MODELING STAPLE FOOD CONSUMPTION: MEASURING THE TRADE EFFECT ON FOOD SECURITY FOR CHINESE GRAIN FARMERS

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Abstract. This paper derives a simulation model that examines the food security of the grain producing households in China in an open border regime. We define a food inadequacy index ($F.I.$) to measure the change of the food security status under alternative scenarios of border liberalization for the households. We conclude that if opening the border of grain market is followed by a more variable grain price distribution, the food security status will deteriorate for the low-income households on average. However, if border liberalization is followed by a decrease in mean of the price distribution, even with a more variable distribution, the food security status improves.

In this paper we derive a simulation model to analyze the effect of the border liberalization on the food security of the grain producing households in rural China. The stochastic food security of the farm households is analyzed by the probability of being below some consumption threshold of staple grain. This is because grain demand of farm households is derived as function of price, which is a random variable. The simulation model derives a transformation function from price distribution to consumption distribution for the households, and analyzes the scenarios under border liberalization by the change of the grain price distribution.

Price is estimated by an annual market price data from 1990 to 2000. The parameters of farm households are from a rural household survey data in 2000.

Huang, Rozelle and Chang (2004a,b) show the protection on agricultural market in China before WTO accession. The protection is measured by the difference of price between comparable commodities at the port markets and the inland markets within China. With the evidence of market integration also demonstrated in the study, authors conclude that these difference in price should create a ripple effect from the border to inland as the price equalized.

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Anderson et al. (2004) further estimate the size of the price change at the border when China's border opens. Results from authors' GTAP model project that price will fall by 0.9 percent for rice, 1.7 percent for wheat and 1.9 percent for maize.

The effect of the price change when the border opens is felt most strongly in the costal regions and is diminished in the markets which locate in further inland regions.

In Chang and Sumner (2004) grain demand of farm households is derived as function of grain price and household total income, and furthermore, the household total income is derived as function of grain price. We discuss that a change in prices affects households demand directly through price effect and indirectly through income effect, depending on several key parameters. Ideally, these parameters would be estimated directly given sufficient data or are taken from earlier studies in which they were estimated.

This paper discusses the simulation procedure and the results of the simulation analysis in detail. Baseline parameters are part estimated from household data and are part taken from previous studies. Alternative scenarios are estimated as the change from the baseline, given the parameters. To better understand the effect of these key parameters, sensitivity analysis on different sets of parameters is included in the analysis on baseline and on alternative scenarios in the simulation.

In the next section we discuss how food security is analyzed in the dissertation. We define an index to measure the change of the food security status of farm households rather than to define the level of the food security. From the results in Chang and Sumner (2004), the second section sets up the simulation model. It is based on a transformation function that maps a distribution of grain price to the distribution of grain consumption of farm households. The third section discusses the empirical data on grain consumption of farm households (from RHSD and FAOSTAT). From FAO Food Balance Sheets (FAOSTAT 2004) and the World Food Summit (1996), in this section we calculate the grain consumption threshold of being food secure. The threshold is calculated for an average farm households and for an average low-income household, given their typical staple grain consumption patterns. Section four discusses the implementation of the simulation, starting from the set-up of the alternative scenarios under investigation, followed by the discussion of the ranges of key parameters for sensitivity analysis and the detail step-by-step procedure of the simulation. Results from simulation and conclusions are in the last section.

1. Measuring Food Security

This study follows the World Bank definition that being food security is to be "able to obtain adequate food to maintain a healthy and active life at all time" (World Bank 1986), to examine the food security status of farm households in China when the grain market liberalized. Given a high contribution of grain consumption to the overall caloric intake in Chinese diet overall (From FAO: about 50% of the daily caloric intake per person), it makes sense to analyze food security of farm households in China by focusing on the staple grain consumption over time. This is the approach we take here.

Instead of setting an index that defines being food secure or not, we define a measurement to examine whether the food security of farm households is improving or deteriorating from the baseline. An improvement of the food security for farm households is when the probability of being food inadequate ($F.I.$) decreases from the baseline, while an increase of $F.I.$ represents a deterioration of the food security for farm households.

We define food inadequacy ($F.I.$) as the grain consumption of the farm households falls below some threshold, C^*. I.e.,

$$\text{Food Inadequate } (F.I.) = \text{Prob}\{C < C^*\}, \tag{1}$$

where C^* is the threshold amount of total staple grain needed to be food secure.

This measurement allows us to examine the effect of price changes on income and on consumption of farm households. The advantage of this measurement is to be able to tight the policy instrumental variables, such as price and income, into food security analysis. The measurement is based on whether the grain consumption falls below a threshold or not, and considers all lower-than-threshold consumptions equally as being food inadequate. Notice that it does not measure how much food inadequate farm households are, but whether or not farm households are food inadequate.

A distribution of grain consumption can be mapped from a distribution of grain price. We assume a log normal distribution for price of grain. Log-normal distribution is applied to estimate the price distribution because it is positive-definite and well defined for variables that cannot have negative values. Given that the distribution of price is well defined the distribution of grain consumption is also well defined.

Under alternative scenarios, households will have different probability of being food inadequate. A numerical procedure that transforms the distribution of price to the distribution of consumption is discussed in detail in the next section. In what follows are the detail calculation of this probability and of the threshold amount of staple grain for farm households.

2. Simulation Model– Transforming from the Distribution of Grain Price to the Distribution of Grain Consumption

The grain demands of farm households are log linear functions of grain price and income, and at the baseline, it is

$$\ln C_0 = (\eta_h - \beta S_c) \ln P_0 + \beta \ln Y_0 + \ln \nu, \tag{2}$$

where η_h is the Hicksian price elasticity, S_c is the expenditure share on grain consumption, and β is the income elasticity as above. The intercept $\ln \nu$ calibrates equation (2) such that the mean consumption matches the mean from the data.

Consider a representative household at the sample mean. The total income of this household at the baseline is

$$Y_0 = P_0 \times Q_0 + (\text{All non-grain income}) - (\text{Cost})\,, \tag{3}$$

where Q_0, (All non-grain income) and (cost) are given by the sample mean. Y_0 is a random variable given the price of grain P_0 is a random variable. The distribution of Y_0 is all the possible incomes for this average household when faced by the baseline price distribution P_0. As a result, grain consumption distribution is an one-to-one mapping from the price distribution.

The grain consumption distribution in scenario k is given by the consumption in baseline plus the change,

$$\ln C_k = \ln C_0 + \Delta \ln C_k, \tag{4}$$

where $\Delta \ln C_k$ is the percentage change of grain consumption from baseline under scenario k.

The percentage change of the grain consumption can be written as

$$\Delta \ln C_k = \underbrace{(\eta_h - \beta S_c)}_{\eta_m} \Delta \ln P_k + \beta \underbrace{\frac{d \ln Y}{d \ln P} \Delta \ln P}_{\Delta \ln Y}, \tag{5}$$

The change in grain consumption is determined by two forces. The first term on the right-hand-side of (5) represents an increase in purchasing power from a now lower price of grain. It is clear that a lower price will encourage households to consume more. The second term on the right-hand-side shows a decrease of income and may discourage consumption. To estimate the change of income due to the change of price, we will take a closer look at the second term.

Following a change in price by $(\Delta \ln P)$, income changes by $\left(\frac{d \ln Y}{d \ln P}\ \Delta \ln P\right)$. If the price falls, there will be an income loss from grain production. But this might be mitigated by the ability of the household to reallocate resources towards other productions.

One can estimate the change in income following a change in price as the change in producer surplus without assuming how much the other non-grain income will increase when the grain price decreases. This is because that households who are more flexible in grain production may also have a greater ability to reallocate resources over different options. Therefore, a price fall for these households will transfer to a smaller income loss. A more flexible grain production can be translated into a greater supply elasticity. The non-grain income can be assumed constant when grain price changes.

One can assume any functional form for the grain supply to derive the price–income relationship for the farm households. We assume that farm households have a constant elasticity function for grain supply.

$$\ln Q = \alpha + \epsilon \ln P,$$

where ϵ is the price elasticity of grain supply. As the price risk on farm production of grain and non-grain will not be considered in the model, the quantity supplied is function of the realized price.

The change of producer surplus when price decreases from P_0 to P_1 is given by

$$\Delta PS = \int_{P_0}^{P_k} \exp(\alpha) P^{\epsilon} dP = \frac{\exp(\alpha)}{(\epsilon + 1)} \left(P_k^{\epsilon+1} - P_0^{\epsilon+1}\right). \tag{6}$$

If $P_k < P_0$, it follows that $\Delta PS < 0$.

The percentage change in income, $\Delta \ln Y$, can be calculated by the percentage change in producer surplus of the total income, such as,

$$\Delta \ln Y_k = \frac{\Delta PS}{Y_0}, \tag{7}$$

where Y_0 is the total income in baseline and $\Delta \ln Y_k$ is the percentage change of income from baseline under scenario k.

Substituting for $(\Delta \ln Y_k)$ in equation (5), the change of grain consumption is written as

$$\Delta \ln C_k = (\eta_h - \beta S_c)(\ln P_k - \ln P_0) + \beta\ \frac{\frac{\exp(\alpha)}{(\epsilon+1)} \left(P_k^{\epsilon+1} - P_0^{\epsilon+1}\right)}{Y_0}. \tag{8}$$

Substituting for $\Delta \ln C_k$ in equation (4), we calculate the grain consumption under scenario k.

3. Household Grain Consumption in Rural China and the Food Adequacy Threshold

Grain consumption is measured by an index of the aggregate consumption of rice, wheat and corn from the household data. The units are price-weighted kilogram-equivalents. The calculation is the following.

(1) Calculate the expenditure share from the total expenses on grain for each staple food grain, including rice, wheat and corn.
(2) Calculate a price index as an weighted average price of rice, wheat and corn in year 2000 in Shanghai market, while the weights are the expenditure share as in step 1.[1]
(3) Calculate the total amount of rice, wheat and corn, in kilogram, consumed in year 2000 by each household.
(4) Calculate the grain consumption index by the expenditure of rice, wheat and corn, evaluated at the price of year 2000 in Shanghai market, divided by the price index.

From the household data, the total kilogram of rice an average household consumed in year 2000 is 367.37 kg, and the total amount of wheat is 201.93 kg, and corn, 35.77 kg. The index of the total grain consumption for an average household is the weighted average of these three figures, 580.297 kg-equivalent per year.

To examine whether this amount of grain consumption is adequate or not, I need to find a lower bound threshold of the grain consumption of being food adequate for farm households. The lower bound threshold of grain consumption is converted from the calories threshold of being food secure, which is defined by World Food Summit (1996). The conversion coefficients for each staple grain are calculated from the Food Balance Sheets (FAOSTAT 2004).

In the World Food Summit (1996, Rome, Italy), FAO documented the lower bound of total calories for being food secure is from 1,720– 1,960 calories per person per day, given gender, age distribution and average body weights. This threshold represents a minimum level of energy requirements for individuals, allowing for only light activity. Given the average household size is 4 people, the threshold calories for a household is 6,880 cal./day/household– 7,840 cal./day/household.

The threshold of the daily calories intake from grain for an average farm household in China is set as 65% of 1,960 cal./day/person (7,840 cal./day/household) in the analysis for the following reasons. First, in year 2000, the total calories available for consumption per person

[1] Detail discussion on the calculation of price index is in the Appendix A.

at the national average in China is above 3000 calories (FAOSTAT 2004). This is much higher than the upper bound calories threshold of food security. While the national average includes both the very rich and the very poor, the upper bound threshold is a conservative measure of the food security for an average farm household.

Second, in China, about 50% of the total daily calories intake per person at the national average is from staple grain. It is reasonable to set a little higher than national average of daily calories intake from staple grain for grain producing households, who can always consume staple grain from their own production.

We calculate the conversion coefficients for rice, wheat and corn from FAO Food Balance Sheets on China. According to the Food Balance Sheets, in year 2000, the national average consumption of staple grain in China is 88.4 kg/year/ person of rice, 74 kg/year/person of wheat, and 16.6 kg/year/person of corn. The equivalent calories are: 891 calories per person per day from rice, 541 cal./day/person from wheat and 132 cal./day/person from corn. The calories per kilogram from rice is then 3,678.9, 2,668.45 cal./kg from wheat, and 2,902.41 cal./kg from corn.

Given the amount of kilogram from each grain for an average farm household and the conversion coefficients calculated from the Food Balance Sheets, I calculate the total amount of calories the sample mean household gets from these three staple grains, and then I calculate the share of calories it gets from each staple grain. The calories share is 0.678 from rice, 0.270 from wheat, and 0.052 from corn, for an average farm household.

Recall that the calories threshold from grain for an average farm household in China is set as 65% of the upper bound: $1,274$ cal./day/person $= 1,960 \times 0.65$. Recall also that the average household size is 4 people per household. The threshold calories per household is therefore 5,096 cal./day/household. Applying the share of calories this household gets from each staple grain, I calculate the threshold amount of calories this household can get from each staple grain. The threshold calories for a household is 3,453.74 cal./kg from rice, 1,376.98 cal./kg from wheat and 265.28 cal.kg from corn.

I then convert the amount of calories from each grain back to kilogram using the convention coefficients discussed above. The threshold amount of rice is 0.939 kg/day, 0.516 kg/day of wheat and 0.091 kg/day of corn.

The index of the threshold amount of the total staple grain is given by the weighted average of the threshold of each grain, the weights are given by the price index. The threshold amount of the aggregate staple grain for an average household is 535.16 kg-equivalent/year (or 1.466 kg-equivalent/day).

Recall that the aggregate grain consumption index for an average household is 580.297 kg-equivalent per year, which is way above the threshold, 535.16 kg-equivalent. This is to say that an average farm household are very unlikely to be food inadequate and become food insecure when the price of grain changes only slightly. This is consistent with the results found in Chapter 4.

The results on the farm households at the sample mean bring the attention to a more vulnerable group of population in terms of food security. It is more important to investigate the food security of the households at the lower 50% income quintile than an average farm household when the border opens. Table 6.1 shows that the low-income households depend more on grain income and thus are more vulnerable to a decrease of grain price distribution than households at the sample mean. An average low-income household consumes 3,172 cal./kg/day from rice, 1,648.78 cal./kg/day from wheat, and 254.9 cal./kg/day from corn. The consumption of staple grain is 525.86 kg-equivalent total grain per year per household.

While the threshold calories is set as the upper bound of 1,960 cal./day/person for an average household at the sample mean, it is set between 1,720 and 1,960 cal./day per person for an average low-income household, as 1,800 cal./day/person. Table 6.2 shows different thresholds of grain consumption for an average household and for an average low-income household, given different percentage of calories from grain. For example, the threshold, when 68% of the total 1,800 cal./day/person is from grain, is 509.02 kg-equivalent per year for the low-income household.

Given the average grain consumption is not too much higher than the threshold amount and from table 3 the low-income household on average gets more percentage of income from grain (that is, a bigger effect on total income when grain income changes), though the mean consumption is above threshold, it is quite likely the consumption may fall below the threshold.

The simulation analysis is conducted for the farm households at the sample mean and for the average low-income farm households, from the lower 50% income distribution quintile.

4. Simulation Implementation

4.1. **Alternative Scenarios.** The baseline scenario is as if farmers were facing the production choice in year 2000. The alternative scenarios consider changes in policies at the border which results in a change in the price distribution from the baseline. While the analysis focuses on the effect of the grain market liberalization on farm households, the alternative scenarios will consider specifically the change in the grain price distribution.

It is unclear whether the price distribution will become more or less volatile when a country opens its border to world market. One one hand, it is believed that a pooled world market should result in an overall lower variability of price distribution. On the other hand, worries constantly surface that a country with a more open agricultural policy at the border and less control over its domestic market will end up facing a higher variance of the price distribution in the market (Asia Development Bank 2000). In this paper we consider a more pessimistic concern over a higher variance of the price distribution and draw the policy implications form the more conservative analysis.

Anderson, Huang, and Ianchovichina (2004) estimated that trade liberalization will change the mean price of rice, wheat and corn by around -1 to -2 percent for all three crops from the baseline.[2] The price transmission result in Huang, Rozelle and Chang shows that the transmission coefficient ranges from 50% to 12% for rice. Based on the findings from the literature, we consider three alternative scenarios of border liberalization and compare the change of grain consumption when grain price changes (decreases) from a baseline scenario.

The baseline scenario is represented by a random draw of price distribution from year 2000. As a more pessimistic and more conservative estimation, in the simulation we will consider a decrease of grain price of 20% from the baseline and a 50% price transmission coefficient for the inland farm households in the first scenarios. That is, inland farm households are faced by a 10% decrease in mean of the price distribution from baseline.

In the second and the third scenarios, we consider effects of a more variable price of grain. The second scenario examines an increase in variance by 50% from the baseline alone. The third scenario considers a combination of an increase in variance by 50% and a decreases in mean by 10%.

In order to get a better understanding on the effect of the border liberalization on consumption, we combine these three policy scenarios with four sets of key parameters in the simulation, that is, the combinations of (β, η_h, ϵ) are (0.1, -0.3, 1.5), (0.1, -0.3, 0.22), (0.2, -0.3, 1.5), and (0.2, -0.3, 0.22).

4.2. **Simulation Procedure.** The simulation procedures are as follows.

I. Set two combinations of the parameter values on income and price elasticity of grain demand ($\beta = 0.1$ $\eta_h = -0.3$) and ($\beta = 0.2,$ $\eta_h = -0.3$), the elasticity of supply ($\epsilon = 1.5$ and 0.22) (see detail discussion in Chang and Sumner 2004);
II. Set the baseline price distribution as P^0. See Appendix A for detail procedure of calculating price distribution;
III. Map P^0 to a distribution of grain consumption C^0, using equation (3) and (2), and table 1 on the value of ($\ln \nu$);

[2] The baseline in Anderson et al. assumes that China retain its protection policies as of 1995 and that all countries fully implement their Uruguay Round obligations on schedule before 2005.

IV. Calculate the probability that C^0 is lower than threshold C^*, indicated as $F.I._1$, using equation (1);

V. Simulate a price distribution for P^k under alternative scenarios, see discussion in 6.4 and detail calculation in Appendix A;

VI. The price distribution of P^k maps to a consumption distribution C^k, using definition in (4), given the equation (8);

VII. Calculate the probability that C^k is lower than threshold C^*, indicated as $F.I._2$, using equation (1);

VIII. Calculate the change of probability: $(F.I._2 - F.I._1)$. A bigger increases in this change of probability implies a deterioration of the food security of farm households from baseline.

5. The Change of the Food Security Status of the Low-Income Households

The discussion on the impact of price change under alternative scenarios will be focused on the low-income households. The analysis is done for a representative low-income household, who is at the mean of the sub-sample of the lower 50% income quintile.

5.1. **Scenario One: A 10% Decrease in Mean of the Price Distribution.** Results of the change of the food security status of the average low income household under scenario one are shown in the panel (b) in figures 1, 2, 3, and 4.

Given the threshold consumption is 509.02 kg-equivalent per year per household, the $F.I.$ is 0.162 under baseline when $\beta = 0.1$, $\eta_h = -0.3$, and 0.048 under scenario one when $\epsilon = 1.5$ in figure 1, while in figure 2, when $\epsilon = 0.22$, the $F.I.$ is 0.050 under scenario one.

The negative income effect on consumption is smaller when the supply elasticity (ϵ) is bigger and it is bigger when ϵ is smaller, and it is more evident when β is 0.2 for the low income households. When $\beta = 0.2$, $\eta_h = -0.3$, $F.I.$ is 0.123 under baseline (see figure 3). When $\epsilon = 1.5$, $F.I.$ is 0.013 under scenario one, and when $\epsilon = 0.22$, $F.I.$ is 0.025 under scenario one (see figure 4).

5.2. **Scenario Two: A 50% Increase in Variance of the Price Distribution Alone.** The results under the scenario two are in the panel (c) of figures 1, 2, 3, and 4.

Food security deteriorates form baseline under this scenario as the consumption distribution becomes more wide-spread as the variance of the price distribution increases. In baseline $F.I.$ is 0.162. $F.I.$ is 0.199 when $\epsilon = 1.5$ (see figure 1(c)) and 0.200 when $\epsilon = 0.22$ (see figure 2(c)).

When $\beta = 0.2$, $\eta_h = -0.1$, $F.I.$ is 0.123 in baseline (see figure 3(a)). In figure 3 (c), when $\epsilon = 1.5$, $F.I.$ is 0.137 under scenario two and it is 0.149 when $\epsilon = 0.22$ in figure 4(c). The food security status deteriorates more when supply elasticity (ϵ) of the low income households is smaller. However, food security status does not deteriorate as much as when $\beta = 0.1$ since the consumption distribution is not as spreading-out as when $\beta = 0.1$. When β and the absolute value of η_h is closer, the two offsetting effect cancel one another and therefore the distribution of consumption is more concentrated. As a result, the probability of a lower grain consumption is smaller.

5.3. **Scenario Three: Downward Shifting and Increase in Variation of the Price Distribution.** The results in this scenario are shown in panel (d) in the figures. They are combinations of the result from scenario one and two. Given the threshold is 509.02 kg-equivalent, food security of the low income household improves from baseline for both ϵs. *F.I.* is 0.090 under scenario three in both cases. However from the graphs, the left tail of the consumption distribution is shorter, that is, the probability of a even lower consumption is smaller, when $\epsilon = 1.5$.

When $\beta = 0.2$, $\eta_h = -0.3$, the food security status improves more than when $\beta = 0.1$. *F.I.* is 0.018 when $\epsilon = 1.5$ and 0.042 when $\epsilon = 0.22$. This is a result of a combination of a lower price (encourage more consumption) and a more concentrated consumption distribution (a closer values of β and $|\eta_h|$). Also, the higher the supply elasticity (ϵ), the more the improvement of the food security status (the more the decrease of *F.I* from baseline).

6. CONCLUSION

In this paper, we define a food inadequacy index (*F.I.*) and discuss how the food security of farm households is examined by this index. This index measures whether the grain consumption of farm households falls below a threshold or not, and it considers all lower-than-threshold consumptions equally as being food inadequate. The threshold of being food adequate is calculated from FAO Food Balance Sheets (2004) and World Food Summit (1996). Under alternative scenarios of border liberalization, the food security of the farm households is examined as whether their *F.I.* decreases or increases from the baseline. A decrease in *F.I.* is defined as an improvement of food security for the farm households from baseline, and an increase in *F.I.* is defined as a deterioration of food security for the farm households.

For the low income households, the food security status changes depending on the changes of the price distribution. When the mean of the price distribution decreases, the probability of a lower-than-threshold grain consumption is becoming smaller, and as a result, the food security status improves. When there is only a decrease in the variance of the price distribution, the food security status deteriorates because the consumption distribution is becoming more spreading-out and it is more possible to consume lower than the threshold amount.

The change of the food security status also depends on the income elasticity (β) and price elasticity (η_h). As these two parameters are closer in absolute values, the two offsetting effects in consumption cancel one another and the consumption distribution is more concentrated. A more concentrated distribution of grain consumption will result in a thiner left tail, thus, a lower probability of consumption falling below the threshold. For example, given $\eta_h = -0.1$, the $F.I.$ in baseline is 0.123 when $\beta = 0.2$ and 0.162 when $\beta = 0.1$.

The bigger the supply elasticity (ϵ) implies more flexible the households are in grain production, and therefore, the percentage decrease of income due to the decrease of the grain price is smaller. This is shown by the smaller $F.I.$s when $\epsilon = 1.5$ than when $\epsilon = 0.22$.

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Appendix A. Estimating the Grain Price Distribution from the Time Series Price Data

I estimate the distributions for grain price (P) from time series price data (MPD).[3] Prices series are closely approximated by random walks and can be estimated using time series data.

The price of grain P includes rice, wheat and corn as staple food grain for Chinese farm households. Given the market is integrated in China, the model is simulated as if farmers are facing the Shanghai price while making production choices.

I assume that log of the price is a normally distributed random variable. First, the log of the time series data (1991– 2000) of each staple grain is used to calculate the first order price difference ($\Delta \ln P_i$) to take off the trend. Second, I calculate the standard deviation of the first degree (log) price difference, σ_i^2.

The price of each staple grain is simulated from the following;

$$\ln P_i = \mu_i + \ln P_{i,2000} + \xi_i, \tag{9}$$

where $i =$ rice, wheat and corn, $\mu \approx 0$, and $\xi_i \sim N(0, {\sigma_i}^2)$.

Secondly, the grain price index (P) for each household is the weighted average of the price of each staple from equation (9). The weights are the production shares of these three staple grains from the RHSD data set for production price index.

$$P_j = \sum_{i=1}^{3} P_i \times s_{ij}, \;\; \forall j,$$

where $i =$ rice, wheat and corn, and S_{ij} is the production share of each staple grain of each household j when calculating the production price index of grain, and it is the consumption share when calculating the consumption price index.

The average production share of rice is 0.46, the average share of wheat is 0.25, and the average share of corn, 0.28 from the household data. At the production side, I assume that farm households produce these three staple grain crops with the same proportion. Although slight variation of the production shares for different households between these three crops may yield slight different production price index, in practice, the difference is small enough to be ignored for two reasons. First, the price of each staple grain is similar. Second, this difference will be dampened in calculating the effect of income on grain consumption.

The production profile on the combination of grain crops of farm households will not change from baseline when the overall grain price index changes under alternative scenarios. As the

[3] The price data, including 50 wholesale markets (sample sites) in fifteen provinces across China, every 10 days from 1990- 2000, is collected by the China's State Market Administration Bureau (SMAB) in Beijing (see detail discussion in appendix).

simulation analysis focus on the grain consumption as a whole, staple grain is considered as one aggregate good. Alternative scenarios are analyzed by the change in mean and/or variance of the distribution of the aggregate grain price index (log price) but not by the change in mean and/or variance of the distribution of the individual staple grain price.

The crucial index is the consumption price index to calculate the distribution of grain consumption and the threshold of grain consumption for farm households. When calculating the consumption price index, the different consumption combinations of these staple food grains of different households will be taken into account.

Assume that price is a log-normal random variable and log of price is a normal random variable. The relationships of mean and variance between these two random variables are

$$EP = e^{\left(E\ln P + \frac{1}{2}V\ln P\right)}$$

$$VP = e^{2E\ln P}\left(e^{2V\ln P} - e^{V\ln P}\right),$$

where EP and VP are the mean and variance of the price, $E\ln P$ and $V\ln P$ are the mean and variance of the log price.

The change of the grain price index from baseline is defined as

$$\Delta \ln P = \ln P^1 - \ln P^0,$$

where P^1 is the price at scenario one and P^0 is the price in the baseline scenario.

A price distribution where the mean decreases from baseline, say an $A\%$ decrease, is simulated by a random draw from a log normal distribution with mean $E\ln P^1$ and variance $V(\ln P^1)$, where,

$$E\ln P^1 = -A + E\ln P^0,$$

The variance of the price will need a slight adjustment to offset the $A\%$ decreases in mean such that $VP^1 = VP^0$. Given the change of the log price is small, for example $A = 10\%$, the calibration is

$$V\ln P^1 = \frac{V\ln P^0}{0.9} \approx V\ln P^0,$$

and the variance of log price also stays about the same.

A price distribution where only the variance increases from baseline is simulated by a random draw from a log normal distribution as follows

$$\ln P^1 = (B+1)^{1/2}\ln P^0 - (B+1)^{1/2}E\ln P^0 + E\ln P^0,$$

where B is the percentage of the change in variance from baseline, i.e. $V(\ln P^1) = (B+1)\,V(\ln P^0)$. The mean of $\left(\ln P^1\right)$ is unchanged from the baseline.

TABLE 1. The intercept value ($\ln \nu$) that calibrates the mean of $\ln C$, the grain demand, to be equal to the mean from the data of the whole sample for alternative combinations of parameters. Second panel includes the value that calibrates the calculation to be equal to the mean from the sub-sample of the lower 50% income quintile.

	η_h		
β	-0.3	-0.2	-0.1
	Sample mean[1]		
0.3	3.729795907	3.689249396	3.648702885
0.2	4.648257129	4.607710618	4.567164108
0.1	5.566718352	5.526171841	5.48562533
	Low-income[2]		
0.3	3.955906797	3.915360286	3.874813775
0.2	4.766162715	4.725616204	4.685069693
0.1	5.576418632	5.535872122	5.495325611

[1] The whole sample contains 543 grain producing households. [2] The sub-sample of the lower 50% income quintile has 254 households.

Table 2. Summary statistics of grain consumption in China, from Rural Household Survey Data (RHSD) and FAO Food Balance Sheets, and the sample calculation of the threshold calories, for the average household at the sample mean and the average low-income (in the lower 50% quintile of income distribution) household.

	Rice	Wheat	Corn
FAO Food Balance Sheets in China(2000)[1] :			
Kg/year/person	88.4	74	16.6
Kg/day/person	0.2422	0.2027	0.0455
Calories/day/person	891	541	132
Calories/kg	3,678.903	2,668.446	2,902.410
From RHSD (2000):			
The household at the sample mean			
Kg/year/household	367.36	201.925	35.765
kg/day/housheold	1.006	0.553	0.098
Calories/day/household	3,702.69	1,476.24	283.40
Share of calories/household	0.678	0.270	0.052
Threshold calories/day/household[2]	3,453.74	1,376.98	265.28
Threshold kg/day/household	0.939	0.516	0.091
From RHSD (2000):			
The average low-income household			
Kg/year/household	314.709	225.526	32.055
Kg/day/household	0.862	0.619	0.088
Calories/day/household	3,172.00	1,648.78	254.90
Share of calories/household	0.625	0.325	0.05
Threshold calories/day/household[3]	3,149.71	1,637.19	253.10
Threshold kg/day/household	0.856	0.614	0.087

[1] Use 4 people per household. [2] For the average household, the total threshold calories is 7,840 (i.e. $1,960 \times 4$) cal./day/household and set 65% of the threshold calories are from grain. [3] For the average low-income household the total threshold calories is 7,200 (i.e. $1,800 \times 4$) cal./day/household and set 70% of the threshold calories are from grain.

Table 3. Parameters of the average households and the low-income households from RHSD.

Variable	Sample mean	Low-income[1]
Total income (yuan)	9,719.55	3,241.12
Total non-grain income (yuan)	8,189	2,183.9
Total grain production (kg-equivalent)	2,344.61	1,893.12
Total grain consumption (kg-equivalent)	580.3	525.86
Rice consumption (kg/day/HH)	1.006	0.862
Wheat consumption (kg/day/HH)	0.553	0.618
Corn consumption (kg/day/HH)	0.098	0.878
Calories from rice (cal./kg/day/HH)	3,702.69	3,172.01
Calories from wheat (cal./kg/day/HH)	1,476.24	1,648.78
Calories from corn (cal./kg/day/HH)	284.40	254.90

FAO Food Balance Sheets: rice consumption is 0.242 kg/day/person, wheat consumption, 0.203 kg/day/person, and corn consumption 0.0455 kg/day/person. The equivalent calories from rice is 891 cal./day/person, 541 cal./day/person from wheat and 132 cal./day/person from corn. [1] The mean of the sub-sample of which households' total income is less than 5,966.31 (yuan) and greater than zeros.

Table 4. The threshold of total grain consumption for households per year, unit: kg-equivalent.

Percentage of calories from grain	Threshold cal. from grain (cal./day/person)	Threshold grain consumption (kg-equivalent/year/household)
	Sample mean households	
	Threshold: 1,960 cal./day/person	
50%	980	411.66
55%	1,078	452.83
60%	1,176	493.99
65%	1,274	535.16
70%	1,372	576.32
	Low-income households	
	Threshold: 1,800 cal./day/person	
60%	1,080	449.14
65%	1,170	486.56
68%	1,224	509.02
70%	1,260	523.99
73%	1,314	546.45
75%	1,350	561.42

The threshold of calories to be food secure ranges from 1,720–1,960 cal./day/person (World Food Summit, FAO, Rome, Italy, 1996). The average household size is 4 people. Thus the threshold calories to be food secure is from $1,720 \times 4$ to $1,960 \times 4$ cal./day/household.

Table 5. Summary statistics of the annual price data on rice, wheat and corn in Shanghai market, 1990-2000.

(RMB)	Rice	Wheat	Corn
Mean	1.767	1.162	1.277
Standard deviation[1]	0.280	0.234	0.266

[1] The standard deviation is calculated from the series of the first degree log price differences.

Table 6. Summary statistics of the distributions of the grain price index in baseline and under alternative scenarios.

Alternative scenarios		Mean	Standard deviation
Baseline:		1.501	0.2045
Scenario (1):	$\Delta E \ln P = -10\%$	1.361	0.2045
Scenario (2):	$V(\ln P) = 1.5\, V(\ln P_b)$	1.496	0.2503
Scenario (3):	$E\Delta \ln P = -10\%$ and $V(\ln P) = 1.5\, V(\ln P_b)$	1.361	0.2506

Author's calculation from a 1000 random draw. The baseline price data is the Shanghai market price from MPD, and the mean and variance (of the log price) are calculated from the annually price series.

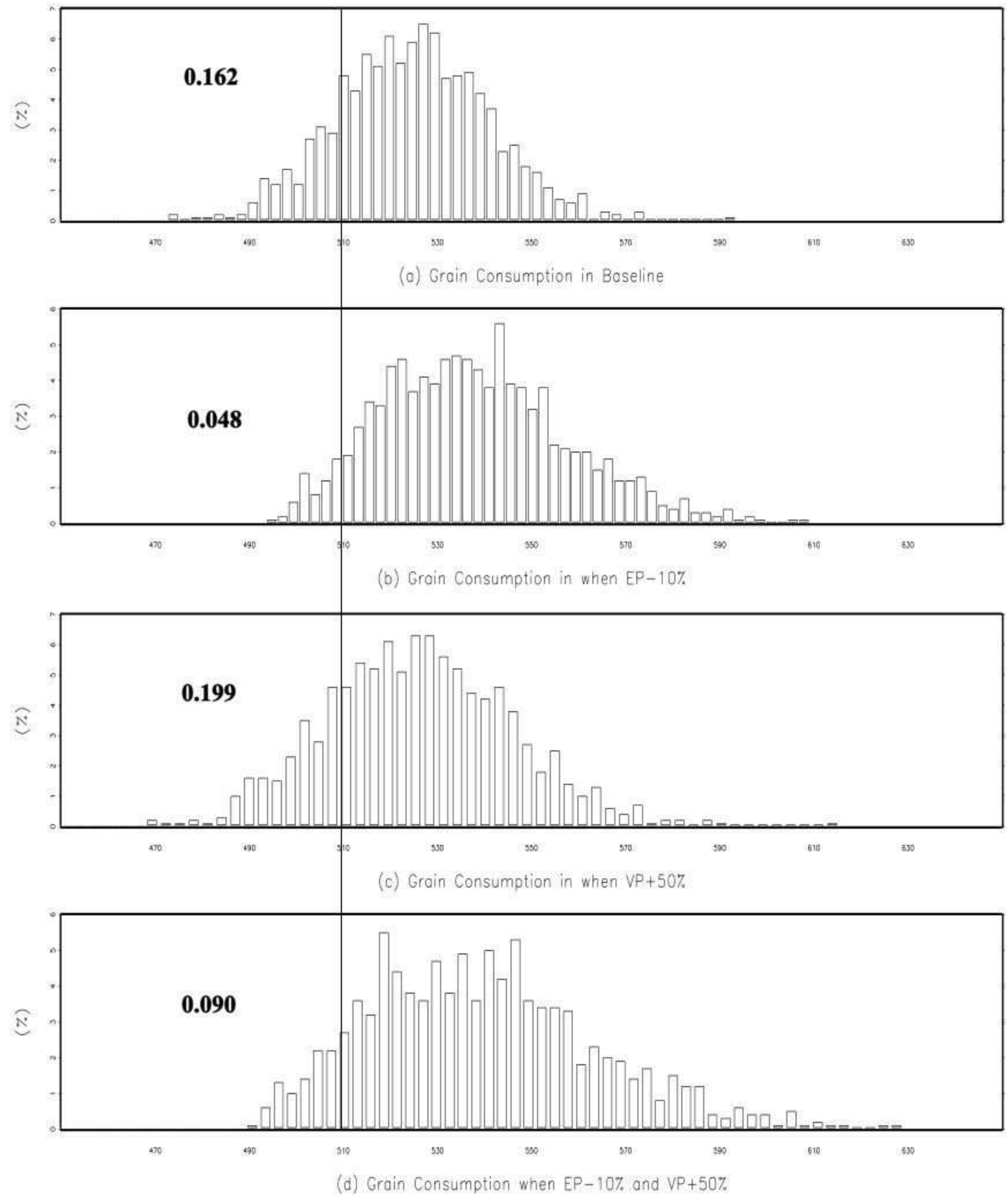

FIGURE 1. Distribution of grain consumption, $\beta = 0.1$, $\eta_h = -0.3$ and $\epsilon = 1.5$.

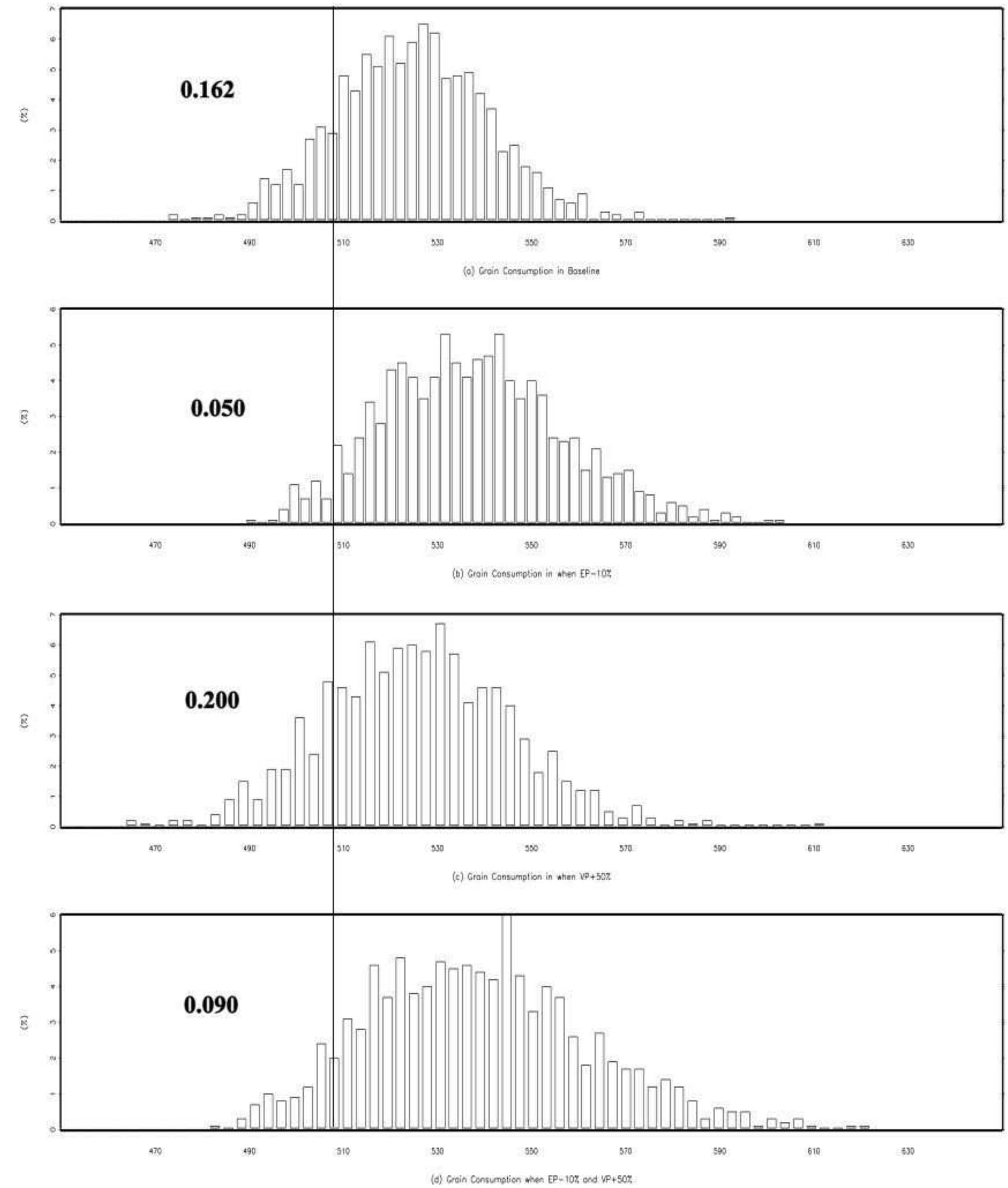

FIGURE 2. Distribution of grain consumption, $\beta = 0.1,\ \eta_h = -0.3$ and $\epsilon = 0.22$.

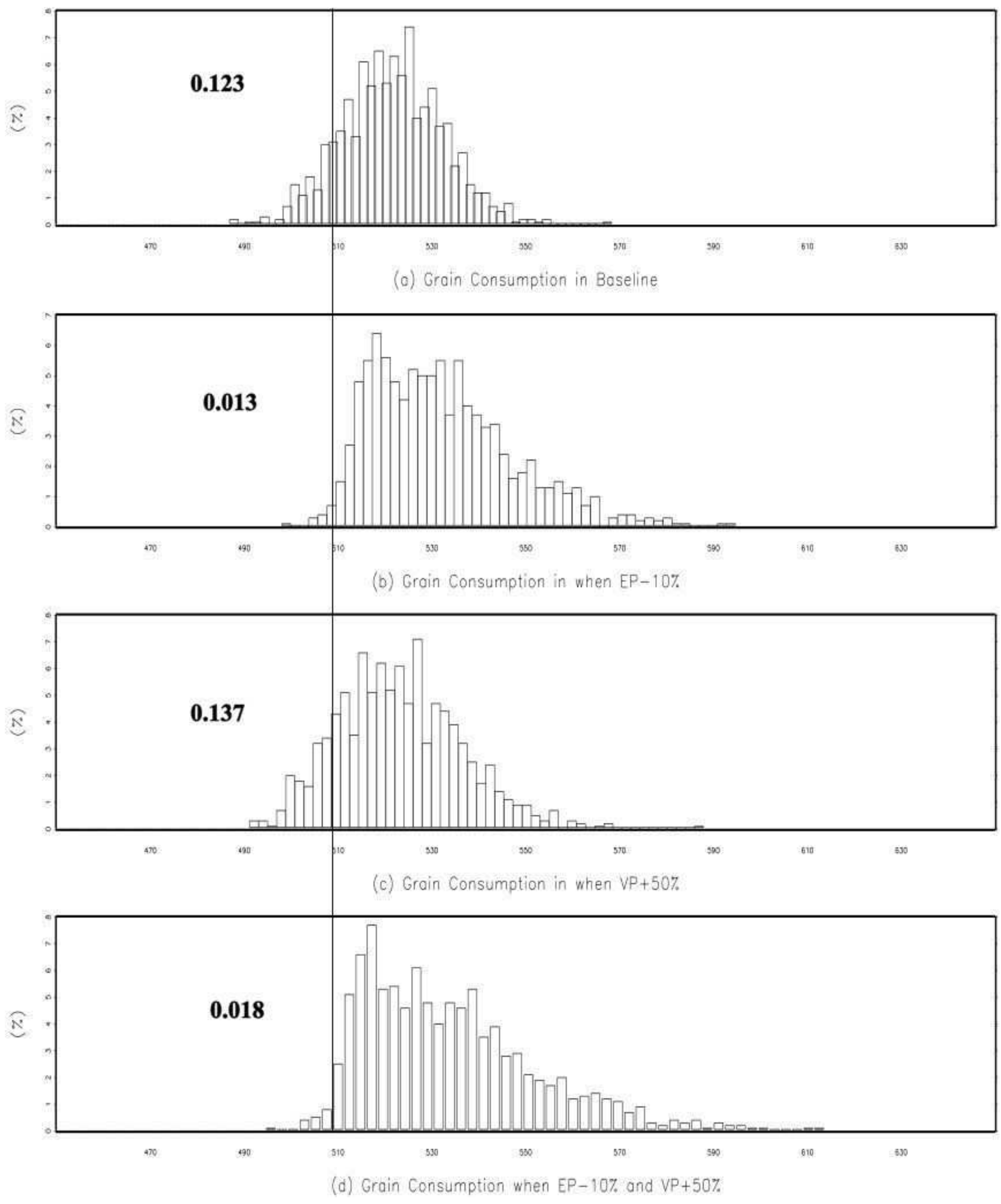

FIGURE 3. Distribution of grain consumption, $\beta = 0.2$, $\eta_h = -0.3$ and $\epsilon = 1.5$.

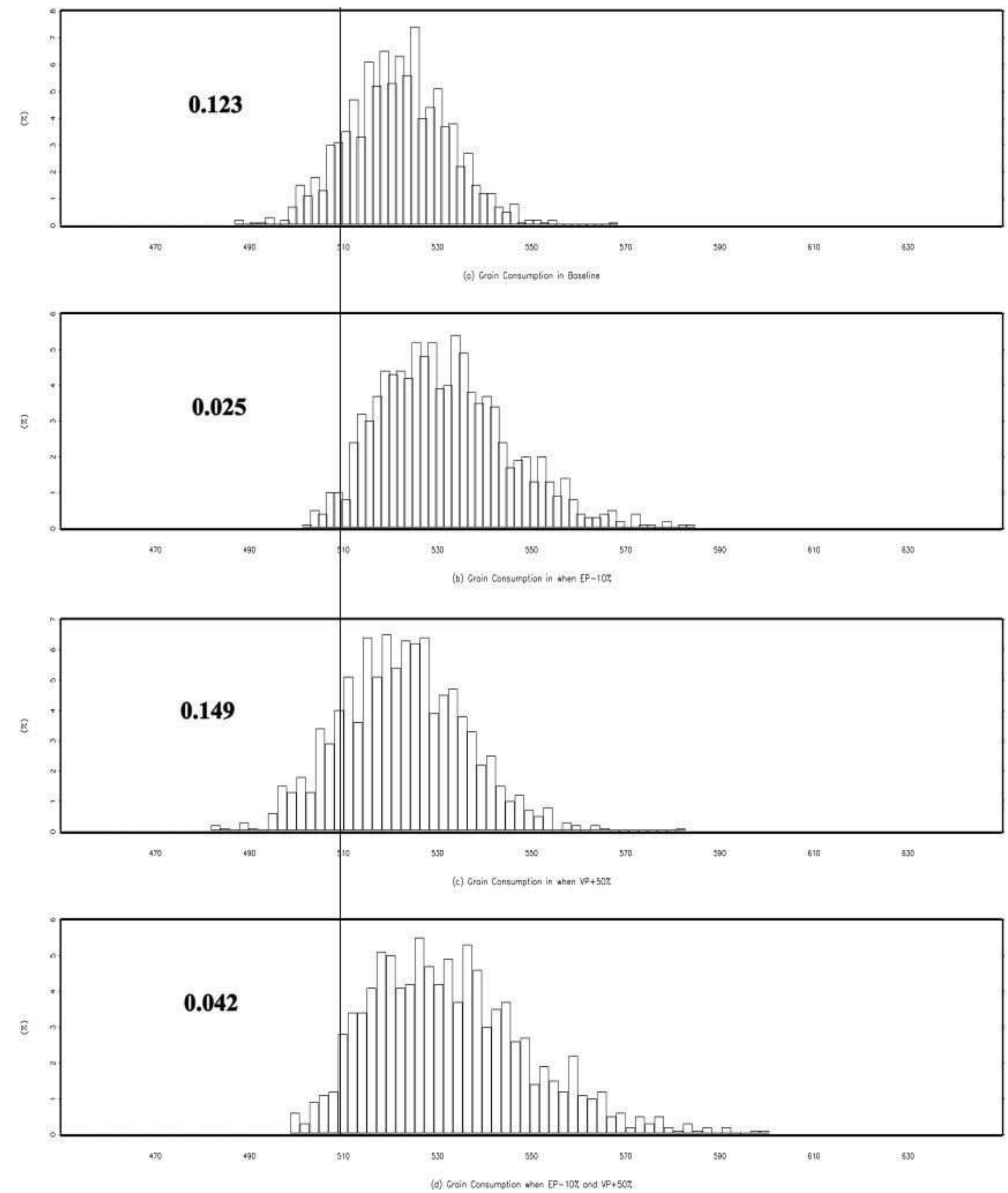

FIGURE 4. Distribution of grain consumption, $\beta = 0.2,\ \eta_h = -0.3$ and $\epsilon = 0.22$.