Grain into gold? The impact of agricultural income shocks on rural Chinese households*

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Abstract

This paper analyzes whether there is evidence of a poverty trap driven by credit constraints and non-linearities in the return to capital in rural China in the 1990s, estimating the effect of positive income shocks experienced by rural households as a result of increases in the price paid for mandatory grain quota sales. Households were required to sell part of their grain output to the state at a below-market price, and increases in the quota price generated income shocks that also varied cross-sectionally in accordance with crop composition. The identification strategy exploits climatically driven variation in crop composition in conjunction with quota price fluctuations to identify quasi-random variation in the size of the positive income shock and estimate its impact on economic outcomes. The results suggest agricultural investment decreases and investment in non-agricultural businesses and migration increase as households gain increased income, consistent with a poverty trap in which households are initially constrained from entering new productive sectors. There is also evidence of large increases in consumption and borrowing.

1 Introduction

A large literature in development economics has sought to identify whether the persistence of poverty in developing countries is partially attributable to poverty traps: interactions between capital market imperfections, missing insurance markets, and non-linearities in the returns to capital that render it challenging for households living in poverty to exit. Analysts have particularly focused on the salience of poverty traps in rural areas, where evidence suggests that rural households persist in low-return forms of cultivation due to the absence of sufficient capital to enter higher-return sectors, either alternate crops or non-agricultural production (Dercon, 1998; Barrett et al., 2001), or because they are unable to insure themselves fully against consumption risk and thus persist in low-risk, low-return cultivation (Dercon and Christiaensen, 2011). While the theoretical framework for poverty traps is well-established, the empirical literature is more mixed, and often constrained by the absence of plausibly exogenous shocks to income in a context where household's investments across a range of productive activities can be observed.

This paper estimates the impact of a policy-driven positive income shock to rural households on investment in agricultural and non-agricultural production in China, seeking to identify whether this shock leads to movement from agricultural to non-agricultural production that would be consistent with an ex ante poverty trap created by the interaction of non-linearities in the returns to capital in non-agricultural production and credit constraints. In the post-1983 period, rural Chinese households were required to sell a fixed quota of grain to the state at a below-market price as part of the so-called Household

Responsibility System implemented following decollectivization. However, the central government began to raise this price gradually in the mid-1990s (Huang and Rozelle, 2002). This shift was equivalent to a reduction in the size of the lump-sum tax imposed on rural households (Huang, 1998), or conversely, a positive income shock.

Crucially, however, the size of this shock varied systematically as a function of the composition of crops cultivated, given the stark difference in the treatment of different crops under the quota system (Huang, Rozelle, Ha and Li, 2002). Predominantly rice-growing areas systematically experience larger income shocks, given that they are subject to larger mandatory quota quantities than predominantly wheat-growing areas. The identification strategy here exploits this cross-sectional variation in conjunction with shocks to the quota price over time. While cultivation of rice is itself an endogenous household decision, the specification of interest will analyze the impact of increasing quota income for areas that have a greater propensity to cultivate rice based on their climatic conditions, conditional on village and province-year fixed effects.

The results suggest that in an instrumental variables specification in which income is predicted by the interaction of the propensity to cultivate rice and quota price, an increase in quota income leads to a decrease in agricultural investment and an increase in non-agricultural investment and migration. There is also an increase in consumption of non-staple goods, and a large increase in borrowing. The observed pattern is consistent with a model in which households with low initial endowments and limited access to credit are unable to make certain minimum investments required to enter non-agricultural production. The increase in quota income relaxes this constraint.

The results are also robust to a series of specification checks. The effects of the quota shocks are observed primarily for households that have not diversified into non-agricultural production ex ante, i.e., those that are plausibly constrained. There is no evidence that these patterns reflect differential trends in areas with different climatic conditions, or differential shocks in policy or other output prices correlated with the quota price. There is also little evidence that variations in quota policy are endogenously driven by varying conditions in the local economy.

This paper contributes to several related literatures. First, a large literature on poverty traps has argued that various market imperfections in rural sectors – including lumpy investments, credit constraints, and/or the absence of consumption-smoothing mechanisms – lead to agricultural households with initially poor endowments failing to exploit higher-return opportunities in non-agricultural production. The theoretical literature here is anchored by Banerjee and Newman (1993), though there are a number of more recent papers. There is also a large empirical literature, primarily though not exclusively focused on rural areas.[1] The evidence presented here suggesting that lump-sum income shocks lead to a shift in the portfolio of investments between agricultural and non-agricultural activities is broadly consistent with this literature, a point that will be explored in further detail in the conceptual framework in Section 2.2.

Second, a number of papers have analyzed how households respond to evolution in the rate of return on agricultural investments. Foster and Rosenzweig (2004) estimate the impact of shocks to the returns to agriculture in India induced by the adoption of Green Revolution technology and find that industrial growth is fastest in areas where agricultural growth is lagging. Jedwab (2011) finds that positive price shocks to cocoa during cocoa booms in Ghana and the Ivory Coast lead to an increase in urbanization. Kaboski and Townsend (2011) evaluate the impact of a government-sponsored microcredit program as a major income shock in rural Thailand on consumption and investment. Bustos et al. (2015) present evidence that the introduction of genetically engineered soybean seeds in Brazil leads to industrial growth.

Third, there is some evidence about the impact of positive income shocks in the form of cash transfers on investment, primarily in an urban context. Gertler, Martinez and Rubio-Codina (2012) and Sadoulet, de Janvry and Davis (2001) find that households benefiting from cash transfer programs in Mexico invest transfers in productive assets, resulting in a long-term increase in consumption; Gilligan, Hoddinott and Taffesse (2008) find similar results examining a government assistance program in Ethiopia. Blattman, Fiala and Martinez (2014) find that cash transfers to young adults for non-agricultural activities lead to increases in business assets and income.

Fourth, this paper contributes to the body of work focused on analyzing the grain quota system as it operated in China. Lu (1999) describe broad trends in the operation of the quota system over time. Rozelle et al. (2000) describe reform over the decade of the 1990s, particularly the backlash following early attempts at liberalization. Huang, Rozelle and Wang (2006) evaluate the quota system as part of a broader analysis of capital flows in and out of the agricultural sector. Further discussion of existing work describing the grain quota system can be found in Section 2.1.

More recently, a broader literature in macroeconomics has documented the evidence of a large gap in labor productivity between the agricultural and non-agricultural sectors in developing countries, and relatedly, a large gap in labor productivity comparing the

[1]See, for example, Barrett, Bezuneh and Aboud (2001); Dercon and Krishnan (1996); Dercon (1998); Dercon and Christiaensen (2011); Jalan and Ravallion (2002); McKenzie and Woodruff (2006); Reardon, Delgado and Matlon (1992); Reardon, Taylor, Stamoulis, Lanjouw and Balisacan (2000). All of these papers present evidence consistent with poverty traps in rural areas except McKenzie and Woodruff (2006), in which the authors find no evidence consistent with a poverty trap for urban microenterprises in Mexico. Azariadis and Stachurski (2005) provides a useful overview of the broader literature as it links to theories of economic growth.

agricultural sector in developing and developed countries (Gollin, Lagakos and Waugh, 2014; Lagakos and Waugh, 2013). This paper provides evidence of constraints on exit from agriculture that would be consistent with the presence of a large and relatively unproductive agricultural sector.

Relative to this literature, this paper is one of the first to my knowledge to exploit a quasi-exogenous source of variation in income in rural areas in order to identify the presence of a poverty trap. It is also one of the first papers to analyze the impact of variation in quota policy in China on diversification in non-agricultural production. The paper proceeds as follows. Section 2 outlines the institutional structure and a conceptual framework, and Section 3 describes the data. Section 4 presents the identification strategy. Sections 5 and 6 present results and robustness checks, and Section 7 concludes.

2 Institutional background

2.1 Grain policy in China

Prior to 1978, agricultural production in China was highly collectivized. The primary unit of production was the production team, a cluster of 20 to 30 households that jointly farmed agricultural land and sold the resulting output. After the death of Mao Zedong, however, major changes in agricultural policy were introduced. The household was reinstated as the primary unit of production under a system known as the Household Responsibility System. Each household was provided with an allocation of land for its own use, while land title continued to be held by the village (Brandt et al., 2002).

In addition, households were mandated to deliver a fixed amount of quota grain to the state at a preset price. Excess production could be sold to the state at a higher, above-quota price, or at rural markets (Lin, 1992). Grain thus sold to the state was primarily funneled via official grain bureaus to urban consumers, who were entitled to purchase staple consumption goods at subsidized prices (Lu, 1999; Rozelle et al., 2000).

This mandatory grain procurement by the state, widely known as the grain quota system, remained a key dimension of agricultural policy through the early post-2000 period. The volume of grain quotas did decline after 1995 relative to earlier in the decade; subsequent surveys have found that state procurement accounts for 25–30% of rural households' grain output, though in this sample, quota sales constitute only around 10% of grain production on average (Wang et al., 2003; Sicular, 1995).[2]

[2]Sicular (1995) reports aggregate statistics on the percentage of farm output sold as quota sales between around 1985 and 1993; grain quotas fall rapidly in this period, accounting for the fact that the percentage of total output constituted by the quota in this sample, observed between 1993 and 2002, is lower. Wang et al. (2003) report data on the operation of the grain quota system assembled from

More importantly, there was a substantial increase in quota prices beginning in 1993. The primary analysis in this paper will focus on the period 1993 to 2002; evidence in this sample suggests that at the beginning of the period, the quota price was 30% lower than the market price. In some years later in the period, however, the prices were nearly equal. This change is equivalent to a large reduction in the magnitude of the lump-sum tax imposed on farmers via the mandatory quota system (Huang, 1998).

It is also useful to note that quota policy was far from monolithic, and in particular, the treatment of different grains was very different. Rice consistently was the crop most heavily penalized by the quota policy. Procurement prices for rice were lower, and rose more slowly. In addition, the quota quantity constituted a higher proportion of total production for rice producers than for wheat producers (Huang, Rozelle, Ha and Li, 2002). The identification strategy in this paper will exploit this systematic variation in quota policy by crop and cross-sectional variation in the propensity to cultivate rice in order to generate variation in the magnitude of the income shock induced by shifts in the quota price over time.

More recently, grain quotas have been widely eliminated. The timing of this change varied, but generally occurred after the period of interest here (Huang, Wu and Rozelle, 2009).

2.2 Conceptual framework

This section will outline a simple conceptual framework that will be useful in analyzing the quota policy. Assume households produce grain output Y^A, where A denotes agriculture, and quantity Q must be sold at the quota price P_q^A. Remaining output is sold at the market price P_m^A. Households' agricultural income I^A can be decomposed as follows.

$$I^A = QP_q^A + (Y^A - Q)P_m^A \tag{1}$$

The implicit lump-sum tax imposed by the quota system is $Q(P_m^A - P_q^A)$. This tax is increasing in the quota quantity, and in the gap between the market and quota price.

Assume that the quota price is set to be equal to a linear function of the market price, i.e. $P_q = \alpha + \beta P_m$, where $\beta < 1$; the market price is assumed to be constant. α and β are parameters capturing the wedge introduced into prices by government quota policy

secondary data sources (i.e., not household surveys) in 25 counties in Zhejiang, Jiangsu and Sichuan for the years 1980 to 1999. They report that the share of the quota in total output is less than 25% after 1995. Given that two of the three provinces included in the survey are relatively high-income, high-productivity provinces, the fact that quota sales constitute a relatively higher percentage of output may be unsurprising; there is in general a positive correlation between the level of agricultural production and the proportion of total output sold as quota sales.

on average. (While this formulation does not restrict the quota price to be less than or equal to the market price, the subsequent empirical analysis will demonstrate that the average quota price has not exceeded the average market price in any year in the data employed here.) The mean price earned by the household is thus a weighted average of the market and the quota price, where the weights correspond to the fraction of total output sold at the market and quota price.

The model of household production employed here draws on simple models of household allocation of capital and labor across sectors, particularly Dercon and Krishnan (1996) and Dercon (1998). Households maximize utility over two periods, with no discounting. Markets for land and labor are missing; accordingly, households face the choice only of how to allocate their labor and capital between agricultural and non-agricultural production, denoted with superscripts A and N, respectively. Output can be written as follows, where the endowment of land for cultivation is denoted C^A.

$$Y_t^A = f^A(L_t^A, K_t^A, C^A) \tag{2}$$

$$Y_t^N = f^N(L_t^N, K_t^N) \tag{3}$$

Substituting into equation (1), we can write income from agricultural production as $QP_q^A + P_m^A(f^A(L_t^A, K_t^A, C^A) - Q)$, while income from non-agricultural production can be written as simply $P^N f^N(L_t^N, K_t^N)$.

In addition, initial investments in the non-agricultural sector are lumpy: the non-agricultural technology can only be operated with a minimum positive capital investment. This restriction is embodied in a simple constraint, $K^N \geq K_{min} \mid K^N > 0$, where K_{min} is the minimum level of non-agricultural capital. This constraint is consistent with a range of evidence that barriers to entry exist for rural households to enter non-agricultural sectors, and a substantial initial investment may be required (Reardon et al., 2000). It is also assumed that returns to non-agricultural investment are higher than returns to agricultural investment for some initial range beyond the minimum, i.e.

$$P^N \frac{\partial f^N}{\partial K^N} > P_m^A \frac{\partial f^A}{\partial K^A} \;\; \forall \; K_{min} \leq K^N < K_{eq} \tag{4}$$

K_{eq} denotes the point at which returns to agricultural and non-agricultural investment equalize. Figure 1 summarizes the assumptions made about returns to capital.

Households begin with an endowment, $\underline{Y}$, that varies across households. $\underline{Y} < K_{min}$ for all households, or households cannot invest capital in non-agricultural production in the first period. Households can access credit at an interest rate r, assumed to be high enough such that $r > P^A f'(L^A, K^A, C^A) \; \forall \; K^A$. Given the assumptions about the interest rate, there is no borrowing prior to the first period; the amount borrowed prior to the second period is denoted B. Households can also save an amount S, earning zero interest.

The timing in each period is as follows: households use available cash and credit to purchase capital, and production is followed by consumption and loan repayment. The household seeks to maximize $U(C_1) + U(C_2)$, where U is assumed to be increasing and concave, subject to the following constraints. Total household labor available in each period is denoted $\bar{L}$, and standard non-negativity constraints also apply.

$$K_2^A + K_2^N \leq P^A Y_1^A + P^N Y_1^N - C_1 + B \quad (5)$$

$$C_2 \leq P^A Y_2^A + P^N Y_2^N - rB \quad (6)$$

$$K_2^N \geq K_{min} \mid K_2^N > 0 \quad (7)$$

$$L_2^A + L_2^N \leq \bar{L} \quad (8)$$

The first order conditions corresponding to this optimization problem can be found in Section A in the Appendix, as well as a more detailed discussion of the model predictions. Rather than fully specifying the solution, the primary focus here is some simple comparative statics: particularly, the impact of a higher quota price and thus a higher weighted price for agricultural output. (For simplicity, the quota price is assumed to be constant across the two periods.)

More specifically, the analysis will focus on a certain type of price shock: an increase in the quota price, conditional on the market price. The market price is presumed constant at some level P_m, and the expected quota price is thus $\alpha + \beta P_m$. Without loss of generality, I will define the price shock as a shift from the expected quota price $\underline{P}_q \equiv \alpha + \beta P_m$ to a higher quota price $\bar{P}_q \equiv \alpha + \beta P_m + \epsilon$, where $\epsilon > 0$. In other words, the government unexpectedly chooses to increase the quota price relative to the market price by some amount ϵ, while the market price remains unchanged; thus the only effect on the household is an increase in quota income. (In the primary analysis, I will be exploiting the interaction between these price shocks and local variation in the propensity to cultivate rice and thus in quota quantity.)

This shock will have several effects. First, some previously constrained households will exit agricultural production and enter non-agricultural production. (Households already producing in both sectors, on the other hand, may shift investment to agriculture.) In general, the entry effect will be larger, the more households were initially constrained.

Second, there will be parallel shifts in the credit market. Given the assumptions about low returns to agricultural investments, purely agricultural households will not access credit. However, some households that enter non-agricultural production may borrow for the first time. Households that were previously engaged in non-agricultural production prior to the shock may borrow less (or cease to borrow) as a result of the positive shock to their income.

Third, there is an ambiguous effect on consumption in the first period. Some households previously characterized by earned income in the first period below the investment threshold K_{min} may now find that this constraint is relaxed. In this case, they may save more and consume less in order to enter non-agricultural production in the second period. On the other hand, the income effect will increase consumption in both periods.

3 Data

3.1 Overview of data sources

The data employed here is the China Research Center for the Rural Economy panel dataset, collected in a sample of 206 villages in 13 provinces in China between 1986 and 2001, excluding 1992 and 1994.[3] Provinces observed include Shanxi, Jilin, Jiangsu, Zhejiang, Anhui, Henan, Hunan, Sichuan and Gansu. The surveys prior to 1993 were considerably briefer, and thus the primary analysis is restricted to the post-1993 panel; 1993 is identified as the baseline year.

In addition, the analysis employs two climatic or agronomic data sets. The first is monthly climatic data from a network of weather stations in China collected by the Carbon Dioxide Information Analysis Center (CDIAC). Using data on the latitude and longitude of the county centroid, climatic measurements for each county and year are constructed by interpolating using the inverse distance weighting method.[4] The second is an index of climatic suitability for rice cultivation generated by the FAO, incorporating precipitation and temperature as well as other soil and topographic features. More specifically, I utilize the FAO's index of suitability for high input-level irrigated rice, given that Chinese agriculture is characterized by a relatively high level of input use and irrigation, and estimate the mean index value within the county in which each sampled village lies.

The primary household data set also provides information on the price for both mandatory grain quota sales and market sales.[5] Both the quota and the market price are ob-

[3] A randomly selected sample of households in each surveyed village forms the panel; the mean number of households in a village-year cell is 69.

[4] Each interpolation employs only data from stations within 150 kilometers of the county centroid. The average number of stations employed to construct climatic data for a county is three. While county-level weather data reported directly by counties to provincial weather bureaus is also available, using weather station data has the advantage of ensuring consistency of data quality and reporting methods across the sample.

[5] After they have fulfilled their grain quota, rural households also have the option to sell their excess production to the government at a higher, negotiated procurement price. Huang, Rozelle, Ha and Li (2002) show that these negotiated procurement prices are generally intermediate between the quota price

served at the household level. Figure 2 shows the market and quota price of grain by year between 1986 and 2002. Prior to 1991, both prices are low and stable. The market price begins to dramatically increase after 1991, and the quota price likewise increases, though more slowly.

While the price for grain quota sales varies over time, the graphical evidence clearly suggests that some of this variation is driven by variation in the market price. Recall that the conceptual framework assumes that the quota price is set as a linear function of the market price, $\alpha + \beta P_m + \epsilon$, where the parameters α and β reflect the average relationship between the market and quota price over time, and in general $P_q < P_m$. Accordingly, one reason that the quota price fluctuates in this period is that the market price is also fluctuating. Given that shifts in the market price can have many other complex effects, however, this is not the margin of variation that I will seek to exploit in this analysis.

Rather, I am primarily interested in exploiting variation in quota policy in which the government sets a quota price that is abnormally high (or low) relative to the market price — that is, increases (decreases) in the quota price **conditional** on the market price. Again returning to the conceptual framework, I characterize a high quota price shock as a positive ϵ, resulting in the quota price exceeding the predicted quota price based on prevailing market prices ($\hat{P}_q = \alpha + \beta P_m$). There will correspondingly be years in which the quota price is lower than expected based on the market price, and ϵ is negative.

In order to generate estimates of these shocks, it is necessary to first identify the underlying relationship between the quota price and the market price. The mean quota price in each village v in province p in year t is regressed on the corresponding market price in the following equation, conditional on village fixed effects λ_{vp}.[6]

$$P^q_{vpt} = \beta P^m_{vpt} + \lambda_{vp} + \epsilon_{vpt} \tag{9}$$

I then construct the residual from this regression, denoted $\tilde{P}_{vpt}$. A positive residual captures the fact that the quota price is higher than expected in a particular year, even conditional on shifts in the market price; a negative residual captures the fact that the quota price is lower than expected. By construction, the residual is uncorrelated with the market price, and thus all subsequent analysis of the quota price will employ this

and the wholesale market price. In this data, negotiated procurement prices are not reported, and no distinction is made between these two types of sales, as both represent the price that the rural producer would face for the marginal unit of production. The market price is thus used to denote the price for marginal grain sales.

[6]Observations corresponding to the top and bottom 1% of observed market and quota prices are trimmed to avoid undue influence of outliers. This regression is run at the village-year level, rather than at the household level, due to the large number of missing variables at the household level corresponding to households that report no market sales in a given year. At the village-year level, every cell has sufficient data to estimate a market price and a quota price.

variable $\tilde{P}_{vpt}$.

In the primary analysis, this price variable will be interacted with a cross-sectional measure of climatic conditions and employed as an instrument for quota income. Again, the objective is to abstract from underlying variation in the market price and identify shocks in which the quota price fluctuates up or down due to policy choices that are largely uncorrelated with observable market conditions. (I will also demonstrate that the results are robust to re-defining the quota price in Section 5.5. The hypothesis that fluctuations in $\tilde{P}_{vpt}$ may be correlated with other observable covariates will be explored further in Section 6.3.)

3.2 Summary statistics

Table 1 provides some summary statistics about the primary sample. The average household consists of four individuals, cultivating an area of around 1.4 hectares primarily in grain.[7] 90% of household-year observations report ownership of at least one productive asset for use in agriculture (e.g., animals, tools or machinery). 26% of household-year observations report ownership of non-agricultural capital, and about 40% report that at least one household member is engaged in wage labor outside the household.

However, patterns of engagement in both agricultural and non-agricultural production are changing in this period (Benjamin, Brandt and Giles, 2005). Figure 3a reports the mean by year of agricultural income and non-agricultural income, where non-agricultural income includes income from non-agricultural household businesses and wages.[8] Agricultural income is roughly stagnant, while non-agricultural income is increasing and has nearly converged to agricultural income by 2002. This increase is in fact entirely driven by income from non-agricultural household businesses; wage income shows only a small increase in this period.

Against this backdrop, how does the implicit tax imposed by the quota system evolve? I have already noted that quota quantity is around 10% of grain sold during this period; the implicit tax imposed by quota sales can be estimated by calculating the difference between the market and quota price and multiplying this difference by quota sales. I then calculate the tax as a percentage of total income for households in each quantile

[7] In China, mu is the traditional unit employed for land area; 1.4 hectares is equal to 21 mu.

[8] Agricultural income is calculated valuing all agricultural production (including livestock, fish, and forestry products) 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. This income measure is then deflated using a weighted Laspeyres price index constructed from the same prices, employing 1993 as the base year. Non-agricultural income is the sum of income from non-agricultural household businesses and wage income, and is deflated using employing a price index of ex factory prices compiled by the National Bureau of Statistics in China. The same variables will be employed as dependent variables in the primary analysis reported in Section 5.

of income. The evolution of the quota tax is summarized in Figure 3b. For households in the first (lowest) quantile, the implicit tax represented by the quota averages around 2.5% over this period; for households in the second and third quantile, it is around 2%; and for the highest quantile of households, the implicit tax is close to zero. The implicit tax peaks in 1995, where it is between 5% and 10% of income. It is lowest in 1998 and 1999, where it is nearly zero for all households.

The conceptual framework postulates that these positive shocks may serve to relax an ex ante poverty trap affecting purely agricultural households, households that are unable to access credit and thus precluded from making lumpy investments required to enter non-agricultural production. To conclude the description of the sample, I will provide some brief evidence about the differences between purely agricultural and already diversified households at baseline. I define "purely agricultural households" as those that report no ownership of non-agricultural assets in any year prior to 1993 (inclusive), and define all other households as diversified.[9] I then examine the differences in non-agricultural income, total income, and the probability of borrowing comparing across purely agricultural and diversified households in the baseline year, 1993. Non-agricultural income is around 70% higher in diversified households; total income is about 24% higher; and access to credit is about 25% higher. All of these differences are significant at the five percent level, and the differences in income are significant at the one percent level. Figure 4 presents this evidence in graphical format.[10]

Thus at baseline, already diversified households are richer and have greater access to credit, while purely agricultural households show evidence of lower income and more limited access to credit. When positive shocks to quota income follow in the mid-1990s, these shocks are particularly large for low-income households. These households are also more likely to be producing only in agriculture; only 13% of households in the lowest three quantiles are already diversified in 1993, while 20% of households in the highest quantile are already diversified. The objective of this analysis will be to identify whether quota income shocks generate shifts in agricultural and non-agricultural investment that would be consistent with the relaxation of a poverty trap, particularly for these low-income, purely agricultural households that may be constrained ex ante.

[9]More specifically, purely agricultural households report ownership of a non-agricultural asset in no more than one year in the six years reported prior to 1993.

[10]It should be noted that non-agricultural income is not zero for households reporting no ownership of assets, perhaps reflecting investment in non-agricultural businesses that require only labor or utilize leased assets.

4 Identification strategy

4.1 Decomposing quota income

The primary independent variable of interest in this analysis is quota income, defined as the income received by households from their grain quota sales. Quota income shifts over time and space as a function of changes in both the quota quantity and the quota price.

Wang et al. (2003) provide a detailed analysis of the operation of the quota system during the period examined here. Quota prices were set by the central government and were constant at the national or provincial level, while quota quantities in the form of grain deliverable per household were generally set by county leaders for all villages within their jurisdiction, and varied with village characteristics. Wealthier villages, more productive villages, and more agricultural villages generally receive higher quotas. Given that these analyses employ secondary data that report county- or village-level averages for quota quantity, there is no analysis of intra-village variation in quota quantity.

Furthermore, quota quantities for a given village change only incrementally once set by county leaders. By contrast, the central government had discretion over the grain quota price and would change it annually (Rozelle et al., 2000; Lin, 1991). Accordingly, it is plausible to hypothesize that the primary source of variation in quota income stems from cross-sectional variation in quota quantity interacted with a time-varying price.

In this data, quota quantity and price are reported at the household level, and accordingly, the hypotheses around the primary sources of variation in these variables can be tested empirically. If quota quantity is regressed on village fixed effects and year fixed effects, village fixed effects account for around 35% of the variation in quota quantity; if household fixed effects are included instead of village fixed effects, the R-squared increases to 67%. Year fixed effects, by contrast, account for only 7% of variation. This is consistent with the hypothesis that there is some within-village variation in quota quantity, in addition to the cross-village variation discussed in Wang et al. (2003).[11]

For the quota price measure constructed here, however, the results are inverted. The price variable $\tilde{P}_{vpt}$ was estimated conditional on village fixed effects, and accordingly does not systematically vary by village. If the quota price variable is regressed on year fixed effects, the R-squared is around 50%; if year fixed effects are replaced by province-year fixed effects, the R-squared again increases to 70%. Accordingly, it seems plausible to decompose quota income as the product of a quota price $\tilde{P}$ that is time-varying but does not systematically vary by village, and a quota quantity Q that varies across localities (and to some degree within them), but is approximately constant over time. Importantly,

[11] Again, previous analyses of quota quantity have primarily employed secondary data reported at the village or county level, and thus have been unable to analyze within-village variation in quotas.

quota quantity not only varies across localities, but varies systematically, and will generally be higher for richer and more agriculturally productive villages; this comparative static will also be confirmed in the data.

4.2 Endogeneity of quota quantity

As already noted, quota quantity is endogenous, correlated with many observable and unobservable characteristics of a village and/or household. My objective here is to identify a time-invariant, cross-sectional variable correlated with quota quantity and interact it with the price in order to generate an instrument for quota income. Given the widespread analysis in the literature of the systematic cross-sectional differences in quota policy implementation that correspond to variation in crop composition, variation in the propensity to cultivate rice will be the key source of variation this analysis will exploit, focusing on the positive relationship between the propensity to cultivate rice and quota quantity.

To demonstrate the robustness of this relationship and increase precision in the primary two-stage least squares results, I will utilize two different variables capturing the propensity to cultivate rice based on agronomic and climatic conditions. The first measure is constructed directly from climatic data (referred to thereafter as the "climatic index"); the second measure is drawn from an index generated by the Food and Agriculture Organization (referred to as the "FAO index").

First, in China, as in other countries, the suitability of a region for rice cultivation is partially determined by temperature and precipitation. I define "total temperature" as the total accumulated temperature over a year for days with temperatures above 10 degrees Celsius; the agronomic literature suggests the total temperature must exceed 2000 degrees to cultivate rice in China (Shao et al., 2001). Similarly, "seasonal precipitation" is defined as mean precipitation observed between May and October, the key cultivation months for rice (Tang et al., 2010). For both variables, I calculate the mean total temperature or seasonal precipitation observed in each county over the period of interest to generate a time-invariant climatic variable. I then define a climatic index that is the mean of both variables, and denote this index $Clim_{vp}$ for village v in province p.[12]

Second, I utilize a FAO-generated index of agronomic suitability for high-input irrigated rice. This index is time-invariant, and I calculate the index for each sampled locality as the mean value observed within the borders of the county in which the locality lies. (Village-level geocoding information is not available.) I denote this index FAO_{vp} for village v in year p.

[12]Precipitation is re-scaled to have the same mean as total temperature. The top and bottom 2% of climatic index observations are trimmed to minimize the effects of outliers.

It is important to clarify the level at which both indices vary. I construct the variables of interest ($Clim_{vp}$ and FAO_{vp}) using the geographic coordinates reported for the county in which each village lies, given that this is the lowest level at which linkable geographic indicators are reported for this dataset. However, in this sample, cross-county heterogeneity is virtually equivalent to cross-village heterogeneity, as only one village is sampled per county.[13] The underlying variation for the climatic index is drawn from geocoded data reported by 730 weather stations across China. To take into account spatial correlation in climatic characteristics, the standard errors in all subsequent specifications will be estimated employing two-way clustering at the province and year level, to allow for arbitrary correlation in the climatic index across observations in the same province.[14]

The relationship of interest between climatic conditions and quota quantity can be estimated by regressing quota quantity on these climatic indices, conditional on province-year fixed effects; in addition, I estimate the direct correlation between quota quantity and rice area. Quota quantity for household i in village v, province p, and year t is denoted Q_{ivpt}; area cultivated in rice is denoted A_{ivpt}; and province-year fixed effects are denoted ν_{pt}. The equations of interest are thus written as follows:

$$Q_{ivpt} = \beta Clim_{vp} + \nu_{pt} + \epsilon_{ivpt} \quad (10)$$

$$Q_{ivpt} = \beta FAO_{vp} + \nu_{pt} + \epsilon_{ivpt} \quad (11)$$

$$Q_{ivpt} = \beta A_{ivpt} + \nu_{pt} + \epsilon_{ivpt} \quad (12)$$

Columns (1) through (3) of Panel A of Table 2 report the results, suggesting that a one standard deviation increase in the propensity to cultivate rice increases the quota quantity by at least 40% for localities within the same province and year.[15] A one standard deviation increase in rice area increases the quota quantity by 50%. This is an effect of substantial magnitude, and it does not rely on the cross-provincial heterogeneity evident in China between southern rice-cultivating and northern wheat-cultivating provinces.

[13] There are two pairs of villages located in the same county in the core sample.

[14] More specifically, standard errors are estimated employing the ivreg2 command in Stata and the two-way clustering option.

[15] It should be noted that the sample for these and all subsequent regressions is limited to household-year observations that report both quota quantity and climatic data. Less than 1% of household-year observations do not report the quantity of grain sold for the quota. About 13% of household-year observations are missing climatic data. This reflects villages located in counties for which only outdated county codes are available, as the original county has since changed boundaries or dissolved; given that it is not possible to ascertain in which successor county the village of interest lies, these localities have been dropped. There is no correlation between the probability a given village is missing climatic data and the average quota quantity, quota price, or area reported cultivated in rice in that village.

4.3 First stage

Again, the objective of the identification strategy is to identify variation in quota quantity that is correlated only with variation within a province in the propensity to cultivate rice. This variation is then presumed to be uncorrelated with other economic or political variables that enter into the county leader's determination of quota quantity.

Accordingly, the two climatic indices previously shown to be correlated with the quota quantity are interacted with a time-varying measure of quota price to generate instruments for quota income. Columns 4 and 5 of Panel A of Table 2 report the two specifications of interest, regressing quota income on the interaction of climatic index and price conditional on village and province-year fixed effects. Standard errors are estimated employing two-way clustering at the province and year level. The estimating equation is as follows, where I_{ivpt} denotes quota income, and λ_{vp} and ν_{pt} are village and province-year fixed effects, respectively; a parallel specification is estimated employing the FAO index.

$$\begin{aligned} I_{ivpt} &= \beta Clim_{vp} \times \tilde{P}_{vpt} + \lambda_{vp} + \nu_{pt} + Clim_{vp} \times P^{sum}_{ivpt} + \eta^{clim}_{vp} \times P^{g}_{ivp,t-1} + \eta^{clim}_{vp} \times \gamma_t \\ &+ \eta^{ind}_{vp} \times \gamma_t + \epsilon_{ivpt} \end{aligned} \tag{13}$$

The price variable employed is uncorrelated with the market price of grain by construction, but controls are also included for the interaction of the climatic index and a summary variable of other agricultural prices P^{sum}_{ivpt}, and the interaction of dummy variables for quantiles of the overall climatic index η^{clim}_{vp} with the lagged market price of grain.[16] In addition, I include climate quantile fixed effects interacted with year fixed effects, and dummy variables corresponding to the quantiles of industrial employment in the village η^{ind}_{vp} interacted with year fixed effects to allow for varying trends over time in areas of differing levels of industrialization.

The results indicate that a one standard deviation increase in the interacted instrument leads to an increase in quota income of around 15%, and in both cases, the relationship is precisely estimated and of comparable magnitude.[17] To reiterate, the exclusion restriction for these specifications requires that an increase in the quota price has no differential impact across areas with varying propensity to cultivate rice, other than a varying lump-sum income shock. The objective is to capture the differential effect of an increase in the quota price on a locality where the quota quantity is higher on the margin by virtue of its climatic suitability for rice cultivation. This household will thus experience a larger increase in quota income.

[16]The summary price variable constructed is the mean of the market prices of the most common agricultural products reported sold: rice, wheat, corn, soy, fruit, vegetables, and cotton.

[17]Unsurprisingly, the two instruments are highly correlated with each other (correlation coefficient of .88).

Several assumptions are embodied in this specification. First, a shift in the quota price is assumed to represent an income shock, rather than a price shock. Second, the implicit decomposition of quota income postulated is $Q \times \tilde{P}$, where Q is treated as time-fixed and endogenous and $\tilde{P}$ as time-varying and exogenous. Third, it is assumed that shifts in climate do not induce systematic changes in quota income other than those mediated by changes in rice area cultivated. Fourth, it is assumed that yearly fluctuations in climate are uncorrelated with shifts in the quota quantity. The next subsection will present evidence consistent with these assumptions, as these results are essential to defining the primary specification.

4.4 Specification checks

The key assumption throughout this analysis is that the quota price is not the price of the marginal unit of grain sold and thus does not affect a household's decision about the optimal level of production; i.e., a shift in the quota price is an income effect rather than a price effect. However, there are several ways in which this assumption could be violated: substitution in and out of agriculture, substitution between crops, and the presence of households for which quota production is equal to total production.

The first potential channel for a price effect of the quota price is relevant if shifts in the quota price induce households to substitute in and out of agriculture entirely. Households not cultivating grain are still required to provide grain they have purchased or an equivalent cash payment (Brandt, Rozelle and Turner, 2004); however, when they re-optimize their production decisions in the next year, the quota price will be the price of the marginal unit of grain production. Complete exit from grain cultivation is rare. Only 10% of households report even one year in which they do not cultivate grain, and on average these households still report cultivation in about half the years surveyed. For analytical clarity, however, all households that do not report grain cultivation in every year have been dropped from the analysis. Importantly, the probability that a household reports complete exit from grain cultivation is uncorrelated with the propensity to cultivate rice, and thus, dropping these households does not create differential patterns of selection into the sample in treatment and control areas.[18]

A second channel through which an income effect could be a price effect is if households switch crops in response to changes in the quota price and begin selling a larger quantity

[18]This strategy may pose a challenge for external validity, as the resulting estimates cannot be extrapolated to households for which exiting agriculture entirely is a meaningful counterfactual. However, given the extremely small number of households that show this pattern and the fact that a much more common empirical regularity – as will be elaborated further below – is households that simultaneously pursue agricultural production, non-agricultural household production and/or employment outside the household – this does not seem to be a major concern.

of rice as their mandated quota (rather than the smaller mandated quantity of wheat) when the price increases. While this may not be optimal if the quota price remains below the market price, as it does on average, it could be locally optimal if the quota price is close to the market price in some village-years. In this case, if households have some discretion over the quantity they sell, then a change in the quota price can no longer be plausibly interpreted as a change in a lump-sum tax.

In order to test this hypothesis, villages are classified as heterogeneous or homogeneous in the primary grain crops of interest (rice or wheat) using a simple rule: any village in which the total amount of both rice and wheat cultivated over all observations exceeds zero are denoted as heterogeneous cultivators.[19] The remaining villages (constituting approximately 60% of all observations) are classified as homogeneous cultivators. Columns 1 and 2 of Panel B of Table 2 show the results of estimating the following regression to test whether quota quantity varies year-on-year with changes in quota price. This equation is estimated for both homogeneous and heterogeneous villages, denoted "Hom" and "Het," respectively.

$$Q_{ivpt} = \beta \tilde{P}_{vpt} + \lambda_{vp} + \epsilon_{ivpt} \tag{14}$$

The results show that the relationship in homogeneous villages is close to zero and insignificant, while the coefficient in heterogeneous villages is positive and significant. This suggests either that households are crop-switching or there are other inconsistencies in quota implementation in heterogeneous areas. For example, if when the quota price increases, households are more likely to comply with their quota, then this would result in the observed pattern. Alternatively, some households in heterogeneous production areas may be opting to produce a crop other than rice to avoid the high rice quota. If this choice is costly, when the quota price increases, households may opt to return to rice production. This will also result in the observed pattern.

Accordingly, the primary sample will also be restricted to villages that are homogeneous in grain production of rice or wheat; in these villages, there is no evidence that quota quantity is endogenously determined by the price. This also applies to subsequent specification checks reported in Panel B of Table 2, leading to a smaller reported sample.

A third channel through which the income effect of quota production could become a price effect is if households are constrained in quota production: i.e., they are selling all their grain as quota sales. Only around 1% of household-years in the relevant sample report grain production equal to quota sales. Column 3 of the same table shows the results of the following regression, where C_{ivpt} is a dummy for households that are constrained

[19] Observations reporting cultivation of less than .01 hectare rounded down to zero.

in quota production.

$$C_{ivpt} = \beta Clim_{vp} + \nu_{pt} + \epsilon_{ivpt} \tag{15}$$

The results show no evidence that there is a correlation between the probability that a household is constrained in quota sales and the climatic index.[20]

Columns 4 and 5 of Panel B of Table 2 show the results of two regressions that test the decomposition of quota income. The objective is to check whether residual variation in quantity over time and variation in quota price can be treated as exogenous conditional on province-year fixed effects: i.e., to test whether there is a first stage in ΔQ or $\tilde{P}$. To do so, the following equations are estimated to test for a correlation between the climatic index and the quantity residual (Q^{res}_{ivpt}) and quota price ($\tilde{P}_{vt}$). Q^{res}_{ivpt} is defined as the residual from regressing the quota quantity Q_{ivpt} on village fixed effects.

$$Q^{res}_{ivpt} = \beta Clim_{vp} + \nu_{pt} + \epsilon_{ivpt} \tag{16}$$

$$\tilde{P}_{vpt} = \beta Clim_{vp} + \nu_{pt} + \epsilon_{vpt} \tag{17}$$

The results show coefficients that are small in magnitude relative to the standard deviation of the dependent variable and insignificant, confirming the hypothesis that the only robust correlation is between mean quota quantity and the climate index.[21] The specification checks reported in Columns (3) through (5) are also consistent if they are re-estimated employing the FAO index as the independent variable.[22]

I also conduct several additional specification checks on the first stage. I verify that shifts in climate do not affect the quota quantity via any channel other than shifts in rice area cultivated, and that there is no relationship between propensity to cultivate rice and quota phase-out.[23] In addition, I demonstrate that the quota is uncorrelated with annual fluctuations in climate. These results are reported in the on-line appendix in Table 1.[24]

To sum up, the specification checks are consistent with the hypothesis that quota income varies cross-sectionally in accordance with climatic conditions, and over time as the quota price varies. The specifications of interest reporting the first stage in the restricted sample of homogeneous villages are presented in Columns (6) and (7) of Panel B of Table 2, and suggest a one standard deviation increase in the interacted instrument

[20] The primary two-stage least squares results are also robust to dropping these households entirely.

[21] This result may initially seem counterintuitive given the evidence in the literature cited above that the mean quota price is also generally lower for rice. In fact, this correlation is evident across provinces, but not within provinces. Residual price variation within a province-year is idiosyncratic.

[22] The only exception is that the coefficient in equation (17) is marginally significant at the ten percent level.

[23] It is also useful to note there is very little evidence of quota phase-out in general: only 8% of all village-year cells observed show any evidence of absent grain quotas, and in some cases the number of households sampled is low.

[24] The on-line appendix is available on the author's website.

leads to an increase in quota income of around 10%. The exclusion restriction for this analysis requires that fluctuations in quota price are not correlated with any other shocks that also vary systematically across areas with varying propensity to cultivate rice based on their climatic conditions. In other words, the only channel through which an increase in the quota price differentially affects areas more and less likely to cultivate rice is via the differential impact of a quota price increase on quota income.

5 Results

5.1 Dependent variables

In the primary analysis, I will explore the effect 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. For two outcomes of interest – investment in agriculture, and investment in non-agricultural businesses – I will report the results employing a summary variable that is the mean of the variables of interest, standardized to have mean zero and standard deviation one, as well as disaggregated results for a number of separate variables. Additional details about variable construction, particularly for agricultural income and consumption, are reported in Appendix B.

For agricultural investment, I report a summary variable that is the mean of six variables: area sown, labor invested in days, value of fertilizer employed, value of seeds employed, investment in animals, and investment in tools. Fertilizer, seeds and agricultural investment are reported as expenditure in yuan, and deflated using a summary price index for agricultural inputs published by the China National Bureau of Statistics.

Agricultural income is calculated valuing all agricultural production (including livestock, fish, and forestry products) 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. This income measure is then deflated using a weighted Laspeyres price index constructed from the same prices, employing 1993 as the base year. (Note this calculation abstracts from any variation introduced by quota policy itself, as all production is valued at the market price rather than the quota price.)

To analyze non-agricultural production, I again report results for variables capturing non-agricultural investment and income. For non-agricultural investment, I construct a summary outcome measure that is the mean of four variables: a dummy variable equal to one if the household reports any new cash investment in a non-agricultural business, a dummy variable equal to one if the household reports any labor invested in non-agricultural machinery, and the amount of labor and cash investment reported in non-agricultural businesses. It is important to note that both agricultural and non-agricultural investment as constructed here are flow measures: they capture new investments in the year of interest, and do not include any prior capital stock. Non-agricultural income is the sum of income from non-agricultural household businesses and wage labor.

In order to deflate non-agricultural investment and income to constant prices, I employ an index of ex-factory prices for industrial products published by the National Bureau of Statistics. Unfortunately, the RCRE panel itself does not report disaggregated sales for any non-agricultural product, and accordingly it is not possible to construct a price index for non-agricultural inputs or outputs. The use of an index of factory prices may not be ideal in the analysis of household-level businesses that may produce very different products; I will return to this point in the discussion of the results below.

In addition, I analyze a dummy variable for outside labor equal to one if the household reports any days worked outside the household and associated wage income; and a dummy variable for migration equal to one if the household reports days worked outside the township. For borrowing, the primary outcome variable is a dummy variable equal to one if the household reports any access to credit (formal or informal).

Finally, I report results for consumption of grain staples as well as non-grain consumption. Both variables are calculated as the sum of directly reported cash consumption in yuan, and the value of consumption of own-farm output. 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 expenditure is deflated employing a province- and year-specific consumer price index generated by Brandt and Holz (2006).

5.2 Ordinary least squares

The ordinary least squares specification of interest can be written as follows, where Y_{ivpt} denotes economic outcomes of interest and the primary independent variable is $I_{ivp,t-1}$, lagged income from grain quota sales. Standard errors are estimated employing two-way clustering at the province and year level.

$$\begin{aligned} Y_{ivpt} &= \beta I_{ivp,t-1} + \lambda_{vp} + \nu_{pt} + Clim_{vp} \times P^{sum}_{vpt} + \eta^{clim}_{vp} \times P^{g}_{ivp,t-2} + \eta^{clim}_{vp} \times \gamma_t \\ &+ \eta^{ind}_{vp} \times \gamma_t + \epsilon_{ivpt} \end{aligned} \tag{18}$$

The specification includes village and province-year fixed effects, the interaction of industrial employment quantile dummies and year fixed effects, and the interaction of climatic index quantile dummies and year fixed effects.[25] Additional controls include the interaction of the climatic index and the summary agricultural price variable, measured contemporaneously, and the interaction of quantiles of the climatic index and the lagged grain market price; as the market price of grain is lagged relative to the quota price, this is a two-year lag relative to the outcomes of interest.

The OLS specification has a clear source of bias: namely, the endogenous determination of quota quantity by county leaders. As already noted, Wang et al. (2003) find in regressing quota quantity on a range of explanatory variables at the village level that quota quantity is generally positively correlated with both income and the relative salience of agriculture. Evidence on this point can also be drawn from this dataset by regressing the same economic outcomes of interest X_{ivpt} on quota quantity in 1993, Q_{ivp}^{1993}, including the same fixed effects employed in the primary specification

$$\begin{aligned} Y_{ivpt} &= \beta Q_{ivp}^{1993} + \lambda_{vp} + \nu_{pt} + Clim_{vp} \times P_{ivpt}^{sum} + \eta_{vp}^{clim} \times P_{ivp,t-2}^{g} + \eta_{vp}^{clim} \times \gamma_t \\ &+ \eta_{vp}^{ind} \times \gamma_t + \epsilon_{ivpt} \end{aligned} \quad (19)$$

This regression captures whether households with greater quota quantities at the start of the period in 1993 show differential trends in primary economic outcomes in subsequent years, conditional on village and province-year fixed effects.[26]

The results are reported in Panel A of Table 3; note the dependent variables are all standardized to have mean zero and standard deviation one, other than the dummy variables for outside labor, migration, and borrowing. The estimated coefficients are generally positive: households with higher quota quantities at the start of the period show more rapid growth in agricultural inputs and outputs, are more likely to report labor outside the household and migration, and consume more grain and non-grain items. Accordingly, the OLS estimates are expected to show strong upward bias on measures of investment in agriculture and outside employment, as well as an upward bias on consumption.[27]

Panel B of Table 3 reports the OLS estimates, where quota income is measured in hundreds of yuan. All the coefficients are positive and significant, with the exception of the coefficients on non-agricultural household investment and borrowing. The magni-

[25] The fixed effects included are defined with respect to quantiles of the climate index constructed employing temperature and rainfall; I will subsequently demonstrate that the primary results are robust to the addition of fixed effects defined using quantiles of the FAO index. The quantiles of the climatic index are identified within the subsample of homogeneous rice- or wheat-cultivating villages included in the analysis.

[26] If households do not report quota quantity or do not appear in the panel in 1993, the quota quantity from the first year in which they appear prior to 1998 is employed as the independent variable. Households that did not enter the panel prior to 1998 are omitted from this specification.

[27] The same results are found if the specification is re-estimated employing quota quantity in 1995 as the measure of initial quota.

tudes imply an increase in quota income of 100 yuan leads to an increase in agricultural investment of .4 standard deviations, an increase in agricultural production of around .1 standard deviations, and an increase in consumption of .2 standard deviations.

5.3 Two-stage least squares

Panel C of Table 3 shows the results from estimating equation (18) in a two-stage least squares framework, employing two instruments for lagged quota income: the interaction of the climatic index and the quota price and the interaction of the FAO index and the quota price. This table reports the primary variables, and disaggregated results for agricultural and non-agricultural investment are reported in Table 4. All of the dependent variables other than the dummy variables are standardized to have mean zero and standard deviation one.

Again, the exclusion restriction for the two-stage least squares specification requires that an increase in the quota price has no differential impact across areas with varying propensity to cultivate rice other than a varying lump-sum income shock. It is assumed that the quota price is not correlated with any other shock that differentially affects areas of varying propensity to cultivate rice; further evidence consistent with this assumption will be presented in Section 6. For each specification, I report the p-value corresponding to the Hansen test of overidentifying restrictions; this test uniformly fails to reject.[28]

The first notable result in Columns 1 and 2 in Panel C is that the sign of both the estimated coefficients for agricultural production and agricultural inputs is reversed, and those coefficients are now negative and significant: in other words, the marginal complier household, induced to experience a larger increase in quota income because of the climatic suitability of its land for rice, actually invests less in agriculture. A 100-yuan increase in quota income in the prior year leads to a decline of around .5 standard deviations in agricultural inputs, and .1 standard deviations in the value of agricultural output. Disaggregated results for agricultural inputs reported in Panel A of Table 4 show a decline in sown area of 15% that is not statistically significant, a 10% decline in labor, and a large (more than 50%) decline in the value of seeds employed. There is no evidence of significant shifts in the value of tools or animals.

In the on-line appendix, I also report results for alternate measures of agricultural investment and income, including the nominal value of expenditure on inputs (seeds, fertilizer, animals and tools); the nominal value of agricultural output; and the value of agricultural output adjusted employing a weighted Paasche index in which output in the final year (2002) is employed to construct the weights. The results are all consistent.[29]

[28]The Kleibergen-Paap F statistic for the first stage is 5.4.

[29]These results can be found in Panel A of Table 2 in the on-line appendix.

Second, there is evidence of a positive effect of a quota income shock on non-agricultural investment of around .7 standard deviations, as reported in Column (3) of Panel C of Table 3. The disaggregated results in Panel B of Table 4 show increases in labor and cash investment in non-agricultural businesses that are noisily estimated, and a significant increase in the probability of investing capital or labor in non-agricultural production. This suggests that households are more likely to be establishing new non-agricultural businesses than expanding existing businesses, consistent with the predictions of the conceptual framework. There is no significant contemporaneous increase in non-agricultural income (including income from non-agricultural businesses and wage labor), as reported in Column (4). If the same specification is estimated employing only income from non-agricultural businesses, however, there is a significant increase in income from this source of around .1 standard deviations.

It is also useful to briefly return to the deflation of non-agricultural investment and income employing an index of ex farm prices. Given that the significant effects here are primarily observed for the dummy variables for investment of cash or labor in a non-agricultural business, rather than the level of investment, the deflation of the level measures may not be of first-order importance. The reported results are also consistent if the level measures are deflated using a consumer price index reported by Brandt and Holz (2006) — an approach that may be unsatisfactory given that this index also incorporates prices of agricultural products — or if nominal values are employed.

In Column (5), we observe that there is no significant shift in the probability of engaging in outside labor, though the coefficient of interest is positive; there is, however, a significant increase in the probability of migration observed in Column (6). This suggests that the positive income shock may also allow households to fund migration costs.[30]

Finally, in Columns (7) through (9), the results suggest a large positive effect on the probability of borrowing, a decrease in staple consumption that is insignificant, and an increase in all other reported consumption.[31] The probability of accessing credit increases by about 10 percentage points on a base probability of around 20%, and non-staple consumption increases by .1 standard deviations. The disaggregated results show an increase in the level of borrowing that is insignificant and no change in lending behavior, as reported in Columns (5) and (6) in Panel B of Table 4.[32]

[30] The mean value of the outside labor dummy is .40, and the mean value of the migration dummy is .20.

[31] Previous research in Jensen and Miller (2008) presented evidence that rice and wheat are Giffen goods for households in poverty in urban areas in China, suggesting a negative income effect. These results do not indicate a significant negative income effect, but it should be noted that the pattern may be very different for rural vis-a-vis urban households.

[32] There is no robust data on human capital investment or attainment in this dataset, and thus it is not possible to examine in great detail whether human capital investments are responsive to the observed income shock. Data is available on expenditure on medical care, tuition and cultural services, and the

Taken together, these results suggest that rural households in China that experience income shocks show a clear pattern of behavior consistent with the predictions of the conceptual framework for households initially facing an asset-based poverty trap. They disinvest in agriculture – i.e., the income effect for agriculture is negative – and increase investment in non-agricultural household businesses. They also consume more non-staple goods, and access new sources of credit.

Comparing the OLS and 2SLS results, the differences between the two sets of estimates are generally consistent with the evidence of differential trends for high quota quantity villages presented in Panel A of Table 3. Households with greater quota quantities early in the period show more rapid increases in agricultural inputs, agricultural production, and grain consumption; the OLS estimates show a strong positive bias relative to the 2SLS estimates in each case. The cases in which the differential trend is not consistent with the bias are the variables capturing non-agricultural income and investment and borrowing, where the OLS estimates are in fact biased downward.

I also estimate a number of alternate specifications for the two-stage least squares results. This includes restricting the sample to households in which quota sales are unambiguously less than total grain sales; dropping any village-years in which there is evidence of quota phase-out; adding interactions between climatic index quantile fixed effects and the leads of the market price, rather than the lags; and adding the interactions between quantile dummy variables defined using the FAO index of propensity for rice cultivation and year fixed effects. The primary results are generally consistent.[33]

Given that the sample of interest is not a fully balanced panel, there is also the risk of bias introduced by differential attrition. The core sample includes eight years, and the average household in the sample is observed in six years. However, there is no systematic difference in the average duration of a household in the panel comparing across areas with different propensity to cultivate rice. In addition, there is no evidence that the first, second or third lags of quota income predict attrition from the sample. This suggests that attrition is not systematically correlated with the variation in quota income that is of interest here, and thus is unlikely to be a source of bias.[34]

It is also useful to return to the primary sample restriction included in the main results, in which the sample is limited to the sample of homogeneous rice-cultivating or wheat-cultivating villages in which there is no evidence of quota manipulation (increased quota sales in years with a higher quota price). Given the evidence that households

educational attainment of the primary laborer. Estimating the same specification of interest, equation (18), there is no evidence of a significant impact of income shocks on any of these outcomes. Tabulations are reported in Panel B of Table 2 in the on-line appendix.

[33] Tabulations are reported in Table 3 in the on-line appendix.

[34] Tabulations are reported in Table 4 in the on-line appendix.

are switching in and out of crops in heterogeneous cultivation villages, it is plausible to believe that the quota price may be the price of the marginal unit of production in these villages. In that case, the effect of a higher quota price is not merely a positive income shock, but also a price shock for agriculture. This should generate upward bias on measures of investment in agriculture, and downward bias on variables capturing non-agricultural investment. In fact, this is exactly the pattern of bias observed in the sample of heterogeneous villages.[35]

5.4 Channels

Heterogeneous effects for previously constrained households While the evidence here is consistent with the postulated channel of an asset-based poverty trap, it is also useful to explore the observed patterns in further detail to analyze whether the observed effects are plausibly driven by a quota price shock.

First, I will assess the magnitude of the income shocks generated by the increased quota price. The implicit tax posed by the quota system was always close to zero for households in the top quantile of income; however, it averaged 2% of income for households outside the top income quantile, and 5% of income for households outside the top income quantile prior to 1996. By 1998, the quota price converged to the market price temporarily, eliminating the quota tax, before declining again. Thus from trough to peak, households outside the top quantile could expect a 5% increase in income. An investment at the median of reported positive investments in non-agricultural businesses for households outside the top quantile of income represents approximately 17% of income, and thus the quota shock would fund around a third of this investment. It seems feasible that a positive shock, in conjunction with funds saved and/or new access to credit, could then lead to entry into new sectors for some previously credit-constrained households.

Second, in order to further explore the channels through which the quota shock affects household economic behavior, I can evaluate evidence of heterogeneous effects along several dimensions. The conceptual model outlines very different predictions regarding the impact of increased quota income for households that are and are not initially constrained in non-agricultural production. As previously discussed, households that invest in non-agricultural production even prior to a price increase (denoted "always non-agricultural households") are never affected by the poverty trap; their initial endowment is such that they can immediately invest in higher-return non-agricultural production and access credit. An increase in the quota price will not increase their investment in non-agricultural production; in addition, it should not affect their propensity to borrow.

[35]Tabulations are reported in Panel E of Table 3 in the on-line appendix.

By contrast, for households that do not invest in non-agricultural capital prior to a price increase ("switcher" households), a price increase is predicted to lead to a decrease in agricultural investment, an increase in non-agricultural investment, and an increase in borrowing. (The predictions about consumption are ambiguous for both sets of households, though the empirical evidence suggests that consumption effect is positive.) There may also be "always-agricultural" households in the sample that do not invest in non-agricultural production even after the price increase. The diverse predictions for these different sets of households are outlined in more detail in Section A in the Appendix.

The results presented here have been estimated for a pooled sample of households. Given that only about 15% of households reports any positive investment in non-agricultural assets prior to 1993, it is unsurprising that the predicted effects for the "switcher" households have dominated. However, evaluating whether heterogeneous effects are observed comparing households that are and are not initially diversified constitutes a useful and more demanding test of the theoretical predictions. In addition, I will analyze whether a differential response is observed for households in the top income quantile, as calculated using average income observed prior to 1993. These households are more likely to be already diversified households; moreover, the quota tax constitutes a very small fraction of their income throughout the period.

For ease of interpretation, I will focus on the reduced form specification, defining a dummy variable $Nagri_{ivp}$ equal to one if the household reports any ownership of non-agricultural assets in 1993 or in any preceding year, and zero otherwise. As noted in Section 3.2, households for which $Nagri_{ivp} = 1$ show evidence of significantly higher income and access to credit at baseline in 1993. I then estimate the following specification, interacting this dummy variable with the instrument of interest.[36]

$$\begin{aligned} Y_{ivpt} &= \beta_1 Clim_{vp} \times \tilde{P}_{vp,t-1} + \beta_2 Clim_{vp} \times \tilde{P}_{vp,t-1} \times Nagri_{ivp} + \beta_3 Nagri_{ivp} \\ &\quad + \lambda_{vp} + \nu_{pt} + Clim_{vp} \times P^{sum}_{vpt} + \eta^{clim}_{vp} \times P^{g}_{ivp,t-2} + \eta^{clim}_{vp} \times \gamma_t + \eta^{ind}_{vp} \times \gamma_t + \epsilon_{ivpt} \end{aligned} \tag{20}$$

The theoretical predictions suggest that β_2 should be of opposite sign to β_1 for measures of investment in agriculture, non-agricultural production, and borrowing. The results of estimating equation (20) are reported in Panel A of Table 5. We can observe in Columns (1) and (2) that β_2 is in fact insignificant or negative for measures of agricultural investment. However, we observe in Column (3) the expected negative coefficient on the interaction term: there is no evidence of faster substitution into non-agricultural production for already diversified households. Similarly, in Columns (5) and (6), we ob-

[36]To increase precision, I trim an additional 2% from the top and bottom of the distribution of the climatic index times price instrument.

serve negative and significant interaction terms in the specifications analyzing migration and borrowing, suggesting no increase in access to credit or increased migration for these households. (For the dummy variables for migration and outside labor, there are some cells defined by province-year, village and $Nagri_{ivp}$ in which there is no variation in the dependent variable. The observations in these cells are dropped, yielding the lower observation numbers in these specifications.) The final row of the panel reports the linear combination $\beta_1+\beta_2$. The only significant effects evident for initially diversified households are a decline in agricultural inputs and an increase in consumption.

In Panel B of Table 5, I report similar results employing a dummy variable for households in the highest quantile of income at baseline; the quantile is calculated employing the average income observed over the years in which a household appears in the panel prior to 1993.[37] The evidence is similar: high-income households show no evidence of greater investment in non-agricultural businesses, migration, or borrowing as a result of quota income shocks. (In this specification, there is also some evidence of an increase in non-agricultural income for households in lower income quantiles at baseline, but not for households in higher income quantiles.) Parallel results employing the FAO index are reported in Table 5 of the on-line appendix, and are consistent.

Taken together, these results suggest that the observed heterogeneity in the primary effects is generally consistent with the model predictions. For households that may be initially constrained, and households experiencing larger quota price shocks — households producing only in agriculture and characterized by lower income at baseline — the quota price shocks seem to result in greater substitution into non-agricultural business, migration, and borrowing. However, for households already engaged in non-agricultural production and higher-income households, comparable effects are not detected. This pattern is consistent with both the hypothesis that these already diversified households are unlikely to be constrained, and the evidence that the quota price shocks they experience are, proportionally, quite small.

Other channels It is also useful to briefly explore two other potential channels that would be consistent with the observed pattern in which positive income shocks lead to substitution into non-agricultural production. There is a rich literature that analyzes risk-based poverty traps: households required to maintain a minimum subsistence level of consumption may fail to enter high-risk, high-return productive sectors not due to credit constraints, but rather due to the higher risk associated with these productive activities if access to consumption-smoothing mechanisms is limited.

In this sample, evidence about the mean and variance of returns to labor and capital

[37] The specification also includes the dummy variable and a linear control for average income at baseline.

in different sectors can be generated by estimating production functions for investment in grain cultivation, cash crop cultivation, and each of the specified non-agricultural sectors, and then evaluating the standard deviation of these returns across villages. For both labor and capital, the variance of returns is lowest in grain cultivation, followed by cash crop cultivation and non-agricultural production; the same is generally true for the mean return.[38] In this sample, however, there is no evidence of substitution from staple to cash crop cultivation. In fact, if the primary two-stage least squares specification is re-estimated employing cash crop income as a percentage of total agricultural income as a dependent variable, the estimated coefficient is negative, though insignificant.[39] The absence of any substitution from staple to cash crop cultivation is suggestive evidence that the alleviation of a risk-based poverty trap is not of first-order importance.

An additional potential channel could be a correlation between quota price shocks and shifts in the returns to investment in agricultural and non-agricultural production. Further evidence will be presented in Section 6 that quota quantity and price are generally uncorrelated with economic outcomes previously observed in the household or village. However, if an increase in quota prices is associated with an (unobserved) increase in the average local relative return to investment in non-agricultural production vis-a-vis agricultural production, then households may exit agricultural production.

In this case, if there is any household-level heterogeneity in relative productivity in the two sectors, exit would be concentrated among households expected to be relatively more productive in non-agricultural production. This hypothesis can be tested by examining heterogeneity with respect to the educational level of the primary worker in the household, presumed to be correlated with relatively higher returns in non-agricultural production. The reduced form can be re-estimated including an interaction term with this educational variable, $Educ_{ivpt}$, and additional controls for household educational attainment, denoted X_{ivpt}.[40] This yields the following specification.

$$\begin{aligned} Y_{ivpt} = {} & \beta_1 Clim_{vp} \times \tilde{P}_{vp,t-1} + \beta_2 Clim_{vp} \times \tilde{P}_{vp,t-1} \times Educ_{ivpt} + X_{ivpt} \\ & + \lambda_{vp} + \nu_{pt} + Clim_{vp} \times P^{sum}_{vpt} + \eta^{clim}_{vp} \times P^{g}_{ivp,t-2} + \eta^{clim}_{vp} \times \gamma_t + \eta^{ind}_{vp} \times \gamma_t + \epsilon_{ivpt} \end{aligned} \tag{21}$$

The results are reported in Panel C of Table 5, and show little evidence of any het-

[38]Tabulations are not reported for concision, but are available upon request.

[39]This result is reported in Column (7) in Table 2, Panel A in the on-line appendix.

[40]The control variables include a linear control for education, a dummy for education above primary school, both variables interacted with the climate-agricultural price interaction term, and an additional control variable for the household demographic structure (multi-generational household), closely correlated with education. The educational variable is de-meaned for ease of interpretation. While there is relatively little variation in education over time, this variable is reported in each year and can vary if the identity of the primary laborer worker over time.

erogeneity in the observed results with respect to education other than a faster decline in agricultural inputs for more educated households. (Some households do not report educational attainment, leading to a slightly smaller sample.) The absence of any variation in substitution into non-agricultural production with respect to education suggests that the quota price shock is not simply proxying for unobserved shifts in the relative returns to investment in different sectors.

5.5 Additional specifications

Lagged village-level controls and migration Given the evidence from the literature that income from migration is rapidly increasing for rural households during this period (Benjamin, Brandt and Giles, 2005), it is also useful to examine potential bias in these results due to time-varying patterns of migration in different villages. More specifically, a history of higher outmigration from a given region may be associated with both greater exit from agriculture and higher quota prices, if local authorities then seek to increase grain procurement given a smaller base of cultivators. It is also possible that higher quota prices could be correlated with other previous economic trends in the region; more direct evidence on this point will be analyzed in Section 6.3.

A contemporaneous village-level panel provides data about outmigration on an annual basis after 1995; the average number of reported outmigrants is only about one percent of the average village's residents. The same survey also provides data about general economic conditions in the village, including its size, the number of firms, overall agricultural production, etc. Employing this data, I re-estimate the primary specification, equation (18), employing the same primary independent variable and instruments and adding lagged controls for migration levels as a percentage of population as well as a number of additional village characteristics: the number of residents, the number of village enterprises, the size of the village labor force, value of productive assets, the quantity of arable land, area sown in grain and cash crops, and total production of grain and cotton.

The results are reported in Panel D of Table 5, and are consistent with the primary results.[41] An alternate specification in which mean migration observed per village is calculated and fixed effects are added for villages in each quantile of overall migration also generates parallel results; the results are also robust if additional lags of migration or other village characteristics are added. This suggests that differential outmigration or differential trends in other village characteristics are not a meaningful source of bias.

[41] The number of observations is slightly smaller given that some village-years are missing in the village survey data. Given that migration data is not reported prior to 1993, the first lag must be imputed for observations in the year 1995, and it is set equal to the observed level in 1995.

Alternate definitions of the quota price In the primary specification, the instrument employed interacts climatic characteristics with a quota price variable constructed as the residual of a regression of the quota price on the market price. As described in Section 3.1, this strategy has the advantage of identifying the component of the observed quota price fluctuations that corresponds to policy shocks not driven by underlying market conditions. The quota price is uncorrelated with the market price by construction, and thus the effect of the quota price shocks is not confounded by simultaneous shocks to the market price.

An alternate, simpler approach is to calculate the linear difference between the quota and market prices and interact this difference with the climatic indices to construct the instruments of interest. There is, however, the potential for violations of the exclusion restriction given that this difference is correlated with the market price, and the market price may have a direct causal effect on the outcomes of interest. I report this alternate specification in Panel E of Table 5. The results are generally consistent; the coefficient on non-agricultural investment is more noisily estimated, while the increases in outside labor and non-agricultural income are now statistically significant. Importantly, it is clear that the primary results do not depend on the precise specification of the quota price shock.

6 Robustness checks

This section presents a number of robustness checks on the primary results. First, I run placebo tests in a pre-period where the quota price exhibited limited variation. Second, I show that the quota price is not correlated with any systematic cross-sectional shocks in either policy or market prices that could be a source of bias. Third, I examine evidence of endogenous determination of the quota quantity and the quota price.

6.1 Placebo tests

The fundamental identifying assumption of the main analysis requires that there is no unobserved variable correlated with fluctuations in the quota price that also has a disparate impact across areas with different climatic conditions. A useful test of this assumption is to evaluate whether trends in major economic outcomes are parallel between those areas in a period without major changes in the quota price.

Between 1986 and 1993, the quota price, again defined as the unexplained residual in a regression of market on quota price, showed no major fluctuations; this is evident in Figure 2. Accordingly, I can evaluate whether parallel trends are observed across areas with different climatic conditions in this period, using a more limited set of outcomes that are reported in these earlier surveys.[42]

I present two sources of evidence on this point. First, I re-estimate the primary specification, equation (18), using the earlier data. Referring to the years in which the dependent variables are observed, the primary analysis examines the years 1995 to 2002, and the placebo analysis examines the years 1986 to 1993; again, quota income is measured in the year prior to the dependent variables of interest. The results can be found in Panel A of Table 6. It is evident that there is no significant first stage in the pre-period, and the second-stage results are likewise small in magnitude and generally statistically insignificant; in many cases, the coefficients are opposite in sign relative to the coefficients for the main results reported in Panel C of Table 3.

Even in the absence of any significant correlation with the instrument, however, there may be diverging trends over time in areas that are and are not favorable for rice cultivation. In order to test this hypothesis, I evaluate trends over time between 1986 and 1991 in the economic outcomes of interest, comparing villages where the average propensity to cultivate rice is above or below the median.[43] (Given that data from 1992 and 1994 are missing, I employ 1991 as the endpoint in order to examine a continuous period of data.) The graphs are shown in Figure 5; the graphs capture trends over time in the variables of interest standardized to have mean zero and standard deviation one. There is no evidence of diverging trends that would be a systematic source of bias.

6.2 Correlated shocks

The existence of other policy or price shocks correlated with changes in the quota price that also exhibit systematic cross-sectional variation would also be problematic for the identification strategy. In order to test whether there is evidence of this phenomenon, I evaluate whether there is any correlation between the quota price shocks, indices of local agricultural and non-agricultural prices, and variables capturing local policy variation: the number of local officials recorded in the sample, the proportion of agricultural inputs that are state-subsidized, and taxes and collective fees.

The method of calculating prices for agricultural output has been described in Section

[42]In this analysis, agricultural investment is the mean of sown area, agricultural labor, and the value of investment in animals and tools. Agricultural income is the value of grain and pork production. Non-agricultural investment is the mean of a dummy variable equal to one if the household reports any new cash investment in non-agricultural assets, a dummy variable equal to one if the household reports any labor invested in non-agricultural businesses, and the amount of labor reported invested in non-agricultural businesses. Non-agricultural income is income from non-agricultural household businesses and wage income. Outside labor and non-staple consumption are not reported in this period; the other variables of interest are defined identically to the primary analysis.

[43]I define the median cutoff using the average of the climatic index and the FAO index employed in the main analysis.

5.1; the price index employed as a dependent variable is P^{sum}_{vpt}, also utilized as a control variable in the main specification. Unfortunately, households do not report information about the prices of the goods or services that non-agricultural household businesses sell. Limited information is available, however, about the price of non-agricultural consumption goods (more specifically, durable goods) that households purchase. More specifically, households report the number of durable goods they own and the amount of consumption expenditure on durable goods in each year, allowing for an estimation of the price per good purchased for those household-year observations in which a durable good was acquired. (This durable goods expenditure is a subset of the non-staple expenditure analyzed in the main results.) I then calculate the mean at the village-year level of the durable goods prices; 31 village-year cells report no durable goods purchases, and thus the durable good price index is missing.

Each variable of interest is standardized to have mean zero and standard deviation one, and employed as the dependent variable in the primary two-stage least squares specification, equation (18). The results are reported in Panel B of Table 6, and show coefficients that are uniformly insignificant. Importantly, there is no evidence that quota price shocks have a significant effect on the price indices for agricultural output, or the summary price index for durable goods consumed. This suggests that general equilibrium effects on local prices are not a significant source of bias.

6.3 Endogenous determination of quota quantity and prices

Another potential source of bias in these results could be strategic behavior by households around the quota quantity. If the determination of the quota quantity is responsive to household behavior, then households facing variation in the quota price may manipulate their consumption or investment decisions in an attempt to lower or increase their quota. If their incentives to do so vary across areas with different climatic conditions, then the observed patterns could simply reflect households' efforts to manipulate the quota target.

In order to test this hypothesis, I regress lagged economic outcomes, employing the same summary measures previously employed, on quota quantity and the interaction of quantity with the climatic index, including household and province-year fixed effects.

$$Y_{ivp,t-1} = \beta_1 Q_{ivpt} + \beta_2 Q_{ivpt} \times Clim_{vp} + \phi_{ivp} + \nu_{pt} + \epsilon_{ivpt} \tag{22}$$

The objective is to test whether there is a pattern of reverse causality in which households' economic decisions determine the quota quantity they face in a subsequent year, and whether this relationship varies systematically across areas with different climatic conditions. The results are shown in Panel C of Table 6; the independent variables are standardized to have mean zero and standard deviation one. The estimated coefficients are uniformly insignificant.[44]

In addition, it is important to evaluate whether the quota price observed is responsive to local variation in economic conditions. The measure of quota price that I employ varies only at the village-year level. Accordingly, I collapse the data to the village-year level and estimate an equation analogous to equation (23), regressing lagged economic outcomes on the price and the interaction of the price and the climatic index. This specification includes 340 village-year cells. The equation of interest can be written as follows, including village and province-year fixed effects.

$$Y_{vp,t-1} = \beta_1 \tilde{P}^q_{vpt} + \tilde{P}^q_{vpt} \times Clim_{vp} + \lambda_{vp} + \nu_{pt} + \epsilon_{vpt} \quad (23)$$

The results of estimating equation (23) are reported in Panel D of Table 6, again employing the same summary measures of economic outcomes and standardizing the right-hand measures to have mean zero and standard deviation one. There is little evidence of systematic correlations between past economic outcomes and the quota price.[45]

In addition, I also evaluate whether quota enforcement differs systematically across areas with different climatic conditions. Unfortunately, enforcement cannot be measured contemporaneously in the primary dataset, as households do not separately report the quota quantity assigned and the quota quantity sold. Evidence from earlier surveys in the same sample suggests that 95% of quota quantity contracted is delivered. Households that fail to produce the quota quantity (including households that have exited agriculture) may face the obligation either to purchase grain at the market price and resell it to the government, or pay the equivalent in cash.[46]

In addition, some data is available that can shed some light on variable quota enforcement. First, households report whether any member is a government employee, a village cadre, or a party member. I can test whether quota income is significantly correlated with these measures of political influence, and if the correlation varies across villages with different climatic conditions. There is some evidence of lower quota income for government employees, but the relationship does not significantly co-vary with climatic conditions.[47]

[44] These results employ the climatic index of propensity to cultivate rice constructed from weather data; results using the FAO index are reported in Table 6, Panel A of the on-line appendix.

[45] Again, results using the FAO index are reported in Table 6, Panel B of the on-line appendix.

[46] In this data, village leaders report in surveys in 1990, 1991 and 1993 what fraction of overall quota sales in their village were re-sales of purchase grain or cash payments by households that did not produce the grain themselves; these sales accounted for only 1.5% and 6% of total quota sales, respectively. Households also report in surveys between 1986 and 1991 what fraction of their quota sales corresponded to re-sales and cash payments, and the reported proportions are 1.4% and 1.7% of the total. It should be noted that quota fulfillment in cash may be higher in years in which the quota constitutes a higher proportion of total grain production, in which case these numbers may be underestimates.

[47] These lower quotas may also reflect the fact that some government employees in rural areas are not

Second, a separate survey of village leaders reports the quantity of quota grain delivered relative to the amount contracted in the years 1990 and 1991; there is no evidence that this proportion is significantly correlated with climatic conditions. This suggests that variation in enforcement may be limited.[48]

7 Conclusion

The vast majority of the population of most developing countries continues to live in rural areas, where many are engaged solely in agricultural production. While this may reflect an optimal choice based on the returns to investment in various productive sectors, the observed pattern would also be consistent with poverty traps in which households face barriers to entry to new productive activities in a context in which credit constraints are important and a certain minimum investment is required to enter non-agricultural production.

This paper analyzes the evolution of an unusual institution in rural China, the grain quota system, in order to estimate the impact of a gradual positive income shock on household economic behavior. This system effectively imposed a lump-sum tax on rural households that declined in magnitude over time as the quota price increased, and also varied in magnitude for counties producing different crops. The identification strategy exploits cross-sectional variation in the climatic suitability of different areas for rice cultivation in conjunction with time variation in the quota price to generate a source of quasi-exogenous variation in quota income.

The results indicate that the effect of a positive income shock on investment in agriculture is strongly negative, while there are positive effects on investment in non-agricultural household businesses, migration, consumption of non-staple goods, and borrowing. These results are consistent with a model in which households are credit-constrained and investments in non-agricultural sectors are lumpy. Accordingly, an increase in agricultural income allows households to invest in non-agricultural activities for the first time. The implications of this shift for the long-run welfare of Chinese rural households remains an interesting topic for future exploration.

allocated land, and thus are not expected to produce grain.

[48]Results are reported in Table 7 of the on-line appendix.

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8 Figures and Tables

Figure 1: Assumed returns to capital

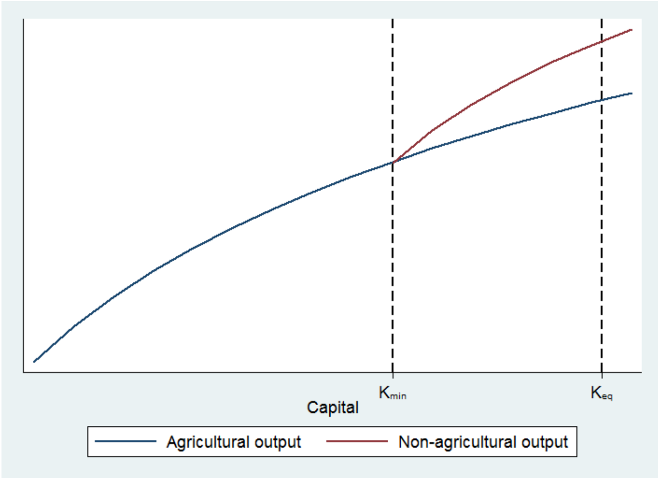
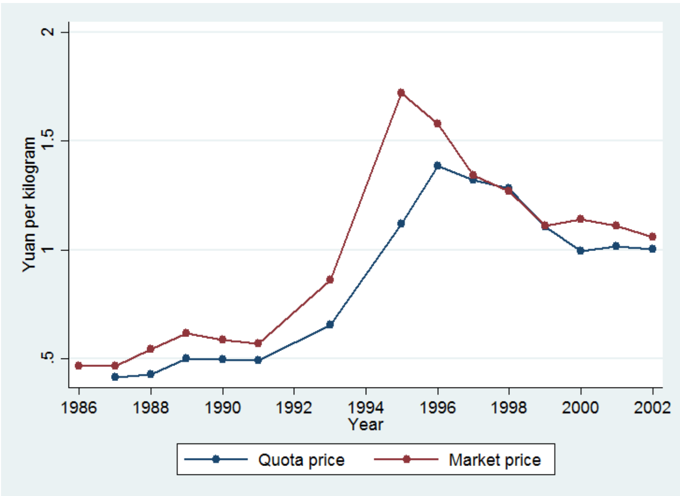


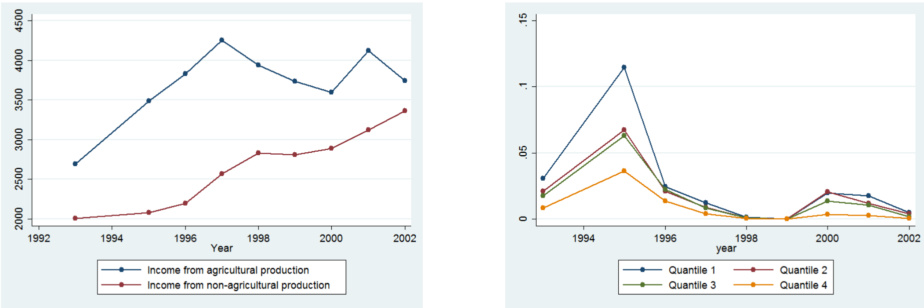
Figure 2: Quota and market prices over time



Notes: This graph shows the market price and the quota price of grain, measured in yuan per kilogram, between 1986 and 2002.

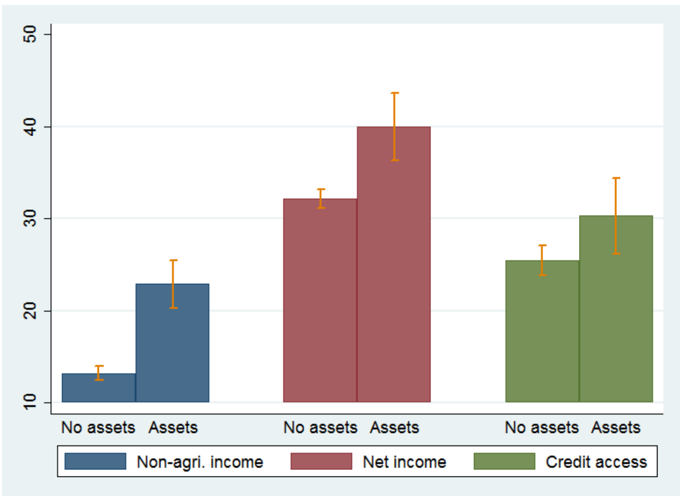
Figure 3: Income and implicit quota tax over time

(a) Ag. and non-ag. income (b) Quota tax as perc. of income



Notes: Figure 3a shows the evolution over time of real mean income from agricultural and non-agricultural production at the household level. Income from agricultural production is calculated valuing all agricultural production at the market price observed in each village-year cell, and deflated using a Laspeyres price index; non-agricultural income is calculated as the sum of income from non-agricultural household businesses and wage income, and deflated using an ex factory price index. Figure 3b shows the evolution over time of the quota tax, calculated as the difference between the market and the quota price multiplied by the quota quantity, as a percentage of total income; the quota tax is reported by quantile of income, where quantiles are defined using average income observed in the pre-1993 period.

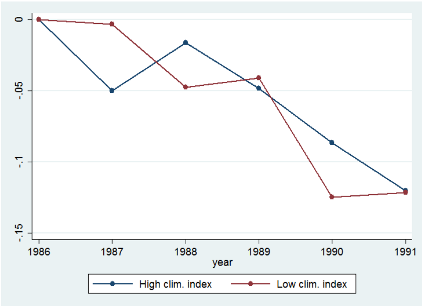
Figure 4: Households owning non-agricultural assets at baseline



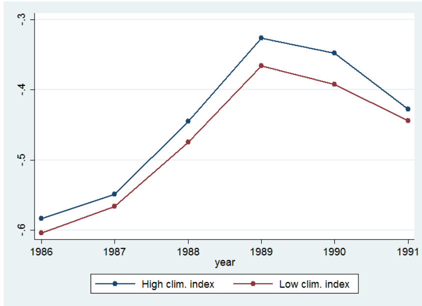
Notes: This figure reports the average levels of non-agricultural income and total net income (in hundreds of yuan), as well as credit access (defined as the percentage of households in the category of interest that report any borrowing from formal or informal sources) in the baseline year of 1993, for households that do and do not report ownership of non-agricultural assets in the pre-1993 period. A household is designated as owning non-agricultural assets if it reports ownership of such assets in more than one year in the pre-1993 period, inclusive.

Figure 5: Pre-trends prior to quota price increase

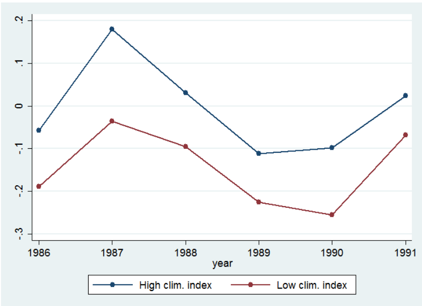
(a) Agri. investment



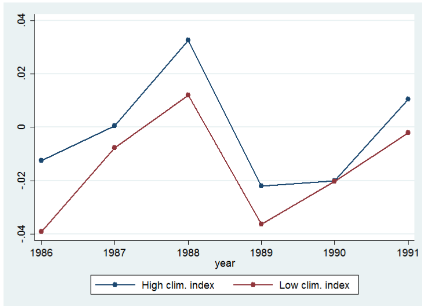
(b) Agri. income



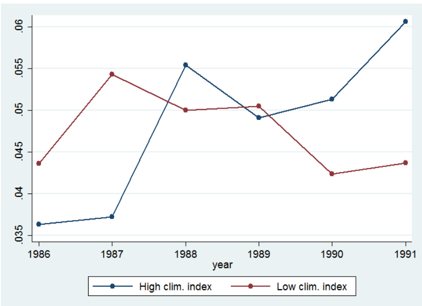
(c) Non-agricultural inv.



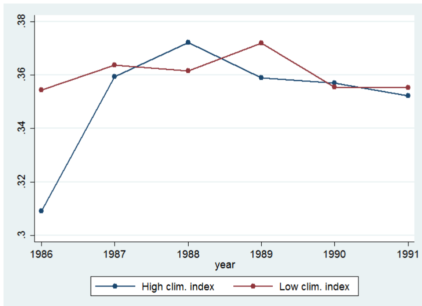
(d) Non-agricultural inc.



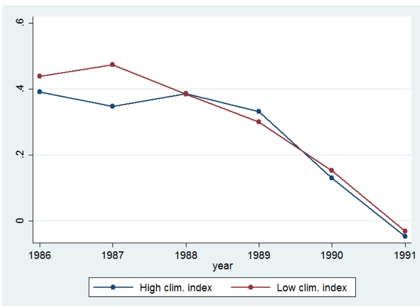
(e) Migration



(f) Borrowing



(g) Grain consumption



Notes: These figures show trends over time in the primary economic outcomes of interest for villages above and below the median of the climatic index capturing suitability for rice cultivation. In this analysis, agricultural investment is the mean of sown area, agricultural labor, and the value of investment in animals and tools. Agricultural income is the value of grain and pork production. Non-agricultural investment is the mean of a dummy variable equal to one if the household reports any new cash investment in non-agricultural assets, a dummy variable equal to one if the household reports any labor invested in non-agricultural businesses, and the amount of labor reported invested in non-agricultural businesses. Non-agricultural income is income from non-agricultural household businesses and wage income. Outside labor and non-staple consumption are not reported in this period; the other variables of interest are defined identically to the primary analysis. All variables are standardized to have mean zero and standard deviation one.

Table 1: Summary statistics

Variable	Mean	Standard deviation	Obs.
Household size	4.093	1.31	15657
Sown area	1.403	.92	16070
Grain sown area	1.233	.816	16115
Productive assets	.909	.287	16203
Non agri. assets	.263	.44	16203
Outside labor	.388	.487	16203

Notes: Summary statistics are reported for variables of interest in the primary analysis sample, including only households in homogeneous cultivation villages. Productive assets is a dummy equal to one if the household reports any agricultural assets (tools, animals or machinery). Non-agricultural assets is a dummy equal to one if the household reports any non-agricultural assets. Outside labor is a dummy equal to one if the household reports any days worked outside the household, and associated wage income.

Table 2: Variation in quota income

Panel A: Decomposition of quota income

	(1)	Quota quan. (2)	(3)	Quota income (4)	(5)
Climatic index	142.936 (45.623)***				
FAO index		70.833 (25.530)***			
Rice area			91.357 (17.026)***		
Climatic index x price				.314 (.071)***	
FAO index x price					.321 (.092)***
Mean dep. var.	195.22	195.22	195.22	2.065	2.065
Obs.	23558	23558	23511	27779	29009
Fixed effects		Prov.-year		Village + prov.-year	
Clustering		Two-way clustering: province, year			

Panel B: First stage and specification checks

	Quota quan. (1)	(2)	Infra. dummy (3)	Quantity res. (4)	Quota price (5)	Quota income (6)	(7)
Quota price	-6.376 (4.774)	17.917 (7.791)**					
Climatic index			-.002 (.009)	-13.653 (10.960)	-.015 (.019)		
Climatic index x price						.190 (.049)***	
FAO index x price							.213 (.085)**
Mean dep. var.	204.813	224.527	.01	12.932	-.015	2.225	2.225
St. dev. dep. var.	196.705	210.842	.101	155.468	.21600001	2.165	2.165
Obs.	16174	11539	16203	16174	16194	16203	16203
F	1.553	4.607	.047	1.416	.608	12.834	5.413
Fixed effects	Village			Prov.-year		Village + Prov.-year	
Clustering	Two-way clustering			Province		Two-way clustering	
Sample selected	Hom.	Het.	Hom.	Hom.	Hom.	Hom.	Hom.

Notes: In Panel A, the dependent variable is quota quantity in Columns (1) to (3), and quota income in Columns (4) and (5). The independent variables are the climatic indices for propensity to cultivate rice derived from weather data and from FAO data; the area cultivated in rice; and both climatic indices interacted with the quota price. Fixed effects and clustering are as reported in the table.

In Panel B, the independent variables are the quota price, the climatic index (derived from weather data) and the two climate-price interactions, normalized to have mean zero and standard deviation one. The dependent variable is quota quantity in Columns (1) and (2); a dummy for whether household quota sales is equal to total production in Column (3); the residual of quota quantity regressed on village fixed effects in Column (4); quota price in Column (5); and quota income in Columns (6) and (7). "Hom." denotes villages that are homogeneous in rice and wheat cultivation, while "Het." denotes villages that are heterogeneous. The sample employed, the fixed effects employed and the clustering of standard errors are as specified in the table; the specifications in Columns (6) and (7) also include 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. Asterisks indicate significance at the ten, five, and one percent level, respectively.

Table 3: OLS and 2SLS: Summary outcomes

	Agri. inv. (1)	Agri. inc. (2)	Non-agri. inv. (3)	Non-agri. inc. (4)	Outside labor (5)	Migration (6)	Borrowing (7)	Grain cons. (8)	Other cons. (9)
Panel A: Quota quantity and differential trends									
Quota quantity 1993	.667	.121	.027	.028	.031	.022	.004	.146	.088
	(.172)***	(.026)***	(.042)	(.012)**	(.013)**	(.013)*	(.005)	(.031)***	(.031)***
Obs.	15873	15873	15873	15873	15873	15873	15873	15873	15873
Panel B: Ordinary least squares									
Quota income	.406	.075	.004	.011	.015	.010	.005	.095	.030
(lagged)	(.060)***	(.012)***	(.010)	(.002)***	(.003)***	(.003)***	(.003)*	(.014)***	(.006)***
Obs.	16203	16203	16203	16203	16203	16203	16203	16203	16203
Panel C: Two-stage least squares									
Quota income	-.519	-.123	.665	.066	.053	.175	.099	-.067	.136
(lagged)	(.223)**	(.071)*	(.324)**	(.058)	(.057)	(.089)**	(.049)**	(.084)	(.050)***
Hansen J-statistic p-value	.179	.813	.805	.334	.935	.769	.676	.322	.608
Obs.	16203	16203	16203	16203	16203	16203	16203	16203	16203

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 in Panel A is quota quantity in 1993 or the first year in which a village is observed in the panel; the independent variable in Panels B and C is quota income, lagged, in hundreds of yuan. In Panel C, quota income is instrumented by the lagged interactions of two climatic indices of the propensity to cultivate rice (derived from weather data and FAO data), interacted with the quota price. Asterisks indicate significance at the ten, five, and one percent level, respectively.

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 non-staple and staple items, valued in yuan.

Table 4: Two-stage least squares: Disaggregated outcomes

Panel A: Agriculture investment

	Sown area (1)	Labor (2)	Fertilizer value (3)	Seeds value (4)	Animal inv. (5)	Tools inv. (6)
Quota income (lagged)	-.114 (.170)	-9.714 (2.034)***	-27.029 (52.041)	-25.946 (6.866)***	25.717 (96.532)	-16.160 (14.318)
Mean dep. var.	1.59	188.42	570.88	87.630	-41.43	7.39
Obs.	16202	16177	16076	16203	15511	15941

Panel B: Non-agricultural investment and borrowing

	Non-agri. labor (1)	Labor dummy (2)	Inv. (3)	Inv. dummy (4)	Credit (5)	Lending dummy (6)
Quota income (lagged)	17.067 (12.612)	.080 (.045)*	2.412 (2.479)	.098 (.044)**	1.079 (4.268)	.041 (.031)
Mean dep. var.	75.79	.41	2.98	.06	2.66	.10
Obs.	16203	16203	16201	16177	16201	16203

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, lagged, in hundreds of yuan, instrumented by the lagged interactions of two climatic indices of the propensity to cultivate rice (derived from weather data and FAO data), interacted with the quota price. Asterisks indicate significance at the ten, five, and one percent level, respectively.

The dependent variables in Panel A include sown area in hectares; days reported worked in agriculture; value of fertilizer and seeds reported used, in yuan; and new investment in tools and animals, reported in yuan. Expenditure reported in yuan is deflated using deflators for agricultural inputs provided by the National Bureau of Statistics. The dependent variables in Panel B include days worked in non-agricultural businesses; a dummy variable for working in a non-agricultural business; cash investment in a non-agricultural business; a dummy variable for positive cash investment; the amount of credit received by a household; and a dummy variable for the household providing any loans. Cash investment is deflated using indices for factory output compiled by the National Bureau of Statistics.

Table 5: Channels and alternate specifications

	Agri. inv. (1)	Agri. inc. (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)	-.033	-.005	.016	.003	.003	.004	.002	.005	.005
	(.007)***	(.005)	(.007)**	(.001)*	(.002)	(.004)	(.0008)***	(.004)	(.000)
Asset ownership int.	-.001	-.003	-.012	-.0002	.001	-.0009	-.002	.003	.003
	(.008)	(.001)**	(.003)***	(.001)	(.001)	(.0002)***	(.001)*	(.001)***	(.002)
$\beta_1 + \beta_2$	-.034	-.007	.005	.002	.004	.003	.000	.008	.008
	(.013)	(.005)	(.007)	(.001)	(.003)	(.004)	(.001)	(.004)	(.003)
Obs.	15118	15118	15118	15118	14643	11515	15118	14975	15118
Panel B: Heterogeneous effects for high-income households									
Clim. index x price (lagged)	-.030	-.004	.018	.003	.003	.006	.002	.006	.005
	(.006)***	(.006)	(.007)**	(.001)*	(.002)	(.003)*	(.0008)***	(.004)	(.0008)***
Top quantile int.	-.013	-.004	-.011	-.001	-.0004	-.001	-.001	-.002	.0004
	(.007)*	(.003)	(.006)**	(.0004)**	(.001)	(.0008)*	(.0006)**	(.002)	(.004)
$\beta_1 + \beta_2$	-.043	-.008	.007	.002	.002	.004	.001	.004	.006
	(.011)	(.006)	(.006)	(.001)	(.003)	(.003)	(.001)	(.004)	(.003)
Obs.	15118	15118	15118	15118	13053	13323	15118	15118	15118
Panel C: Heterogeneous effects for households of varying level of education									
Clim. index x price (lagged)	-.019	-.003	.012	.002	.001	.003	.001	.002	.003
	(.007)***	(.004)	(.004)***	(.001)*	(.001)	(.001)***	(.001)	(.003)	(.002)*
Education int.	.006	-.001	.002	-.0002	-.0003	.0005	.0003	-.0003	.001
	(.002)***	(.001)	(.001)	(.0007)	(.0004)	(.0004)	(.0003)	(.000)	(.0009)
Obs.	16176	16176	16176	16176	16176	16176	16176	15954	16176
Panel D: Migration and lagged village characteristics									
Quota income (lagged)	-.367	-.139	.551	-.0005	-.048	.046	.085	-.071	.213
	(.201)*	(.133)	(.321)*	(.048)	(.039)	(.039)	(.035)**	(.108)	(.095)**
Obs.	16145	16145	16145	16145	16145	16145	16145	16145	16145
Panel E: Alternate quota price measures									
Quota income (lagged)	-.788	-.181	.660	.078	.096	.212	.111	-.147	.176
	(.420)*	(.064)***	(.590)	(.047)*	(.042)**	(.086)**	(.047)**	(.085)*	(.113)
Obs.	16203	16203	16203	16203	16203	16203	16203	15981	16203

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. 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 Panels A, B, and C, the independent variables include the climatic index-price interaction (employing the weather-derived climatic index), and the triple interaction including a dummy variable for households already owning non-agricultural assets (in Panel A), for a household identified as in the top income quantile pre-1993 (in Panel B), and for the educational level of the primary household laborer (in Panel C). In Panels A and B, there are some cells defined by village, province-year and the dummy variable on the right hand side in which there is no variation in outside labor or migration; these cells are dropped, accounting for the lower number of observations. Additional controls include the non-agricultural assets dummy entering linearly in Panel A; the high income dummy entering linearly in Panel B; and in Panel C, the educational level, a dummy for the educational level being above primary school, the household demographic structure, and the educational variables interacted with the summary price control variables.

In Panels D and E, the independent variable is quota income, lagged, instrumented by two climatic index - price interactions. In Panel D, a range of additional lagged village-level controls (migration levels as a percentage of population, the number of village enterprises, the size of the village labor force, value of productive assets, the quantity of arable land, area sown in grain and cash crops, and total production of grain and cotton) are included. In Panel E, the linear difference between the quota and market prices is employed as a measure of the quota price shock and interacted with the climatic indices to construct the instruments.

Table 6: Robustness checks

Panel A: First stage and two-stage least squares, 1987–1993

	Quota rev. (1)	Agri. inv. (2)	Agri. inc. (3)	Non-agri. inv. (4)	Non-agri. inc. (5)	Migration (6)	Borrowing (7)	Grain cons. (8)
Climatic index x price	.145 (.127)							
Quota income (lagged)		.208 (.335)	-.125 (.078)	-.033 (.364)	-.024 (.063)	.009 (.027)	.036 (.109)	-.184 (.098)*
Obs.	16749	16749	16749	16749	16749	16749	16749	16749

Panel B: Correlated shocks

	Ag. price (1)	Non ag. price (2)	Cadre (3)	Party (4)	State inputs (5)	Taxes (6)	Coll. levies (7)	Fees (8)	Fines (9)
Quota income (lagged)	-.009 (.051)	.084 (.259)	.028 (.046)	-.034 (.051)	.062 (.057)	-.028 (.212)	.262 (.207)	.509 (.435)	-.069 (.312)
Obs.	16203	11978	16176	16195	16203	15832	16065	15992	15979

Panel C: Endogenous determination of quota quantity

	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)
Quota quantity	.623 (.411)	.053 (.084)	.263 (.212)	.004 (.031)	-.010 (.049)	.007 (.038)	.031 (.034)	.162 (.125)	.0002 (.037)
Quota quantity int.	-.308 (.345)	-.042 (.066)	-.221 (.176)	-.011 (.022)	.002 (.043)	-.020 (.040)	-.027 (.026)	-.102 (.104)	.014 (.029)
Obs.	16203	16203	16203	16203	16203	16203	16203	15983	16203

Panel D: Endogenous determination of quota price

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Quota price	-.157 (.441)	-.137 (.139)	.205 (.206)	.068 (.036)*	.053 (.054)	-.006 (.033)	.041 (.021)*	-.038 (.150)	.0005 (.059)
Quota price int.	-.169 (.299)	.102 (.133)	-.097 (.241)	-.058 (.032)*	-.073 (.057)	-.010 (.037)	-.020 (.013)	.046 (.120)	-.015 (.071)
Obs.	340	284	340	340	340	340	340	340	284

Notes: In Panels A and B, 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. In Panel A, the first column shows the first stage, where the dependent variable is quota income; Columns (2) through (7) report the two-stage least squares specification for the subset of outcomes reported in the pre-1993 data. In Panel B, the dependent variables are summary measures of prices for agricultural output and non-agricultural (durable) consumption goods, and policy measures measured in the local village and year; the independent variable is lagged quota income, instrumented by the two climatic indices of interest. The results in Panel B are estimated for the primary sample years.

In Panels C and D, the dependent variables are lagged values of the primary outcomes of interest in the main analysis, defined in the notes to Table 3. The independent variables in Panel C are quota quantity and the interaction of quota quantity with the climatic index, both standardized to have mean zero and standard deviation one; household and province-year fixed effects are included. The independent variables in Panel D are quota price and the interaction of quota price with the climatic 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. The results in Panels C and D are again estimated for the primary sample years. Asterisks indicate significance at the ten, five, and one percent level, respectively.

A 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.

$$\begin{aligned}
&\max\ U(P_m^A(f^A(\underline{Y},\bar{L}) - Q) + P_q^A Q - S) \\
&+ U(P_m^A(f^A(S + B - K_2^N, \bar{L} - L_2^N) - Q) + P_q^A Q + P^N f^N(K_2^N, L_2^N) - rB) \\
&+ \lambda_1 \max\ (0,\ K_2^N - K_{min}) \\
&+ \lambda_2(B) \\
&+ \lambda_3(S + B - K_2^N) \\
&+ \lambda_4(L_2^N)
\end{aligned} \tag{24}$$

The first-order conditions can be written as follows.

$$-U'(C_1) + U'(C_2)(P^A \frac{\partial f^A}{\partial K_2^A}) + \lambda_3 = 0 \tag{25}$$

$$U'(C_2)[-P^A \frac{\partial f^A}{\partial K_2^A} - P^N \frac{\partial f^N}{\partial K_2^N}] + \lambda_1 - \lambda_3 = 0 \tag{26}$$

$$U'(C_2)[P^A \frac{\partial f^A}{\partial K_2^A} - r] + \lambda_2 + \lambda_3 = 0 \tag{27}$$

$$-P^A \frac{\partial f^A}{\partial L_2^A} + P^N \frac{\partial f^N}{\partial L_2^N} + \lambda_4 = 0 \tag{28}$$

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 A1.

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.

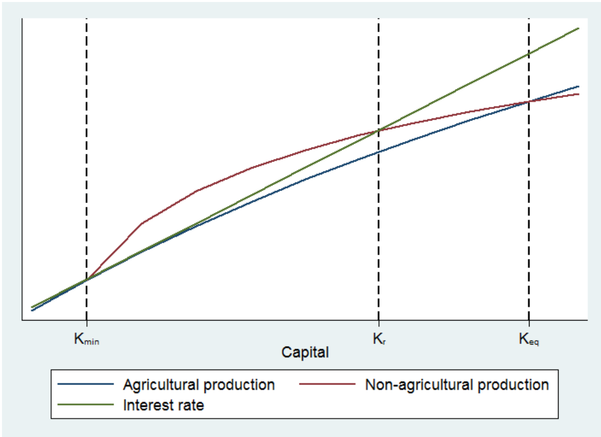
2. Second, households where given a low quota price, $K_{min} \leq \tilde{S} \leq K_r$, and thus $K_2^N = K_r$. (Note that given the assumptions about returns to capital, households that can meet the minimum capital investment with savings will always borrow in order to increase capital investment to 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.[49] 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

[49]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.

non-agricultural production for the first time), and B will increase (they will borrow for the first time). The effect on consumption is ambiguous.

Figure A1: Returns to capital and interest rate



B 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.

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.

$$Lasp_t = \frac{\sum_{i=1}^{N} Q_{i,1993} P_{it}}{\sum_{i=1}^{N} Q_{i,1993} P_{i,1993}} \tag{29}$$

$Q_{i,1993}$ 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.

$$Paasche_t = \frac{\sum_{i=1}^{N} Q_{i,2002} P_{it}}{\sum_{i=1}^{N} Q_{i,2002} P_{i,2002}} \tag{30}$$

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).