On-line appendix (not for publication)

Conceptual framework

The Lagrangian corresponding to the household's optimization problem can be written as follows. Note that the total labor constraint will always bind given that the model does not include leisure. In addition, households will always use their full initial endowment as agricultural capital, $\underline{Y} = K_1^A$, and savings will always be positive, enabling production and consumption in the second period, given the concavity of the utility function.

$$\begin{aligned}
&\max\ U(P_m^A(f^A(\underline{Y}, \bar{L}) - Q) + P_q^A Q - S) \\
&+ U(P_m^A(f^A(S + B - K_2^N, \bar{L} - L_2^N) - Q) + P_q^A Q + P^N f^N(K_2^N, L_2^N) - rB) \\
&+ \lambda_1 \max\ (0,\ K_2^N - K_{min}) \\
&+ \lambda_2(B) \\
&+ \lambda_3(S + B - K_2^N) \\
&+ \lambda_4(L_2^N)
\end{aligned} \tag{1}$$

The first-order conditions can be written as follows.

$$-U'(C_1) + U'(C_2)(P^A \frac{\partial f^A}{\partial K_2^A}) + \lambda_3 = 0 \tag{2}$$

$$U'(C_2)[-P^A \frac{\partial f^A}{\partial K_2^A} - P^N \frac{\partial f^N}{\partial K_2^N}] + \lambda_1 - \lambda_3 = 0 \tag{3}$$

$$U'(C_2)[P^A \frac{\partial f^A}{\partial K_2^A} - r] + \lambda_2 + \lambda_3 = 0 \tag{4}$$

$$-P^A \frac{\partial f^A}{\partial L_2^A} + P^N \frac{\partial f^N}{\partial L_2^N} + \lambda_4 = 0 \tag{5}$$

The solution to this model can be denoted $\tilde{S}$, $\tilde{K}_2^N$, $\tilde{B}$, and $\tilde{L}_2^N$. In addition, I will define K_r as the level of capital at which the returns to capital in non-agricultural production are equal to the interest rate. This is shown graphically in Figure 1.

The primary comparative statics of interest are $\frac{\partial \tilde{S}}{\partial P_q^A}$, $\frac{\partial \tilde{K}_2^N}{\partial P_q^A}$, and $\frac{\partial \tilde{B}}{\partial P_q^A}$. Again, consider two hypothetical scenarios, one in which the quota price is low and one in which the quota price is high. The low quota price is defined as $\underline{P}_q \equiv \alpha + \beta P_m$; in other words, the quota price matches the predicted quota price based on the historic relationship between the quota and the market prices. The high quota price is defined as $\bar{P}_q \equiv \alpha + \beta P_m + \epsilon$, where $\epsilon > 0$; in other words, the quota price is abnormally high relative to the market price, presumably because the government has chosen to increase the quota price to meet some policy objective.

There are three primary cases to consider: households that do not engage in non-agricultural production in both cases, households that do engage in non-agricultural production in both cases, and households that engage in non-agricultural production only when the quota price is high.

"Always agricultural households" These are households for which the liquidity constraint always binds, $P_m^A f^A(\underline{Y}, \bar{L}) - Q) + P_q^A Q < K_{min}$, and thus given the assumptions about returns to capital, there is no borrowing. The increase in the quota price (and thus in the weighted price for agricultural output) will generate an income effect (more income available for consumption in both periods) and a substitution effect (the returns to savings and re-investment are higher). The net effect on savings and consumption will vary based on the relative magnitude of these two effects. There will be no change in the allocation of capital and labor between agricultural or non-agricultural production.

"Always non-agricultural households" These are households for which the liquidity constraint does not bind even at a low quota price, $P_m^A f^A(\underline{Y}, \bar{L}) - Q) + P_q^A Q \geq K_{min}$. There are two sub-cases here.

1. First, households where given a low quota price, $\tilde{S} > K_r$. These are households with a high initial endowment that can afford to enter non-agricultural production using self-financing, and thus do not borrow. They may or may not also be engaged in agricultural production. If the quota price increases, K_2^A will weakly increase, as will L_2^A; K_2^N and L_2^N will weakly decrease. There will be no change in borrowing, and the impact on savings and consumption is again ambiguous.

2. Second, households where given a low quota price, $K_{min} \leq \tilde{S} \leq K_r$, and thus $K_2^N = K_r$. (Note that given the assumptions about returns to capital, households that can meet the minimum capital investment with savings will always borrow in order to increase capital investment to K_r. Thus no household will choose $K_2^N = K_{min}$.) These are households that are engaged only in non-agricultural production, and are borrowing some quantity B. Following an increase in the quota price, their borrowing will decrease. K_2^N and K_2^A will be unaffected, as will L_2^A and L_2^N.[1] The effect on savings and consumption is ambiguous.

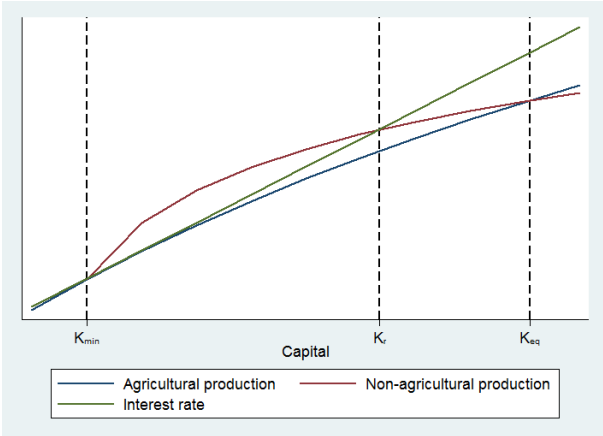
"Switcher households" These are households that are liquidity-constrained given low quota prices, but not liquidity-constrained given high quota prices. For these households, K^N will increase following an increase in the quota price (they will engage in non-agricultural production for the first time), and B will increase (they will borrow for the first time). The effect on consumption is ambiguous.

Data appendix

Again, the primary analysis seeks to estimate the effects of increased quota income on investment in and income derived from agriculture, investment in and income derived from non-agricultural household businesses, outside employment, migration, borrowing, and consumption. I will provide more details here about the construction of agricultural income and consumption.

[1] This will be true unless the positive income shock is of large enough magnitude to enable these households to increase investment in non-agricultural capital to K_{eq} and then resume investing in agriculture.

Figure 1: Returns to capital and interest rate



Agricultural income is calculated valuing all agricultural production at the market price observed in each village-year cell; the market price of each crop or product is calculated as a sales-weighted average of unit prices reported by households. The agricultural products reported include wheat, rice, corn, soybeans, cotton, rapeseed, sugar, fiber, tobacco, fruit, silk, tea, herbs, vegetables, pork, beef and lamb, poultry, eggs, milk, fishery products, lumber, bamboo and forestry products.

This income measure is then deflated using a weighted Laspeyres price index constructed from the same prices, employing 1993 as the base year. Algebraically, the Laspeyres index can be written as follows, where i indices agricultural products of interest.

$$Lasp_t = \frac{\sum_{i=1}^{N} Q_{i,1993} P_{it}}{\sum_{i=1}^{N} Q_{i,1993} P_{i,1993}} \tag{6}$$

$Q_{i,1993}$ is mean output of the good in 1993. P_{it} denotes the mean price observed for the good in year t. Note the Laspeyres index does not vary across provinces.

In the robustness checks, I also demonstrate that the results are consistent when a Paasche index is employed to deflate agricultural income, constructed using output weights based on the final year (2002). The Paasche index can be constructed as follows.

$$Paasche_t = \frac{\sum_{i=1}^{N} Q_{i,2002} P_{it}}{\sum_{i=1}^{N} Q_{i,2002} P_{i,2002}} \tag{7}$$

Consumption is reported as the value of non-staple consumption, including non-staple foods and all other consumption, and staple (grain) consumption in yuan. Both consumption variables are calculated as the sum of directly reported cash consumption and consumption of own-farm output (of both grain and non-grain items).

In order to value own-consumption of farm output, I use data on the reported quantities of consumption of grain and non-grain food. Quantity consumed (though not prices or expenditure) is reported for grain, vegetables, vegetable and animal oil, pork, beef and lamb, milk, poultry, eggs, fish and shrimp, fruit and sugar. For grain, the quantity purchased in the market is also reported, and thus I can calculate what proportion

of total consumption corresponds to own-output. Unfortunately, since this fraction is not reported separately for other consumption goods, I impute this fraction for all other goods reported in order to estimate the quantity of own-farm output consumed. This quantity is then valued employing the market price for this good in the village-year cell, calculated as the sales-weighted average of crop sales; data is not available on the local prices of purchased food items.

Thus "grain consumption" is the sum of expenditure on grain and the imputed value of own-grain consumption; "non-staple consumption" is the sum of expenditure on all consumption items excluding staple grains (both food and non-food), and the imputed value of consumption of own-farm non-grain products. Consumption is reported in yuan and deflated employing a province- and year-specific consumer price index generated by Brandt and Holz (2006).

Figures and Tables

Table 1: Robustness checks on the first stage

	Quan. rice res.	Quota dummy	Quota quan.	
	(1)	(2)	(3)	(4)
Climatic index	27.816	-.0001		
	(55.511)	(.100)		
Annual precip.			9.749	
			(14.741)	
Annual temp.				114.188
				(124.304)
Mean dep. var.	2.929	.920	199.568	402.829
St. dev. dep. var.	178.534	.271	194.488	569.848
Obs.	16034	16203	15522	13081
Fixed effects	Prov.-year		Village	
Clustering	Province		Two-way clustering, province + year	

Notes: The dependent variable in Column (1) is the residual of quota quantity regressed on rice area; in Column (2) it is a dummy variable equal to one if a village reports quota phase-out; and in Column (3) and (4) it is quota quantity. The independent variable is the climatic index constructed using weather data and annual measures of precipitation and temperature, all normalized to have mean zero and standard deviation one. Fixed effects and clustering are as reported in the table. Asterisks indicate significance at the ten, five, and one percent level, respectively.

Table 2: Robustness checks: Agriculture and human capital investment

Panel A: Alternate agricultural variables

	Raw input values				Standardized variables		
	Fertilizer value	Seeds value	Animal inv.	Tools inv.	Output nominal	Output - Paasche-adjusted	Cash crops: frac. total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Quota income (lagged)	-25.346	-22.052	31.501	-15.202	-.120	-.117	-.077
	(48.910)	(4.691)***	(94.616)	(13.446)	(.050)**	(.069)*	(.052)
Obs.	16076	16203	15511	15941	16203	16203	16133

Panel B: Human capital

	Medical exp.	Cultural services	Tuition	Educ. attainment
	(1)	(2)	(3)	(4)
Quota income (lagged)	.572	48.979	-8.966	.090
	(.779)	(88.795)	(85.478)	(.070)
Obs.	16202	16203	16202	16176

Notes: All specifications include village and province-year fixed effects, the interaction of the climatic index and a summary measure of market prices, climatic index quantile fixed effects interacted with the two year lagged market price, climatic quantile index fixed effects interacted with year fixed effects, and industrial quantile fixed effects interacted with year fixed effects. Standard errors are estimated employing two-way clustering at the province and year level. The independent variable is quota income, instrumented by the lagged interactions of two climatic indices of the propensity to cultivate rice (derived from weather data and FAO data respectively), and the quota price. Asterisks indicate significance at the ten, five, and one percent level, respectively.

The dependent variables in Panel A include value of fertilizer and seeds reported used, in yuan; and new investment in tools and animals, reported in yuan. These variables are not deflated to account for inflation. The dependent variable in Column (5) is agricultural income that is not deflated; in Column (6), agricultural income is deflated using a Paasche index; and in Column (7), the fraction of total agricultural income accounted for by cash crops. In Panel B, the dependent variables include reported household expenditure on medical services, cultural services and tuition; and the educational attainment of the primary laborer.

Table 3: Alternate specifications

	Agri. input (1)	Agri. prod. (2)	Non-agri. inv. (3)	Non-agri. inc. (4)	Outside labor (5)	Migration (6)	Borrowing (7)	Grain cons. (8)	Other cons. (9)
Panel A: Sample excluding low grain production households									
Quota income (lagged)	-.539	-.134	.688	.076	.050	.177	.095	-.083	.125
	(.276)*	(.077)*	(.331)**	(.059)	(.058)	(.090)**	(.053)*	(.086)	(.059)**
Obs.	16031	16031	16031	16031	16031	16031	16031	16031	16031
Panel B: Sample excluding cases of quota phase-out									
Quota income (lagged)	-.594	-.219	.922	.140	-.004	.187	.113	-.064	.174
	(.296)**	(.105)**	(.483)*	(.091)	(.054)	(.112)*	(.090)	(.096)	(.085)**
Obs.	14910	14910	14910	14910	14910	14910	14910	14910	14910
Panel C: Sample including additional controls for leading grain market price									
Quota income (lagged)	-.359	-.206	.511	.054	.037	.156	.094	-.043	.125
	(.150)**	(.041)***	(.287)*	(.041)	(.053)	(.077)**	(.026)***	(.063)	(.052)**
Obs.	16203	16203	16203	16203	16203	16203	16203	16203	16203
Panel D: Sample including fixed effects constructed using FAO index									
Quota income (lagged)	-.490	-.027	.543	.052	.080	.162	.108	-.020	.134
	(.276)*	(.099)	(.218)**	(.051)	(.043)*	(.068)**	(.017)***	(.068)	(.071)*
Obs.	16203	16203	16203	16203	16203	16203	16203	16203	16203
Panel E: Sample of heterogeneous cultivation villages									
Quota income (lagged)	-.495	.019	-.008	-.021	.014	.033	.010	.076	-.003
	(.261)*	(.040)	(.144)	(.036)	(.039)	(.021)	(.007)	(.101)	(.041)
Obs.	11576	11576	11576	11576	11576	11576	11576	11576	11576

Notes: All specifications include village and province-year fixed effects, the interaction of the climatic index and a summary measure of market prices, climatic index quantile fixed effects interacted with the two year lagged market price, climatic quantile index fixed effects interacted with year fixed effects, and industrial quantile fixed effects interacted with year fixed effects. Standard errors are estimated employing two-way clustering at the province and year level. The independent variable is quota income, instrumented by the lagged interactions of two climatic indices of the propensity to cultivate rice (derived from weather data and FAO data respectively), and the quota price. Asterisks indicate significance at the ten, five, and one percent level, respectively.

In Panel A, the sample is restricted to exclude households where quota sales are equal to total reported production of grain. In Panel B, the sample is restricted to exclude village-years where there is evidence of quota phase-out (no quota sales reported in that year or any subsequent year). In Panel C, interactions between climatic index quantile effect and leads of the grain market price are included. In Panel D, fixed effects defined using the FAO index are added (quantile-year interactions and quantile-price interactions). In Panel E, the main specification is re-estimated using the sample of heterogeneous cultivation villages.

The dependent variable in Column (1) is a summary variable of agricultural investment; it is calculated as the mean of six component variables (area sown, agricultural labor, value of fertilizer employed, value of seeds employed, investment in animals, and investment in tools), standardized to have mean zero and standard deviation one. The dependent variable in Column (2) is income from agricultural production, calculated valuing all agricultural production at the market price observed in each village-year cell. The dependent variable in Column (3) is a summary variable of non-agricultural investment; it is calculated as the mean of four component variables (a dummy variable equal to one if the household reports any new cash investment in non-agricultural machinery, a dummy variable equal to one if the household reports any labor invested in a non-agricultural business, and the amount of labor and cash investment reported in non-agricultural businesses), standardized to have mean zero and standard deviation one. The dependent variable in Column (4) is income from non-agricultural household businesses and wage labor. The dependent variable in Column (5) is a dummy variable equal to one if the household reports any outside labor; the dependent variable in Column (6) is a dummy variable equal to one if the household reports any labor worked as a migrant; the dependent variable in Column (6) is a dummy variable equal to one if the household reports any access to credit. The dependent variables in Columns (7) and (8) are measures of consumption expenditure on all non-staple items and staple food, valued in yuan.

Table 4: Attrition

	Number observations		Final year	
	(1)	(2)	(3)	(4)
Climatic index	.420			
	(.390)			
FAO index		.150		
		(.431)		
Quota income lagged			.003	-.062
			(.004)	(.075)
Quota income lagged year 1			-.00004	
			(.00003)	
Quota income lagged year 2			-9.18e-06	
			(.00006)	
Obs.	3798	3798	14772	16203

Notes: In Columns (1) and (2), the dependent variable is the number of years a household is observed in the panel. The independent variables are the two climatic indices of propensity to cultivate rice employed in the main analysis, standardized to have mean zero and standard deviation one; standard errors are clustered at the province level. In Columns (3) and (4), the dependent variable is a dummy variable equal to one if it is the last year in which a household appears in the panel. The independent variables are quota income lagged and quota income lagged by two and three years; both specifications include village and province-year fixed effects, the interaction of the climatic index and a summary measure of market prices, climatic index quantile fixed effects interacted with the two year lagged market price, climatic quantile index fixed effects interacted with year fixed effects, and industrial quantile fixed effects interacted with year fixed effects. Standard errors are estimated employing two-way clustering at the province and year level. In Column (4), quota income is instrumented with the instruments constructed using climatic indices and price.

References

Brandt, Loren and Carsten Holz, "Spatial price differences in China: Estimates and implications," *Economic Development and Cultural Change*, 2006, *55* (1), 43–86.

Table 5: Heterogeneous effects employing the FAO-derived climatic index

	Agri. input (1)	Agri. prod. (2)	Non-agri. inv. (3)	Non-agri. inc. (4)	Outside labor (5)	Migration (6)	Borrowing (7)	Grain cons. (8)	Other cons. (9)
Panel A: Heterogeneous effects for previously unconstrained households									
Clim. index x price (lagged)	-.017	-.004	.016	.003	.002	.004	.003	.002	.003
	(.008)**	(.003)	(.013)	(.002)*	(.003)	(.004)	(.001)***	(.003)	(.001)***
Asset ownership int.	-.005	-.001	-.015	-.001	.001	-.0009	-.002	.003	.003
	(.010)	(.002)	(.0009)***	(.001)	(.0009)	(.0007)	(.001)	(.0006)***	(.0009)***
Obs.	15118	15118	15118	15118	14238	11109	15118	15118	15118
Panel B: Heterogeneous effects for high-income households									
Clim. index x price (lagged)	-.014	-.003	.016	.003	.002	.005	.003	.002	.003
	(.007)*	(.003)	(.013)	(.001)*	(.002)	(.003)*	(.001)***	(.002)	(.001)**
Top quantile int.	-.020	-.006	-.011	-.002	.0003	-.0009	-.0008	-.0007	.001
	(.005)***	(.001)***	(.003)***	(.0005)***	(.0009)	(.0003)***	(.0003)***	(.001)	(.004)
Obs.	15118	15118	15118	15118	14611	13323	15118	15118	15118

Notes: All specifications include village and province-year fixed effects, the interaction of the climatic index and a summary measure of market prices, climatic index quantile fixed effects interacted with the two year lagged market price, climatic quantile index fixed effects interacted with year fixed effects, and industrial quantile fixed effects interacted with year fixed effects. Standard errors are estimated employing two-way clustering at the province and year level. Asterisks indicate significance at the ten, five, and one percent level, respectively. The dependent variables are defined in the notes to Table 3.

In Panel A, the independent variables include the FAO index-price interaction, and the triple interaction including a dummy variable for households already owning non-agricultural assets. In Panel B, the independent variables include the FAO index-price interaction, and the triple interaction including a dummy variable for a household identified as in the top income quantile pre-1993.

Table 6: Robustness checks

	Lagged agri. input (1)	Lagged agri. prod. (2)	Lagged non-agri. inv. (3)	Lagged non-agri. inc. (4)	Lagged outside labor (5)	Lagged migration (6)	Lagged borrowing (7)	Lagged grain cons. (8)	Lagged other cons. (9)
Panel A: Endogenous determination of quota quantity									
Quota quantity	-.176	-.030	.221	.005	-.039	.004	.012	.010	-.001
	(.197)	(.033)	(.173)	(.029)	(.021)*	(.013)	(.026)	(.041)	(.026)
Quota quantity int.	.657	.051	-.291	-.019	.044	-.028	-.017	.057	.024
	(.287)**	(.068)	(.234)	(.062)	(.032)	(.015)*	(.035)	(.079)	(.039)
Obs.	16203	16203	16203	16203	16203	16203	16203	15983	16203
Panel B: Endogenous determination of quota price									
Quota price	-.180	-.036	.167	.019	-.007	-.010	.031	.074	.010
	(.154)	(.044)	(.125)	(.014)	(.012)	(.016)	(.012)**	(.076)	(.019)
Quota price int.	-.159	-.003	-.061	-.004	-.007	-.006	-.010	-.087	-.028
	(.084)*	(.045)	(.097)	(.014)	(.021)	(.024)	(.008)	(.072)	(.015)*
Obs.	340	284	340	340	340	340	340	340	284

Notes: The dependent variables are the lagged values of the primary dependent variables of interest, defined in the notes to Table 3. The independent variables in Panel A are quota quantity and the interaction of quota quantity with the FAO-derived index of propensity to cultivate rice, both standardized to have mean zero and standard deviation one; household and province-year fixed effects are included. The independent variables in Panel B are quota price and the interaction of quota price with the FAO index, both standardized to have mean zero and standard deviation one; data at the village-year level is employed, and village and province-year fixed effects are included. Standard errors are estimated employing two-way clustering at the province and year level. Asterisks indicate significance at the ten, five, and one percent level, respectively.

Table 7: Quota enforcement

	Quota quantity			Party	Economic	Cadres	Quota fulfilled	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Government employee	-41.230							
	(11.932)***							
Employee int.	.151							
	(15.377)							
Cadre		7.092						
		(10.022)						
Cadre int.		-8.576						
		(9.687)						
Party member			-3.031					
			(7.531)					
Party member int.			-13.778					
			(5.523)**					
Climatic index				.202	-.117	1.138	-1.752	.003
				(.158)	(.201)	(1.831)	(1.416)	(.015)
Obs.	16128	16147	16155	397	397	396	814	136

Notes: The dependent variable in Columns (1) to (3) is quota quantity; the independent variables are dummy variables for a household including a government employee, a party cadre, or a party member, and these variables interacted with the climatic index for propensity to cultivate rice. The dependent variables in Columns (4) through (8) are the number of party members, administrative committee members, economic committee members, and cadres reported in the village, and the percentage of the assigned quota reported fulfilled. The quota reported fulfilled is only reported prior to 1993. The specifications in Columns (1) through (3) include village and province-year fixed effects, the interaction of the climatic index and a summary measure of market prices, climatic index quantile fixed effects interacted with the two year lagged market price, climatic quantile index fixed effects interacted with year fixed effects, and industrial quantile fixed effects interacted with year fixed effects. Standard errors are estimated employing two-way clustering at the province and year level. The specifications in Columns (4) through (8) include province-year fixed effects, and standard errors clustered at the village level. Asterisks indicate significance at the ten, five, and one percent level, respectively.