural trading authority, reduced the scope of non-tariff barriers and relaxed licensing procedures for some crops (Huang and Chen 1999). Over the same time, the government invested heavily in infrastructure and significantly reduced transactions costs in domestic agricultural markets (Fan, Zhang, and Zhang 2004; Fan and Chan-Kang 2005; Luo et al. 2007).

Agricultural production value, off-farm income, and household food security rose during this time. We find that the share of calories from non-staples (SCNS) in rural China increased by 5 percentage points, from 21% in 1989 to 26% in 2000, where a SCNS of greater than 16% is a reasonable measure of being out of hunger (Jensen and Miller 2010). That being said, rural poverty and food insecurity are still a salient concern. Economic growth has been concentrated in urban areas and urban incomes are now more than three times higher than their rural counterparts. Poverty remains primarily a rural phenomenon, with 99% of the poor in China coming from rural areas (World Bank 2009). In 2010, 152 million people (11.2%) in rural China still lived under the poverty line of less than $1.90 per person per day (World Bank 2014), and in 2015, 133.8 million people were food-insecure, with food intake insufficient to meet daily energy requirements (FAO 2015). Improving access to adequate quantity and diversity of nutrients in rural areas is a major objective for Chinese policy makers (Mangyo 2008; Huang and Rozelle 2009; de Brauw and Mu 2011).

We identify the effect of market liberalization by noting that while liberalization is largely driven by central government policies, it will affect each community differently. Some markets are more isolated than others, and will be less affected by the decrease in protection from the world market. We measure the degree of local market liberalization by using the price difference between world, regional, and local prices for seven agricultural products. This metric captures both transportation costs and policies such as non-tariff barriers that are hard to quantify.

Following Jensen and Miller (2010), we use the household's SCNS as our measure of food security. We control for time-invariant unobserved household characteristics through household fixed effects and agro-climatic shocks and general economic trends through county by year dummy variables. To isolate the effects of liberalization on food security solely through income, we also control for other potential channels through which liberalization could affect household food security, namely demographics, changes in market access, information and food prices. By using a longitudinal household survey (the China Health and Nutrition Survey, CHNS), we can analyze the impacts of liberalization econometrically without restrictive assumptions such as complete markets and perfect information common in simulation models of trade liberalization.

Agricultural market liberalization may affect rural households differently. While wealthy and well-educated farmers may benefit from increased off-farm work opportunities and income (Wang et al. 2009), the poorest farmers may lack access to income-generating assets, credit and technology, and thus have limited ability to switch production or seek off-farm jobs, making them vulnerable to market liberalization (Anderson, Huang, and Ianchovichina 2004; Chen and Ravallion 2004). Conversely, agricultural market liberalization can improve agricultural efficiency, increase rural household income of the poor, and enhance household access to food (Kennedy and Cogill 1988; Ingco 1997; Huang Li and Rozelle 2003; Huang et al. 2007).

Trade theory would predict that producers of export-oriented products (hereafter called export producers) benefit from agricultural market liberalization and producers of import-competing products (hereafter called import producers) may lose from liberalization (Huang, Li, and Rozelle 2003; Huang et al. 2007). While prior research has studied how economic reforms affect the distribution of *urban* residents' nutrition availability (e.g., Meng, Gong, and Wang 2009), it is unclear how liberalization affects the food security of the full distribution of households living in rural areas.

Existing research on the effect of agricultural reforms largely focuses on how liberalization affects agricultural production value, and thereby farmers' welfare. But off-farm jobs can be an effective way for farmers to raise income and reduce rural poverty (Rozelle 1996; de Janvry, Sadoulet, and Zhu 2005;

de Brauw and Giles 2018). Based on the CHNS, from 1989 to 2000, off-farm income gradually increased from 30% to 50% of total rural income. Therefore, unlike much previous research, we analyze how agricultural market liberalization affects farmers both through agricultural production value and off-farm income.

Because food-secure and food-insecure households face different tradeoffs from market liberalization, we use Instrumental Variable Unconditional Quantile Regressions (IVUQR) to study the distributional effects of market liberalization on household food security while addressing the endogeneity of agricultural production and off-farm income. This article is the first empirical application that addresses the endogeneity of continuous regressors when analyzing the unconditional distributional effects.[1] By comparing effects at several points on the unconditional distribution of SCNS, this article evaluates the impact of market liberalization on the most vulnerable population.

We find that the largest effect of liberalization is through facilitating off-farm employment, particularly for food-secure households. By relaxing the grains quota, farmers had more freedom to work off-farm, potentially increasing their income. Further, market liberalization may have caused some farmers and local processors to specialize in the production of agricultural products in which China has a comparative advantage. This specialization may have increased the demand for labor. We also find that market liberalization does not substantially improve food security for food-insecure households. In particular, import-producing households who are food insecure appear to be worse off after agricultural market liberalization. Our findings suggest that while some farmers clearly benefited from market liberalization, some food-insecure rural households may have been left behind. Agricultural market liberalization may have contributed to inequality in income and level of food security in rural China.

The rest of the paper is organized as follows. In the next section, we describe the CHNS data and explain how we construct two key variables: the household food security indicator and the market liberalization index. We then discuss our empirical specification, the IVUQR model, and identification strategy. In the following section, we present the main results, particularly emphasizing the heterogeneous effects of market liberalization and computing its implications in terms of calories. The final section concludes.

Data

We use data from the China Health and Nutrition Survey (CHNS) conducted by the Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety (NINFS) at the Chinese Center for Disease Control and Prevention (CDC). The data cover 104 rural communities and 6,770 rural households in 8 provinces in 5 waves: Liaoning, Jiangsu, Shandong, Hubei, Hunan, Henan, Guizhou, and Guangxi in 1989, 1991, 1993, 1997, and 2000.[2] In this article, we consider only farmers who are defined as households having more than 10% of their gross income from agriculture in rural communities, where rural communities are defined as communities having over 25% of their income from agriculture in at least one of the survey years. By this definition, 96% of communities with agricultural data are included and 94% of all households in rural communities are defined as farmers and included. The CHNS records detailed data at both the household and community levels, including household agricultural production, off-farm income, and community-level economic and retail information.

A key part of the CHNS is a 24-hour food diary filled out by each household member for three days.[3] Each household member reports what they ate and drank the previous day, including food both at and away from home. These foods were recorded in detail to

[1] Unconditional quantile effects with endogeneity for a discrete treatment variable have been examined in Frolich and Melly (2013).

[2] The CHNS also includes Heilongjiang in 1997 because Liaoning cannot participate in the survey in the same year. However, because in our model we use grains quota per mu (1/6 of an acre) in 1989 to construct one of our instruments, we drop the province of Heilongjiang.

[3] The three consecutive days during which detailed household food consumption data were collected were randomly allocated from Monday to Sunday and are almost equally balanced across the seven days of the week for each sampling unit. In a few cases, individuals missed one day because of absence, but over 99% of the sample has the full three days of data.

match the 636 detailed food items listed in the 1991 Food Composition Tables developed by the NINFS, which were used to convert food consumption into caloric intake.

Household Food Security

We use the SCNS as our measure of household food security.[4] This approach is essentially an application of Bennett's Law at the household level. The SCNS is based on the premise that until a household has passed subsistence, they will prioritize consuming sufficient calories from the cheapest sources (staples) since insufficient calorie intake is associated with a large penalty to individual utility (e.g., physical discomfort from hunger). After the household has enough calories to meet their needs, the household will substitute away from staples to satisfy non-caloric attributes such as micronutrients and taste. Although caloric intake requirements are unobservable and will vary by household, households' choice to switch away from staples reveals they are above their minimum caloric requirement, and thus SCNS can be used as a measure of food security.[5]

We construct this measure by first summing the *staple* and *total* calorie intake from all sources for all household members on all diet diary days. Then we divide the staple calorie intake by total calorie intake to get the staple calorie shares (SCS) at the household level.[6] Finally, we subtract SCS from 1 and multiply the result by 100, which scales the SCNS to a range of 0 to 100.

Agricultural Market Liberalization

Traditional measures of agricultural market liberalization such as the Nominal Rate of Assistance at the Farm Gate (NRAf) and tariffs usually do not vary by region (Anderson et al. 2008; Huang et al. 2009). If a rural area faces sufficiently high transactions costs, it will be protected from imports regardless of whether the country has a restrictive trade policy or not (Miller, Morrissey, and Rudaheranwa 2000; Helble, Shepherd, and Wilson 2009). During our period, transactions costs in the domestic Chinese agricultural market are high (Park et al. 2002). We use regional variation in implicit transactions costs to build on the approach of Anderson et al. (2008) and Huang et al. (2009), and generate a local measure of market liberalization. We calculate the difference between the local and the regional consumer market price, and the difference between regional consumer market and world price to identify which communities face effective market liberalization and which communities do not.

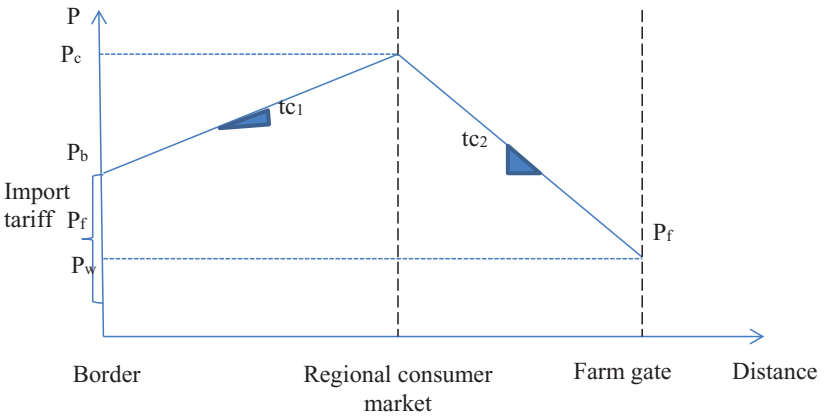
If we use the simple difference between the local and world price as a measure of liberalization, the result might be misleading. For example, a small difference between the price of an import-competing product at the farm gate and the port may result from a low level of protection. Conversely, the relatively low farm-gate price might be caused by high transactions costs of getting the product to the regional consumer market, where the regional market is still highly protected from import competition (illustrated in figure 1).[7] For an import-competing product, the border price (P_b) is higher than the world price (P_w) because of import tariffs. Due to the transactions cost (tc_1) of moving the good from the border to regional consumer markets, the regional consumer markets price (P_c) will be even higher than the border price (P_b). Suppose that a local community in the province has a comparative advantage in the production of that product, then the price at the farm gate (P_f) could actually be lower than the border price (P_b). However, because of the high transactions cost (tc_2) of moving the

[4] Jensen and Miller (2010) treat SCNS mostly as a measure of hunger. We propose that it is also a good measure of food security.

[5] The SCNS has several advantages over staple budget share (SBS) or Engle's curves that are based on expenditure surveys. First, purchased food will not be the same as food consumed if meals are provided by an employer or the purchased food is provided to others. In contrast, SCNS accounts for each household member's food intake from all food sources including free food provided by others. Second, SBS requires detailed price data to calculate the value of the food that farmers grow for their own consumption, which may not be very accurate.

[6] We compute the household-level SCNS following Jensen and Miller (2010), not the average of SCS for each member or for the whole household for each of the three days. By summing over all household members and all diet diary days, we minimize potential measurement error for specific individuals and/or days.

[7] We believe that regional market prices are important as Chinese households consume a substantial amount of the agricultural production grown within the province during this time. During this period, most grains were sold to regional consumers due to the provincial governor grains bag responsibility system, associated with the grains quota discussed later. The provincial governor grains bag responsibility system put the provincial governors in charge of grains quota procurement and supply to satisfy urban needs within the province. Thus, most governors prioritized and subsidized grains sales to local regional markets within their respective provinces. Transportation and storage costs for horticulture and livestock products are high, and therefore local markets are likely the primary markets for these products as well.



P_c: regional consumer market price; P_b: border price; P_f: farm gate price; P_w: world price;
tc_1: transactions cost from border to regional consumer market;
tc_2: transactions cost from farm gate to regional consumer market

Figure 1. Import competing good with high transaction costs from farm

product from the farm gate to regional consumer markets, the price in the regional consumer market (P_c) will be much higher than the farm gate price (P_f). In this case, the calculated NRAf (the percentage difference between P_w and P_f) will indicate little market distortion, and thus high agricultural market liberalization, while the true low local prices reflect the fact that the local community is very isolated from the world market.

Price differences incorporate the effects of trade-distorting policies such as export subsidies, import tariffs and domestic market distortions. We calculate an agricultural market liberalization index for community c in year t by taking the reciprocal of the sum of the absolute differences between farm gate and regional market prices, and that between regional market price and world price across commodities in the community for the year (see equation 1):

$$(1)\quad I_{ct} = \left[\sum_i \left(\frac{|Pf_{it} - Pc_{it}|}{Pc_{it}} + \frac{|Pc_{it} - Pw_{it}|}{Pw_{it}}\right)\right]^{-1}.$$

In equation (1), I_{ct} is the agricultural market liberalization index for community c in year t, Pf_{it} is the farm-gate price (local community retail price), Pw_{it} and Pc_{it} are the world and regional consumer market price for product i in year t, respectively. The regional consumer market price is represented by the price of the most urbanized city in the province for the given year.[8] We use rice, wheat, corn, poultry, pork, vegetables, and soybean oil because they account for more than 50% of the total agricultural output value in China (Huang et al. 2009) and 86.3% of calorie share in an average household's diet based on our data. We then multiply the agricultural market liberalization index by 100. The higher the agricultural market liberalization index, the more liberalized the community.

To explore our measure of liberalization, we compare it to NRAfs over time (supplementary online appendix table A1) and plot the distribution of market liberalization index in 1989 and 2000 (supplementary online appendix figure A1). We find that changes in our local market liberalization index are generally consistent with changes in the NRAfs over time. The table and the figure indicate an increase in not only the mean but also the whole distribution of market liberalization over this period. To test the validity of our measure, we regress the market liberalization index against changes in community infrastructure and market access (supplementary online appendix table A2). We find that better access to communication facilities, market

[8] The urbanicity of the community is constructed in Jones-Smith and Popkin (2010). Urbanicity is a weighted average of population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communication, housing, education, diversity, health infrastructure and social services scores. Given that the provincial capitals are sampled in the CHNS, it is highly likely the most urbanized city of the province is the provincial capital.

Table 1. Summary Statistics by Year

Variables	1989	1991	1993	1997	2000
Share of calories from non-staples (SCNS, %)	20.67	18.84	18.79	20.66	24.30
	(13.68)	(12.26)	(11.13)	(12.11)	(13.66)
Agricultural production value (2009 Yuan)	8,139.78	7,560.05	6,953.87	8,464.84	8,655.95
	(6,675.01)	(5,587.16)	(5,128.66)	(5,797.96)	(7,551.56)
Market off-farm income (2009 Yuan)	3,500.70	3,451.58	4,401.28	6,154.00	8,710.08
	(6,138.17)	(5,138.00)	(6,696.08)	(8,504.12)	(10,473.6)
Grains quota (kg) per mu	96.17	9,9.49	50.17	75.09	0.00
	(145.72)	(147.62)	(92.31)	(143.20)	(0.00)
Number of adults in the household	2.60	2.58	2.67	2.71	2.78
	(1.01)	(0.98)	(1.08)	(1.10)	(1.10)
Household size	4.02	4.06	4.26	4.11	3.97
	(1.51)	(1.37)	(1.30)	(1.25)	(1.27)
Community distance to township center (km)	2.05	2.07	2.00	2.06	2.03
	(2.07)	(2.07)	(2.01)	(1.88)	(2.02)
Community market access score	2.94	2.73	3.00	2.86	3.07
	(2.94)	(3.04)	(2.90)	(2.73)	(2.96)
Community communication score	2.07	3.27	3.43	3.96	4.12
	(1.49)	(1.34)	(1.46)	(1.31)	(1.09)
Agricultural market liberalization	21.07	19.78	21.66	26.94	25.35
	(5.42)	(5.17)	(4.37)	(4.55)	(7.22)
Rice retail price (2009 Yuan/kg)	4.15	3.14	2.94	2.80	2.35
	(1.07)	(0.94)	(0.88)	(0.80)	(0.53)
Chicken retail price (2009 Yuan/kg)	18.13	17.78	18.22	17.32	15.71
	(6.51)	(5.49)	(6.11)	(5.06)	(5.73)
Vegetables retail price (2009 Yuan/kg)	1.44	1.44	1.44	1.37	1.42
	(1.05)	(1.03)	(0.97)	(0.62)	(0.90)
Soybean oil retail price (2009 Yuan/kg)	13.09	12.68	12.19	11.67	10.43
	(3.54)	(3.06)	(2.79)	(2.41)	(2.67)
Number of observations	1,641	1,509	1,369	1,146	1,105

Note: Standard deviations are in parentheses.

access, and improved transportation infrastructure are positively associated with agricultural market liberalization.

Descriptive Statistics

Means and standard deviations by year for our main variables are given in table 1. All income and prices are deflated to 2009 Yuan using the local CPI index calculated by the CHNS survey team.[9] The agricultural production value is calculated as the sum of the sale, consumption and gifts value of field crops, horticulture, livestock, and fish produced by the household.[10] Off-farm income includes the household's wage and business income and excludes retirement wage or government subsidies that are dependent on government policies. Other household-level variables include household size that captures the number of household members, the number of adults who are 18 years or older, and grains quota per mu, where a mu is equivalent to about 1/6 of an acre.

The Chinese central government had mandatory grains delivery quotas for farmers from the 1950s to the 1990s, until they were eliminated around 2000.[11] Under the quota, farmers were required to deliver a specific quantity of grains to the government for what

[9] The local CPI varies by community and year. The average community CPIs are 0.35, 0.36, 0.44, 0.71, and 0.70 in 1989, 1991, 1993, 1997, and 2000, respectively.

[10] The consumption value is based on the survey question "On average, during the past year, how much money would you have to spend per month to buy from the market the agricultural products that were grown and consumed by your household (Yuan)?"

[11] Although some counties had procurement delivery quotas for oilseeds, this quota was not as widespread as for grains (Huang et al. 2009). We use the quantity of grains sold to the government to identify the size of the grains quota. Since the government procurement price (quota price and negotiated price) was lower than the free-market price during the existence of the grains quota system, we assume that farmers do not sell more than the required amount to the government.

was usually less than market price. Along with the mandatory quota, the central government introduced negotiated purchases as an additional component of grains quota by the end of 1985 (Lin 1992; Rozelle et al. 1997; Rozelle et al. 2000). The negotiated purchases were still mandatory but were set at a higher price than the price of the basic grains quota, while still being lower than the market price. The share of negotiated purchases in the total government grains quota climbed from 25% in 1985 to 58% in 1996 (Wu and McErlean 2003). We calculate the grains quota per mu as the sum of basic and negotiated purchases, divided by the land size the household had for cropping last year.

The distance between the community and township center in the CHNS is given by the community leader. The market access scores and communication scores come from Jones-Smith and Popkin (2010) and are provided as part of the CHNS data. The market access scores are calculated based on the number of supermarkets, restaurants, and stores within the community. The communication scores depend on the percentage of households with a television, computer, or phone, and the availability of newspapers, telephone, postal offices, and cinema within the community. These scores are all scaled from 0 to 10. The higher the score, the better the market access and communication of the community (Jones-Smith and Popkin 2010). The prices of agricultural products are all retail prices in the local community markets.

Table 1 shows that agricultural production value and off-farm income increase over time along with better access to communication facilities in communities and improved liberalization over time. We also observe agricultural policy liberalization with the average household's grains quota steadily declining from 1989 to zero by 2000.[12] The price of soybean oil declines over time, which is expected since China dramatically increased its imports of soybeans during this period.

After constructing the SCNS and income variables, we investigate the suitability of SCNS as a measure of household food security by comparing the kernel density distributions of log SCNS across different income groups (figure 2). We define low, medium, and high income households to be those with annual gross income per adult less than 2,401 Yuan (25th percentile), between 2,401 Yuan, and 6,444 Yuan (75th percentile), and more than 6,444 Yuan, respectively. The annual gross income per adult is the sum of agricultural production value and off-farm income, divided by the number of adults in the household. The mode of the distribution of the log SCNS moves from 3 (SCNS of 20%) to almost 3.3 (SCNS of 27%) as gross income increases. Significantly fewer people in the high-income group than in the low-income group have SCNS less than 20%.

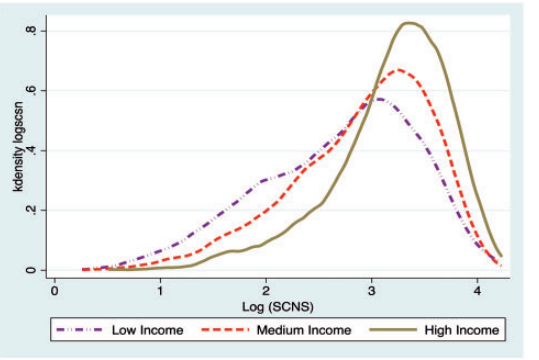


Figure 2. Log SCNS kernel density distributions for different income groups

Next, we compare the relation between different measures of food security and income using unconditional quantile regressions. We calculate calorie and protein intake from CHNS data on household consumption divided by the number of household members. From the regression results (supplementary online appendix table A3), we find that while income is strongly positively correlated with SCNS, its correlations with conventional household food security measures is much lower. The correlation with protein intake is only one-eighth of that with SCNS. Caloric intake is even negatively correlated with income. In addition, the correlation between protein intake per capita and SCNS is 0.155, while caloric intake per capita is almost uncorrelated with the SCNS (correlation coefficient $= -0.026$). The results are similar using caloric intake per adult equivalent when we use equivalence scales following Cutler and Katz (1992). Therefore, SCNS seems to be an informative measure of overall well-being and we use it as our measure of household food security and welfare.

[12] One constraint is that the survey does not contain the amount sold to the government in 2000, but Huang et al. (2009) show that reformers largely eliminated the distortion caused by grains quota by the end of 1990s. Thus, we assume that the effective grains quota in 2000 was zero for all households.

To explore the association between our measure of agricultural market liberalization and food security, we first plot the distribution of income from three different sources against the liberalization index in figure 3. We divide our rural sample into low, medium, and high liberalized communities with cutoff points of 18.8 (25th percentile) and 27.7 (75th percentile). As liberalization index increases, the median of log gross income shifts to the right from 9.21 (9,997 Yuan) to 9.38 (11,849 Yuan).

As we can see from the middle panel of figure 3, the distribution of the log of agricultural production value does not greatly differ by liberalization, with most households producing between 1,097 and 8,103 Yuan of agricultural products. The lack of an obvious correlation suggests that agricultural production value may not be the primary mechanism through which market liberalization affects household food security. That being said, the distribution of agricultural production value broadens somewhat with higher liberalization. This observation suggests that liberalization may drive some farmers to specialize in agriculture while encouraging others to leave the sector. In contrast, the distribution of log off-farm income notably shifts to the right from 7.5 (1,808 Yuan) to 8 (2,981 Yuan) with increased liberalization. Significantly fewer households have zero off-farm income at higher levels of liberalization than at lower levels of liberalization.

We explore the direct association between liberalization and household food security in figure 4. We find that as liberalization increases, household food security increases too; the distribution of household food security shifts to the right, with the median increasing from 3.2 (24.5%) to 3.5 (33.1%).

Methods

We use an unconditional quantile regression to identify the effects of liberalization on households located at specific points on the unconditional distribution of food security. By contrasting the estimated effects at several points on the distribution, we can tell whether responses to exogenous shocks differ in informative ways (D'Souza and Jolliffe 2013). We estimate the following model,

$$A_{hvt} = X_{hvt}\alpha_1 + G_{hvt}\alpha_2 + D_{vt}\alpha_4 + \gamma_h + \upsilon_{ct} + \varepsilon_{hvt} \quad (2)$$

$$O_{hvt} = X_{hvt}\beta_1 + G_{hvt}\beta_2 + Z_{vt}\beta_3 + D_{vt}\beta_4 + \upsilon_{ct} + \varepsilon_{hvt} \quad (3)$$

$$Q_{F_{hvt}}(\tau) = A_{hvt}\delta(\tau)_1 + O_{hvt}\delta(\tau)_2 + X_{hvt}\delta(\tau)_4 + \gamma_h + \upsilon_{ct} + \varepsilon_{hvt} \quad (4)$$

where h indexes for household, v for community, c for county, and t for year. We assume that households face given prices and choose a quantity to produce in agriculture. When deciding the quantity to produce in agriculture given the price (agricultural production value, A_{hvt}), a household will consider their grains quota per mu interacted with province-year shocks (dummies) (G_{hvt}) and their labor endowment (X_{hvt}) (equation 2). The household's agricultural production will also depend on access to off-farm employment and is related to community distance to township center interacted with province-year shocks (dummies) D_{vt} and other community characteristics, Z_{vt}, including access to markets and information in the community, retail prices of major agricultural commodities, and market liberalization as defined in equation (1). These explanatory variables are commonly used in other research to analyze the impact of liberalization or commercialization on income (e.g., Masanjala 2006). Similarly, a household's off-farm income (O_{hvt}) will rely on the same set of household (X_{hvt}, G_{hvt}) and community-level variables, D_{vt} and Z_{vt} (equation 3).

Agricultural production value (A_{hvt}) and off-farm income (O_{hvt}) will influence the unconditional distribution of household food security, $Q_{F_{hvt}}(\tau)$, where τ represents the τth quantile of the unconditional distribution of food security indicator F_{hvt}. To control for household-level unobserved characteristics, we include household fixed effects (γ_h). In addition, we incorporate county by year dummy variables (υ_{ct}) to control for agro-climatic shocks that are likely to vary by county-year such as precipitation and temperature. Therefore, the variation we use is to compare the annual deviations of different households from their long-run average within the same county-year. Finally, ε_{hvt} represents the error term.

Given that both agricultural production value and off-farm income may be endogenous, we estimate the parameters using IV

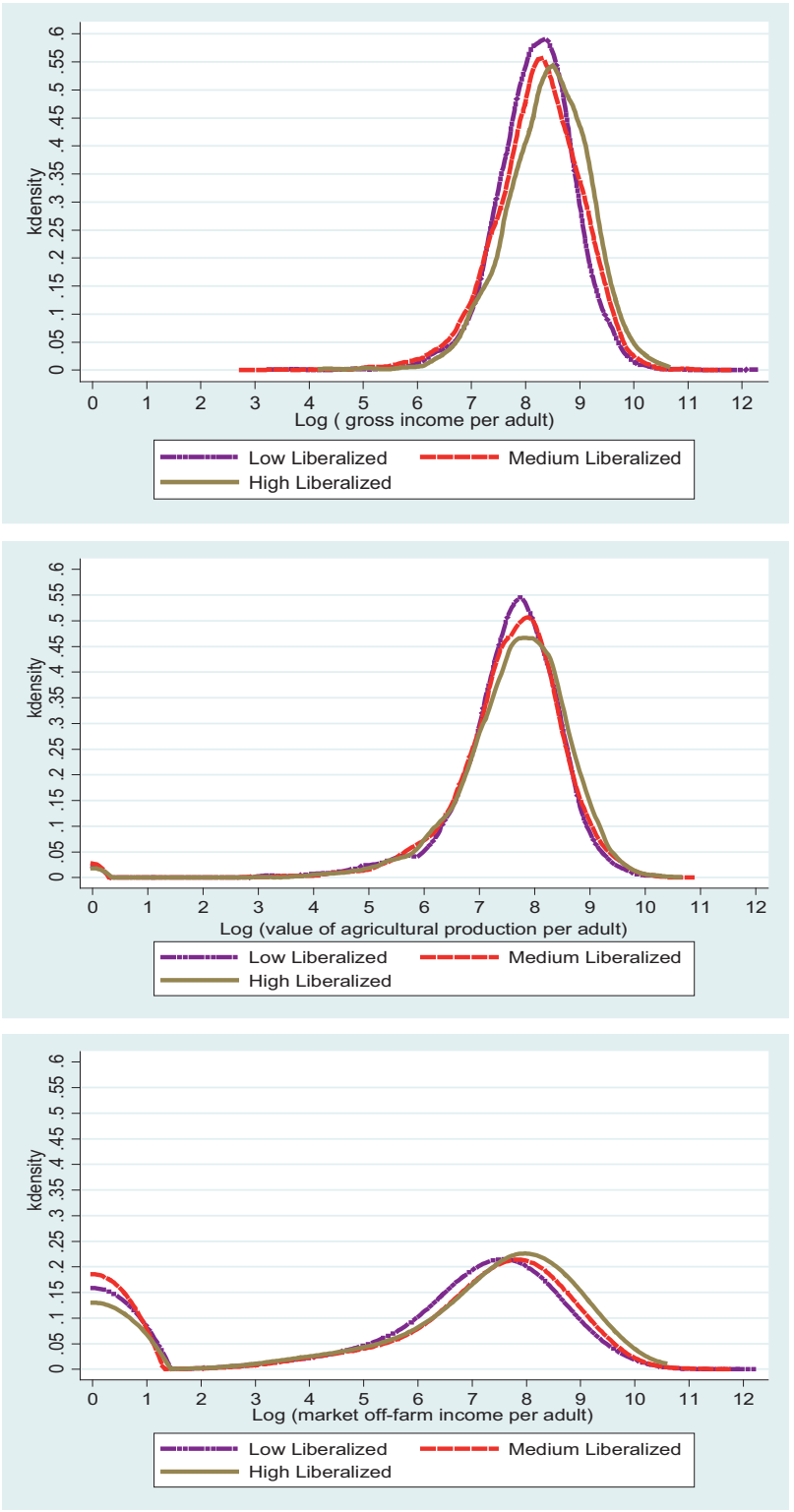


Figure 3. Log gross income, agricultural production value and off-farm income per adult for differently liberalized communities

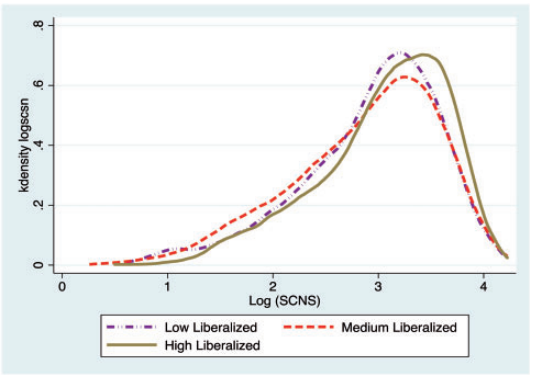


Figure 4. Log SCNS for differently liberalized communities

unconditional quantile regressions (IVUQR). The identifying assumptions underlying the IVUQR model are similar to those in an instrumental variables regression. The instruments need to be correlated with the endogenous variables and orthogonal with the error terms in the model. OLS regressions in equations (2) and (3) are the first stage of the IVUQR, while equation (4) is the second stage of IVUQR. We use a control variable approach as suggested in Rothe (2010) and Imbens and Newey (2009) to obtain the empirical Cumulative Distribution Functions (CDFs) of the residuals in the first stage regressions and then use the CDFs as control variables in the second stage. Like in a standard control variable approach, the CDFs are a one-to-one function of the error terms in the first stage, which are able to absorb the dependence between the regressors and unobserved error term in the second stage if the instruments are valid. The estimation details and other important features of the IVUQR are provided in supplementary online appendix B.

There are three central advantages of IVUQR compared to conventional estimators. First, unlike two-stage-least squares, the IVUQR estimator allows the marginal effect of market liberalization to vary across households with different levels of food security. Compared to the Instrumental Variable Quantile Regression (IVQR) (Chernozhukov and Hansen 2005), the IVUQR allows the marginal effects to differ across the distribution without conditioning on observed covariates. Therefore, the IVUQR estimator is arguably more policy-relevant because households at the bottom of the unconditional distribution are food-insecure regardless of their other attributes, whereas the bottom of the conditional distribution need not be food insecure, they just have low food security conditional on their attributes, such as income. Second, because the unconditional effects are averages of conditional effects, they can be estimated more precisely. Third, because the definition of the unconditional effects does not depend on the explanatory variables included in X, one can therefore consider different sets of covariates X and still estimate the same unconditional quantile effects, which is useful for examining robustness of the results to the set of covariates.

Identification Strategy

To identify the distributional effects of liberalization, we use household grains quota per mu in 1989 interacted with the province-year dummy variables and the distance from the community to the township center interacted with the province-year dummy variables as the instruments for agricultural production value and off-farm income in the IVUQR.

From 1989 to 2000, the role of the central government in determining the amount of grains quota in the province was weakened, and the amount of grains quota in each province was largely determined by the provincial government. The total provincial quota was determined by the weather conditions and the grains production plans of the provincial government. Then the provincial grains quota was divided into a grains quota for each county, township, and community. So the grains quota for the whole community is assigned by the township government and is independent of the *individual* household's production decisions. At the local level, the grains quota for each household was determined by the historical household grains quota per mu, household size, and allocated land, and thus was less dependent on current household crop choice.[13]

The grains quota can be seen as an in-kind local agricultural tax levied on the household. One may be concerned that farmers simultaneously rent out their land, reduce their effective quota burden, and reorient towards off-farm employment. In addition, local grain

[13] We also check that grains quota per mu is not correlated with access to irrigation. The correlation coefficients is only 0.089 between grains quota per mu and share of land under unified irrigation system in the community.

bureaus may accept cash in lieu of grains for the quota payment. Because we use grains quantity sold to government as our measure of grains quota, if either above concern is true, our observed grains sold to government may not be equal to the grains quota initially set by the local community leaders, potentially resulting in measurement error and endogeneity. We address both concerns by using the observed grains quota in 1989 because at that time, the land rental markets are negligible and cash is rarely accepted in lieu of grains. Both existing literature and our data support this argument. China's farmers rented out less than 0.3% of the land they cultivated in 1988 (Brandt, Rozelle, and Turner 2004), a level that had only grown to 2.5% by 1995. In our data, household land size remains essentially unchanged between 1989 and 1991, with no household recording a change in land size greater than one mu. Given the shortage of grains at the provincial level in 1988-1989 (Park et al. 2002), the local grains bureaus strictly enforced grains quota to ensure a sufficient amount of grains were collected, and thus rarely accepted cash in place of grains. Therefore, grains per mu sold to the government likely reflect the required grains quota per mu in 1989.

The historical grains quota per mu affects later household grains quota because it serves as a benchmark for household quota allocation. For example, if a community-level grains quota declines 10% from year to year, then the grains quota on every mu of land is likely to decrease from its prior level by 10%. The historical level of grains quota per mu is likely to determine current grains quota requirements and thus agricultural production choices while not being directly associated with household food security. Ideally, to have an exogenous measure of household quota we would interact the past household quota with provincial or local quota mandates. Given that we do not have specific provincial or local quota requirements, we proxy this variation using the past household quota times province by year dummy variables.

We use the distance from the household's resident community to township center interacted with province-year dummy variables as the other IV in our model. Township and village enterprises (TVEs) located in township centers play an important role in rural off-farm income and employment from 1989–1997. During that time, the average share of rural non-farm workforce in TVEs is still over 50% (Kung and Lin 2007).[14]

We separately control for access to market in our model, which is likely correlated with both household food security and distance to township center. As a robustness test, we use the number of migrant workers in the community in the previous year, and Hukou status in 1989 interacted with province-year dummy variables as alternate instruments for off-farm income (see supplementary online appendix tables C1 and C2).[15,16]

In the 1990s, the barriers of rural to urban migration were gradually relaxed. One might be concerned that our market liberalization index is capturing the increasing ease of migration that affects household food security through off-farm income. To address this concern, we conduct two robustness tests. First, we run regressions on a sample of communities where there is less migration, that is, the shares of migrants among all households are below 8.3%, or the 25th percentile of the sample (results are shown in supplementary online appendix tables C3 and C4). Second, Mu and de Brauw (2015) employ the CHNS data and identify the impact of migration using the interaction between wage growth (by gender) in provincial capital cities and initial village migrant networks as instruments of migration selection. The initial migrant network is measured as the share of men and women between the age of 18 and 45 who had migrated in 1989. In our second robustness test, we construct and include Mu-de Brauw instruments in all regressions (shown in supplementary online appendix tables C5 and C6). Thus, we attempt to control for the migration that might affect household food

[14] In fact, households rarely permanently move out of their communities and relocate in areas with more off-farm work opportunities in the 1990s. Part of the reason is that if farmers permanently leave agriculture, they have to return the land to local authorities, and consequently, give up future income from the land. It is easier to attend to farms if farmers live at least some time in the communities where their allocated land is located.

[15] Migrants in this article are household members between age 18 and 45 that are out of home for at least one month as defined by Mu and de Brauw (2015).

[16] Hukou is the household registration system implemented in China. The hukou system differentiates opportunity structures for the entire population on the basis of position within a clearly defined spatial hierarchy, that is, urban above rural and well-developed above less-developed cities. Rural hukou holders must pay fees and tuitions that are substantially higher than those paid by local residents. Many local governments continue to require business firms, both state-owned and privately-owned, to hire only local residents.

security through its association with the market liberalization index.

One might be concerned that liberalization affects tastes and improves nutritional knowledge, and that may be the true driver of increased SCNS instead of income. To disentangle this effect, we include the liberalization index in the household food security regression to capture changes in tastes and nutritional knowledge. We control for other observable mechanisms through which liberalization could affect household food security such as community access to markets and information, food retail prices, land, and household demographics.

In addition, one might be concerned that market liberalization leads to improvements in infrastructure and industrial development that may affect household food security. Therefore, in the robustness tests we include distance to the nearest paved road, train station, and the number of TVEs and private enterprises in the model to examine changes in market liberalization that are orthogonal to changes in a community's access to railways, roads, and number of enterprises. The regression results are presented in supplementary online appendix tables C7 and C8. Furthermore, to mitigate the concern that our liberalization index is driven primarily by local commodity-specific shocks, we explore the correlation between the liberalization index and individual commodity price in the community and find little correlation (supplementary online appendix table C9). Additionally, to control for time-invariant household heterogeneity we include household fixed effects. We also use county by year dummy variables to capture agro-climatic and changes in infrastructure and economic conditions that vary over time in a county. After controlling for various variables that affect household food security and are potentially correlated with market liberalization, our measure of market liberalization is treated as exogenous. All standard errors are bootstrap estimates clustered at the community level.

Last, we test the robustness of our results against possible measurement error in the agricultural production value and off-farm income that may be correlated with errors in the measurement of the food security indicators in equation (5). In supplementary online appendix table C10, we follow Wooldridge (2003) and Giles and Yoo (2007) and control for the potential endogeneity introduced by correlated measurement errors by using one and two lags of agricultural production value and off-farm income as instruments.

We find that the Hansen J statistics is 69.68 with a p-value of 0.1840, which suggests that there is no direct evidence against the validity of instruments. When testing the weak identification of instruments, because we cluster standard errors at the community level, we use a correspondingly robust Kleibergen-Paap Wald F statistic. Cameron and Miller (2011, 2015) note that with clustering, there is no appropriate rule of thumb and that instruments may be weak for F statistics at levels above 10, or sufficiently strong well below 10. Consequently, we use a Stata program developed by Finlay and Magnusson (2009) to perform overidentification tests that are robust against weak instruments as well as the hypothesis testing of our regression results. We find no direct evidence against the validity of instruments even when the instruments are weak.

Heterogeneous Effect of Liberalization

To see how market liberalization affects households with varying food security status, we divide the sample into food-secure and food-insecure households and then run separate OLS regressions of equations (2) and (3) for these two subsamples.[17] Following Jensen and Miller (2010), we define food-insecure households as those with less than 16% SCNS. Additionally, we split our sample into food-secure import and export producers, food-insecure import and export producers.[18,19] Then we run first-stage regressions for each of these four groups to see how

[17] Using interaction terms between liberalization and food security status gives us similar results.

[18] We define field crops producers as farmers who receive more than 50% of their agricultural production value from field crops. Import producers are then defined as field crops producers in the northern provinces in China (Liaoning, Shandong, and Henan) because we do not observe the specific crops farmers grow, and wheat, maize, and soybeans production makes up the largest portion of the total field crops production in these provinces (about 92% on average from 1989 to 2000 based on China's Statistical Yearbooks in various years).

[19] Export producers include producers of rice, horticulture, and livestock where China has a comparative advantage, and mixed producers. Field crops producers in southern provinces of China, namely Jiangsu, Hubei, Hunan, Guangxi, and Guizhou are defined as rice producers because in these provinces, rice production makes up the biggest portion of total field crops production. Horticulture and livestock producers are farmers who have over 50% of their agricultural production value from horticulture and livestock, respectively. Mixed producers are farmers who are neither horticulture nor livestock producers but have more than 50% of agricultural production value from livestock and horticulture combined.

Table 2. The Distributional Effects of Income on Log SCNS with No Instrumental Variables

Percentiles	10th	20th	50th	80th	90th
Log agricultural production value	0.039	0.036	0.026	0.012	0.018
	(0.042)	(0.028)	(0.019)	(0.020)	(0.020)
Log off-farm income	0.017[b]	0.016[a]	0.007[c]	0.009[b]	0.008[b]
	(0.007)	(0.006)	(0.004)	(0.004)	(0.004)
Agricultural market liberalization	0.001	0.008	0.004	0.012[b]	0.008
	(0.010)	(0.010)	(0.006)	(0.006)	(0.007)
Household FE	X	X	X	X	X
County by Year FE	X	X	X	X	X
Number of observations	6,770	6,770	6,770	6,770	6,770

Note: Superscripts [a], [b], and [c] denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses and are bootstrap standard errors clustered at the community level. Household size, number of adults in the household, community market score, communication score, and average retail prices of green vegetables, chicken, soybean oil, and rice in the community are also included. In this regression, log agricultural production value and off-farm income are treated as exogenous.

the effect of liberalization differs by food security status and by production type. Last, we connect the heterogeneous effects of liberalization on income to changes in household food security using second-stage regressions (equation 4).

We recognize that systematically subsampling on the dependent variable inherently introduces sample-selection bias (Heckman 1979). This concern is one motivation to use the IVUQR to examine effects at different parts of the distribution rather than for different sub-samples of the dependent variable. Nonetheless, to provide a more detailed description, even if potentially biased, we also present findings from the sub-sample approach. We split the sample by food security status and producer type to estimate the heterogeneous effects of liberalization on household food security through income.

Results

We first estimate simple unconditional quantile regressions measuring the overall association between agricultural market liberalization and the distribution of household food security treating agricultural production value and off-farm income as exogenous. The results in table 2 show that the correlations between both income sources and log SCNS decline from significantly positive to nearly zero as the households become more food secure (Wald test with a p-value of 0.0003). This result highlights the decreasing income elasticity of calories as households become more food secure.

These results may be biased because agricultural production value and off-farm income are potentially correlated with unobserved factors that also affect the SCNS. Thus, we use the IVUQR to identify the effects of liberalization on SCNS when addressing the endogeneity of both incomes. In the first-stage results, we find that liberalization insignificantly affects farmers' average agricultural production value while significantly increasing their average off-farm income (table 3). A one-unit increase in the liberalization index, which amounts to a 3 percentage point decrease in the difference between regional and world prices, will lead farmers to increase off-farm income by 7.0%.[20] Given that the average liberalization index increased by about 4.3 units in the 1990s, the change in market liberalization left the value of the average rural household's agricultural production intact while increasing off-farm income by 30.1%. This result suggests that off-farm income is the dominant income channel through which market liberalization affects the average food security levels of households.

The second-stage regressions on SCNS show that the marginal effects of agricultural

[20] The average liberalization index is 21.1 in 1989, which means the total price differences between farm-gate and regional markets plus the price difference between regional and world markets for seven products that compose the liberalization index are 1/21.3%. The average price difference for each agricultural product is 1/(21.1%*7), or 68%. A one-unit increase in the liberalization index means the liberalization index increases to 22.1 and the average price difference for each agricultural product is 1/(22.1%*7), or 65%. Therefore, a one-unit increase in our liberalization index amounts to a 68%-67% decrease, or a decrease of 3 percentage points in the average difference between local and regional plus regional and world prices.

production value and off-farm income decrease as households become more food secure (results are presented in table 4). As shown in figures 5 and 6, the off-farm income coefficients demonstrate a clear decreasing trend over the quantiles, suggesting decreasing income elasticities of non-staples. Although some of the coefficients of agricultural production value and off-farm income are not statistically significant, we argue that they are economically meaningful in terms of non-staples calories, which we discuss at the end of the results section.

Table 3. The Effects of Market Liberalization on Agricultural Production Value and Off-farm Income (equations 2 and 3)

	Log Agricultural Production Value	Log Off-farm Income
Agricultural market liberalization	0.001	0.070[a]
	(0.005)	(0.024)
Household size	0.072[a]	−0.094[c]
	(0.010)	(0.057)
Number of adults in the household	0.045[a]	0.521[a]
	(0.013)	(0.065)
Community market score	−0.003	−0.005
	(0.007)	(0.031)
Community communication score	−0.006	0.035
	(0.014)	(0.095)
Household FE	X	X
County by Year FE	X	X
Number of observations	6,770	6,770

Note: Superscripts [a], [b], and [c] denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses and are clustered at the community level. The IVs, average retail prices of rice, chicken, vegetables, and soybean oil in the community are included.

Effects of Agricultural Market Liberalization on Income by Food Security Status

Market liberalization might affect income differently depending on the initial state of household food security and the type of household production. We first look at the effects of liberalization on import producers (table 5). Both food-secure and food-insecure import producers see their agricultural production value significantly decrease, while food-secure import producers mitigate this income loss with increased off-farm income (29.2%, 4.3 times 6.8%) from 1989 to 2000.

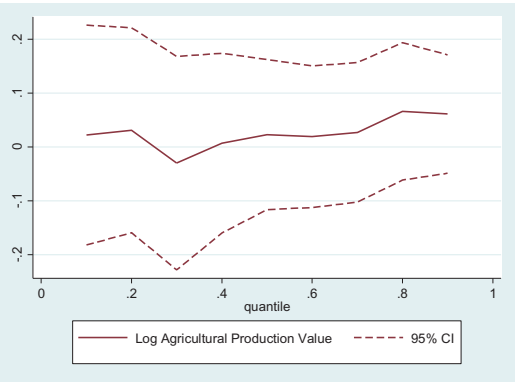


Figure 5. The agricultural production value elasticity of SCNS

Table 4. The Distributional Effects of Agricultural Production Value and Off-farm Income on Log SCNS (Equation 4)

Percentiles	10th	20th	50th	80th	90th	Mean
Log agricultural production value	0.022	0.031	0.023	0.066	0.061	−0.010
	(0.104)	(0.097)	(0.071)	(0.065)	(0.056)	(0.085)
Log off-farm income	0.052[b]	0.020	−0.004	−0.006	0.003	0.041
	(0.025)	(0.024)	(0.017)	(0.017)	(0.018)	(0.018)
Agricultural market liberalization	−0.0007	0.008	0.005	0.013[b]	0.008	−0.001
	(0.011)	(0.010)	(0.006)	(0.006)	(0.007)	(0.006)
Household FE	X	X	X	X	X	X
County by Year FE	X	X	X	X	X	X
Number of observations	6,770	6,770	6,770	6,770	6,770	6,770

Note: Superscript [a], [b], and [c] denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses and are bootstrap standard errors clustered at the community level. Household size, number of adults in the household, community market score, communication score, and average retail prices of green vegetables, chicken, soybean oil, and rice in the community are also included. The mean column presents the results of 2SLS regressions. The IVs for log agricultural production value and off-farm income are log of grains quotas per mu in 1989 interacted with province-year dummy variables and the distance to township center interacted with province-year dummy variables.

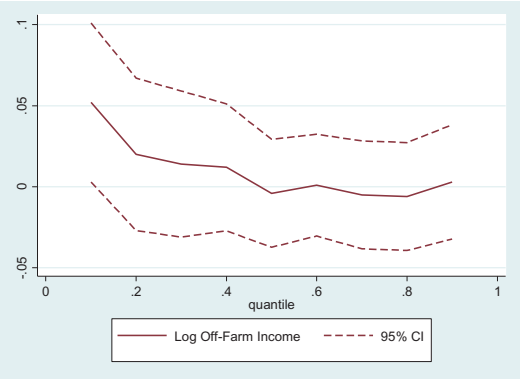


Figure 6. The off-farm income elasticity of SCNS

On the other hand, food-insecure import producers see their value of agricultural production decrease by 14.6% (4.3 times 3.4%) without earning more off-farm income.

Liberalization appears to increase off-farm income for all types of producers except for food-insecure import producers, but the coefficient is only statistically significant for food-secure export producers. Our results indicate that food-insecure import producers at best do not benefit from liberalization, while all other producers appear to benefit, largely from improved off-farm income. This finding is consistent with studies that find poor farmers who have little economic links with the outside world are the most vulnerable to agricultural market liberalization, while wealthier food-secure farmers are capable of capturing off-farm work opportunities given better human capital and access to credit (Anderson, Huang, and Ianchovichina 2004; Chen and Ravallion 2004; Huang and Rozelle 2009; Wang et al. 2009).

To further explore possible reasons why liberalization affects off-farm income differently for food-secure versus food-insecure farmers, we interact liberalization with education. All producers with at least middle school education appear to be better able to capture the opportunities induced by market liberalization and improve their agricultural production value and off-farm income compared to their counterparts without middle school education (table 6).[21] Even for the most vulnerable group—food-insecure import producers—having at least middle school education leads market liberalization to increase their off-farm income.

What Do These Results Imply in Terms of Calories?

To gauge the economic significance of our results, we simulate the predicted changes in a household's non-staple calories intake as a result of market liberalization (see table 7). Combining the distributional effects of liberalization on income and income on household food security, we estimate the total effects of liberalization on household food security.

We first estimate the predicted value of logSCNS with the 2000 liberalization index and the counterfactual value of logSCNS with the 1989 liberalization index. To estimate logSCNS at both levels of liberalization, we use coefficients from table 5 and the 10th and 90th percentile coefficients from table 4 while holding all other explanatory variables at the values of 2000. Then we calculate the change in SCNS using exp(logSCNS with 2000 liberalization index)-exp(logSCNS with 1989 liberalization index).

To back out the non-staple calories, we multiply the daily average caloric intake per person of the food-insecure (1,976.87 Kcal) and food-secure households (2,110.6 Kcal) in 2000 with 365 days and the respective changes in SCNS. Finally, to convert non-staple calories to pounds of pork, we divide the change in calories by 760, the average calories in one pound of pork estimated from the Food Composition Table provided by the CHNS data. We chose pork as a non-staple example because of its importance in the Chinese diet (Larsen 2012).

We find that an average food-insecure import producer's consumption *decreases* by 2,129 calories per person per year, the same calories provided by 2.8 pounds of pork, an equivalent of 28.2% decrease based on average meat consumption of 9.9 pounds for food-insecure import producers in 1989. The reason behind this result is that liberalization reduces food-insecure import producers' agricultural production value without increasing off-farm income. In contrast, both food-secure export and import producers benefit from liberalization and *increase* their non-staple consumption by 9,633 and 6,179 calories per person per year, an equivalent

[21] The shares of households whose head has at least middle school education are 29.3%, 31%, 33.8%, 34.8%, and 39% in 1989, 1991, 1993, 1997, and 2000, respectively.

Table 5. The Effects of Market Liberalization on Income for Food-insecure and Food-secure Producers

	Export Producers		Import Producers	
	Log Ag Production Value	Log Off-farm Income	Log Ag Production Value	Log Off-farm Income
Food-insecure				
Liberalization	−0.002	0.049	−0.034[a]	−0.009
	(0.010)	(0.063)	(0.013)	(0.069)
Number of observations	1,983	1,983	846	846
Food-secure				
Liberalization	−0.002	0.121[a]	−0.050[a]	0.068
	(0.007)	(0.044)	(0.015)	(0.116)
Number of observations	3,350	3,350	591	591

Note: Superscript [a], [b], and [c] denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses and clustered at the community level. If the household has an SCNS higher than 16%, the household is defined as a food-secure household. Log of grains quotas per mu in 1989 interacted with province-year dummy variables, distance to township center interacted with province-year dummy variables, household size, number of adults in the household, community market and communication score, food retail prices, household fixed effects and county by year dummy variables are also included.

Table 6. The Effects of Market Liberalization on Income for Food-insecure and Food-secure Producers with Different Education Levels

	Export Producers		Import Producers	
	Log Ag Production Value	Log Off-farm Income	Log Ag Production Value	Log Off-farm Income
Food-insecure				
Liberalization	−0.004	0.056	−0.036[a]	−0.004
	(0.011)	(0.064)	(0.013)	(0.069)
Liberalization*Middle School	0.006	0.021	0.012[b]	0.028
	(0.004)	(0.022)	(0.005)	(0.025)
Number of observations	1,983	1,983	846	846
Food-secure				
Liberalization	−0.003	0.114[a]	−0.051[a]	0.044
	(0.006)	(0.043)	(0.015)	(0.111)
Liberalization*Middle School	0.002	0.017	0.005	0.082
	(0.002)	(0.011)	(0.006)	(0.052)
Number of observations	3,350	3,350	591	591

Note: Superscript [a], [b], and [c] denote significance at the 1%, 5%, and 10% levels, respectively. Standard errors are in parentheses and clustered at the community level. If the household has an SCNS higher than 16%, the household is defined as a food-secure household. Log of grains quotas per mu in 1989 interacted with province-year dummy variables, distance to township center interacted with province-year dummy variables, household size, number of adults in the household, community market and communication score, food retail prices, household fixed effects, and county-by-year dummy variables are also included.

Table 7. The Effects of Liberalization on Non-staple Caloric Intake per Person per Year by Food Security Status

	Non-staple Calories	Pounds of Pork
Food-insecure		
Export Producers	2,350	3.1
Import Producers	−2,129	−2.8
Food-secure		
Export Producers	9,633	12.7
Import Producers	6,179	8.1

Note: The detailed calculation methods are discussed in the results section.

consumption of 12.7 (13.6%) and 8.1 pounds (11.4%) of pork, respectively. These producers appear able to take advantage of the off-farm work opportunities introduced by market liberalization, and increase their off-farm income substantially.

Robustness Tests

The results of all robustness tests are presented in supplementary online appendix C. As noted in the methods section, we test our identification strategy against different sets of

IVs (supplementary online appendix tables C1, C2 and C10) and other possible mechanisms that could make our market liberalization index endogenous (supplementary online appendix tables C3–C9). We also test different definitions of farmers (supplementary online appendix table C11) and rural communities (supplementary online appendix table C12). The results remain substantively the same.

Next, we compare our measure of household food security against other commonly used measures (supplementary online appendix table C13) and find that the off-farm income does not significantly affect average caloric intake per person per day at each quantile, while we observe that off-farm income affects food-insecure households (10th quantile) significantly when using SCNS. Although none of the coefficients are significant, the income elasticities of protein intake per person per day demonstrate similar decreasing patterns as those of SCNS. Furthermore, we evaluate the income elasticities of food diversity for households with different levels of food security where dietary diversity is quantified by the number of food groups consumed by a household per day.[22] Both agricultural production value and off-farm income seem to have a larger impact on dietary diversity for highly food-insecure and food-secure households, while the effect is negligible for the households with median food security levels.

One might be worried that our sample size declines from 1,641 households in 1989 to 1,105 in 2000. The attrition rates are 8% in 1991, 17% in 1993, 30% in 1997, and 33% in 2000 compared to 1989. This may bias our results if the attrition is systematically related to our outcome variables and other features. To test for this concern, in supplementary online appendix table C14, we keep only households in 1989 and count the number of years each household was surveyed. Then we run a linear regression of logSCNS on the number of years surveyed for each household. We do not find a systematic difference across households who are surveyed by different number of rounds. Thus, this result suggests that the attrition of households is not systematically related to our outcome variable.

In our main analysis, we drop non-farmers in the sample (i.e., rural households with less than 10% of their gross income from agriculture), which could introduce bias if we drop households as they earn more off-farm income. We only drop 4% of the rural sample because they do not meet our definition of being a farmer. We then keep those observations back in the data and run our main regressions again (table C15 and C16); our results do not change substantially.

Last, we test the robustness of our results when dropping the household fixed effects in supplementary online appendix tables C17 and C18. Other than a small increase in significance, our coefficients remain substantively unchanged.

Conclusion

We analyze the effects of China's agricultural market liberalization on rural household food security through agricultural production value and off-farm income. We find that market liberalization primarily affects households' food security through off-farm income. Further, the small average effect of liberalization on food security masks a great deal of heterogeneity across producers.

One might worry that food-insecure households will suffer because of agricultural market liberalization. These households may be constrained by credit and/or human capital, and not able to switch to production that is more comparatively advantageous, or get jobs to increase their off-farm incomes. We study the effects of market liberalization on the distribution of food security. Using a novel empirical method, we find that food-insecure import-producing households decrease their agricultural production value without earning more off-farm income. Specifically, agricultural market liberalization causes food-insecure import producers to decrease their caloric intake by 2,129 calories per person per year; the same calories provided by 2.8 pounds of pork (28.2% decrease). Food-secure producers benefit the most from liberalization because they can grab lucrative off-farm opportunities as a result of market liberalization. An average food-secure export and import household increases their consumption of calories from non-staples by 9,633 and 6,179 calories per person per year, a consumption equivalent to 12.7 and 8.1 pounds

[22] There are 12 food groups, which are cereals, legumes, roots and stems, vegetables, mushrooms, fruits, nuts and seeds, meats, milk, eggs, fish, and other foods. The average dietary diversity scores are 4.73, 4.99, 4.94, 5.25, and 5.38 for the years 1989, 1991, 1993, 1997, and 2000 in our sample.

of pork (13.6% and 11.4% increase), respectively. Education appears to be important to allow producers to capture opportunities afforded by market liberalization and increase their food security. Our results are robust to different definitions of the rural sample, farmers, and various model specifications.

There are at least two possible mechanisms through which the reduction in grains quotas and trade barriers could have increased off-farm income for farmers. First, relaxing the grains quota gave farmers more freedom to work off-farm and earn more income, and second, specialization may have increased the demand for labor. To meet the grains quota, Chinese farmers needed to stay on-farm to grow enough grains to fulfill this mandatory quantity requirement. In addition, evidence indicates that village leaders used the threat of land reallocation as a means of motivating farmers to provide their grains quota and thus limited farmers' off-farm supply (Lohmar 2000). When the quota was gradually reduced, farmers could pay money in lieu of grains, and lending out land, and thus the associated quota, became more feasible. Eventually during our time period, the grains quota ended. With the end of the grains quota, village leaders may have had less of an incentive to threaten to reallocate land, leaving farmers with discretion to work in a more profitable sector and increase their off-farm income. Further, other authors find that the threat of reallocating land came at a cost to elected village leaders, who were more likely to lose their position by engaging in egregious land siezures (Giles and Mu 2014).

On the other hand, market liberalization may have encouraged farmers and local processors to specialize in producing those crops or livestock in which they have a comparative advantage, which may have increased farm scale and demand for farm labor. Although we do not have the data to directly disentangle these two mechanisms, we believe they could both explain how market liberalization increases rural household food security through more off-farm income.

In conclusion, the effects of market liberalization are heterogeneous depending on producer type and initial food security status. Although market liberalization is generally beneficial for food-secure households, it is not as beneficial for food-insecure households, particularly food-insecure import producers. Therefore, Chinese policy makers may wish to take extra steps to protect food-insecure farmers from the negative effects of liberalization by alleviating their human capital, credit, and technology constraints. In this way, agricultural market liberalization may enhance food security for all farmers.

Supplementary Material

Supplementary material are available at *American Journal of Agricultural Economics* online.

Notes

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