Long-term Impacts of Global Food Crisis on Production Decisions
Evidence from Farm Investments in Indonesia

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Long-term Impacts of Global Food Crisis on Production Decisions Evidence from Farm Investments in Indonesia[1]

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Abstract

Did the rise in food prices have a long-term impact on agricultural production? Using household-level panel data from seven provinces of Indonesia, we examine whether the 2007-08 food price crisis triggered farm investments. Empirical results show that (i) the food price crisis created a forward-looking incentive to invest, which can increase farm productivity in the long run, (ii) the expectation formation plays an important role in determining the impact, and (iii) the impact differs by the initial wealth; the positive price shock relaxed liquidity constraints among the poor. Implications on inequalities in income and productivity are discussed.

Key Words: Productive investment, Expectation, Anticipated shock, Liquidity constraint.

JEL classifications: D22, O12, Q12.

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1. Introduction

World prices of food commodities rose dramatically in 2007. The global food price inflation was transmitted to the domestic market of Indonesia, where the agricultural sector's share is about 19% of GDP and 41% of total employment. The rising food prices raised fears that the spike in food expenditures could worsen households' well-being, especially among the poor. Welfare impacts of food price inflation can be particularly large in Indonesia since the average family spends about a half of its income on food[3]. On the other hand, higher food prices increased agricultural profits and created large income gains to agricultural households compared to non-agricultural households (Ravallion, 1990; Yamauchi and Dewina, 2012). Interestingly, World Bank (2011) shows evidence that the positive impacts on producers seemed to outweigh the negative effects on consumers' welfare in Indonesia.

In the literature, a large number of papers have investigated the short-term impact of food price shock on poverty and welfare (e.g. Ivanic and Martin (2008); Ravallion (1990) for Bangladesh; Ferreira, Fruttero, Leite, and Lucchetti (2011) for Brazil; Vu and Glewwe (2011) for Vietnam; Friedman, Hong, and Hou (2011) for Pakistan) and distortions created by governments' trade restrictions to cope with volatile food prices (Do, Levchenko, and Ravallion, 2012; Martin and Anderson, 2012). However, its long-term effects on agricultural

[3] Paxson (1993) showed from Thailand that price changes significantly cause consumption fluctuation. Using the same sample from Indonesia, Yamauchi (2012a) also recently showed that recurrent seasonality of rice prices impacts birth weight, resulting in variations across children in subsequent child growth and schooling investments.

production are still yet to be explored and understood[4]. If the rise in food prices creates positive net gains to farmers, it is important to understand how farmers utilize the gains and change their agricultural production activities. If farmers perceive that the price change is rather permanent and/or if the income gain creates sufficient liquidity, it might give farmers an incentive to invest in production assets. On the other hand, if they perceive that the price shock is transitory, they will increase their savings for the future price fall, leaving their investment unaffected (Paxson, 1992; Rosenzweig and Wolpin, 1993; Kazianga and Udry, 2006). Which of the two effects dominates is ambiguous.

Did the positive food price shock increase investments in production capitals, creating a dynamic positive impact on agricultural productivity? This question is related to "induced innovation" hypothesis which suggests that agricultural development is directed by the change in the conditions of factor and product markets (Hayami and Ruttan, 1985). For example, in our context, if the food price spike decreases real wage of hired labors, it might induce farmers to use more labor. As the output price of food items increases, farmers may also have a stronger incentive to reallocate their resources from non-farming activities to farm investments in response to the price spike.[5] In this paper, we aim to answer the questions of

[4] In recent years, there is an emerging academic interest in examining the long-term impact of political or economic shocks (Collins and Margo (2007) for the impact of the 1960s riots in American cities on the property value; Hornbeck (2012) for the impact of the 1930's American Dust Bowl on the population and agricultural production also in the U.S). However, there is no research which investigates the long-term impact of food price crisis.

[5] Using household panel data from Indonesia, Yamauchi (2012b) showed that (i) large farmers tend to acquire more lands by renting in land when non-agricultural real wages increase, and (ii) they install machines if agricultural real wages increase. In contrast, small farmers seemed not to change their behavior. Since land size

(i) whether farmers increased farm investments to expand the production frontier and (ii) whether any constraints bind farmers' optimal strategies.

We use two rounds of a household panel survey conducted in 2007 and 2010, which represent the main agro-climatic zones in Indonesia. Since the first round was prior to the 2007 food price crisis and the second round was conducted in 2010 after the crisis, we can examine the effect of the food price shock on investment decisions during the period. Using (i) monthly provincial-level food price data and (ii) farm and plot-level data on farming activities, we construct a household-level price shock variable by weighting the commodity-specific price changes with the household's production share. This measure captures farm-specific exposures to the food price crisis. In this way, we create variations of the actual exposure to the price shock across farmers residing in the same village if they produce crops with different proportions. Details will be described in Section 3.

The empirical analysis proceeds as follows. First, we use the price shock variable to estimate the responsiveness of the producer's investment to the price increase. Since the future price level is uncertain, thus unpredictable to households, we also examine whether the expectation formation affects their investment behavior, by decomposing the price shock into the anticipated and unanticipated components. Second, we test whether farmers' responses to the price shock were affected by household characteristics and their asset holdings including farm land. For example, if liquidity constraint is binding farmers, they cannot invest enough in

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is significantly larger in non-Java islands than Java, the above observations imply regional differences in dynamic patterns of landholding distribution along with increasing real wages.

productive assets even though they expect the realization of a higher price in the near future (thus, the expected returns to investments are high when making an investment decision). Family labor endowment can also affect investment decisions if increased production responding to an increase of food price can be accommodated by using more of family labor, reducing necessity for additional physical investments.

In the empirical analysis, we found that farmers benefited from the positive price shock in general and the anticipated components of the shock significantly created an incentive to invest in productive assets. The result confirms that the investment decision depends on the conditional expectations of future price changes. Farmers anticipate the future price, which drives their investment decisions. In contrast, unanticipated parts of the price shock did not affect their investment behavior, which is consistent with our theoretical prediction.

Our analysis highlights the critical role of the initial wealth endowment in determining the trajectory of long-term agricultural development. Their investment decision was influenced by the initial wealth endowment. There is a clear contrast between wealthier and poorer farmers in the presence of food price increase. That is, poorer farmers tend to increase investments in productive assets, probably because an increased food price relaxed their liquidity constraint disproportionately more for the poor. The finding that poor farmers are likely to invest more in response to the price spike implies that inequality between large and small farmers can shrink, and small farmers' investments in productive assets may narrow the existing gap in production capacity between them.

This paper is organized as follows. The next section sets up a simple model to clarify our intuitions. Section 3 explains our empirical strategies, and Section 4 provides survey design and background information. Sections 5 carries out empirical analyses. Finally, Section 6 presents conclusions.

2. A Simple Model

2.1 Environment

In this section, we describe our theoretical framework. Consider a producer using land and capital as factors of production. In the first period, the producer can decide the investment for the next period. For simplicity, we assume out capital depreciation. The producer can borrow and lend with an interest rate competitively determined in the credit market.

Let A denote landholding, and $f(k)$ represent land productivity. k is per-land capital stock. The producer has income from agricultural production $pAf(k)$ where p is the output price. The producer lives in 2 periods. Budget constraints are: $c_1 = p_1 Af(k_1) - \Delta kA + b$ and$c_2 = p_2 Af(k_2) - (1 + r)b$. Borrowing b is allowed with gross interest rate $1 + r$. If the producer saves ($b < 0$), there are positive returns in the next period $(1 + r)b$. With investment $\Delta K = A\Delta k$, the next period capital stock is determined as

$$K_2 = Ak_2 = A(k_1 + \Delta k) \qquad (1)$$

The producer maximizes the discounted sum of current and future utilities over Δk and b:

$\max_{\{\Delta k,b\}} u\,(c_1) + \beta E v(c_2)$, subject to the budget constraints and Eq. (1). At this stage, we do not impose any constraints on b.

The standard Euler equations are:

$$k_2: \qquad u'(c_1) = \beta f'(k_2) E[v'(c_2)p_2|\ \Omega_1] \qquad (2a)$$

$$b: \qquad u'(c_1) = \beta(1+r) E[v'(c_2)|\ \Omega_1] \qquad (2b)$$

Since $E[v'(c_2)p_2|\ \Omega_1] = E[v'(c_2)|\Omega_1]E[p_2|\Omega_1] + Cov(v'(c_2), p_2|\Omega_1)$, we obtain from Eq. (2a) and Eq. (2b):

$$1 + r = f'(k_2)\left[E[p_2|\Omega_1] + \frac{Cov(v'(c_2), p_2|\Omega_1)}{E[v'(c_2)|\Omega_1]}\right] \qquad (3)$$

$$\leqq f'(k_2)E[p_2|\Omega_1],$$

where the last inequality holds since

$$\frac{Cov(v'(c_2), p_2|\Omega_1)}{E[v'(c_2)|\Omega_1]} \leqq 0.$$

The equality holds when there is no uncertainty in p_2 or the producer is risk neutral. The covariance also captures the effect through which capital investment increases the variance of the future production value.

2.2 Anticipated vs Unanticipated Shocks

Next we consider the expectation formation. Our main interest is to clarify theoretical insights of the potential effects of a price spike on the investment, financial savings and consumption.

Proposition 1 Effect of Transitory Price Shocks:

If the price dynamics is i.i.d., then $E[p_2|\Omega_1] = E[p_2] = p^*$*and* $1 + r = p^* f'(k_2)$. *That is, a temporary price shock in* p_2 *(if the producer believes so) does not induce investments since it does not increase the expected marginal productivity of capital in the next period (as the producer thinks* p_2 *moves back to normal.*

Proposition 2 Effect of Anticipated Price Shocks:

If $E[p_2|\Omega_1]$ *increases in response to an increase of* p_1 *(i.e.,* $E[p_2|\Omega_1] > p^*$*), there are two effects through: (i)* $E[p_2|\Omega_1]$ *and (ii)* $\frac{Cov(v'(c_2), p_2|\Omega_1)}{E[v'(c_2)|\Omega_1]}$. *The effect (i) is positive to investments, but the effect (ii) is negative to investments (i.e., due to risk aversion). When the first effect dominates, the investment will increase.*

We illustrate the above predictions directly related to $E[p_2|\Omega_1]$. Suppose that there is a structural change in price dynamics at the initial period, so that the producer has to learn about the new price distribution (i.e., the producer uses the updated distribution in each period to form the expectations). For example, we assume that there are price signals between times 1 and 2 (e.g., observing international prices and monthly domestic prices), so that the producer can learn about the price distribution and form the expectations of p_2. Signals are given as $p_s = \theta + \varepsilon_s$ where θ is the unknown mean in the new regime ($\theta \neq p^*$) and ε_s is an i.i.d. price shock, both following normal distributions. The producer knows that the mean price in the new/current region differs from that of the previous regime. In the above setting, rational learning (Bayesian) gives

$$E[p_2|\Omega_1] = \phi_s p_s + (1 - \phi_s)\mu_1 \qquad (4)$$

and $\phi_s = \frac{\sigma_s^2(h)}{\sigma_s^2(h)+\sigma_\varepsilon^2(h)}$ where μ_1 is the prior mean right after time 1, $\sigma_s^2(h)$ is the prior variance, and $\sigma_\varepsilon^2(h)$ is the noise variance. Let h denote the set of structural factors that determined both $\sigma_s^2(h)$ and $\sigma_\varepsilon^2(h)$. Assume that these variances are taken from the past experience before the structural change. In other words, only the mean has changed. In the empirical analysis, we linearly approximate Eq. (4) to estimate $E[p_2|\Omega_1]$ (the anticipated price) and also derive an unanticipated component, $p_2 - E[p_2|\Omega_1]$.

Prediction: Anticipated vs Unanticipated Prices:

Investments respond to the anticipated price $E[p_2|\Omega_1]$, *and not to the unanticipated shock.* $p_2 - E[p_2|\Omega_1]$

2.3 Liquidity constraint

There are two modifications we consider. First, we incorporate a liquidity constraint (imperfect credit market) in the above model by assuming that the interest rate depends on A. Suppose that r is constant if $b < 0$ but $r(A)$ if $b > 0$ where $r'(A) \leqq 0$. That is, they face the same interest rate when they save, but small farmers have to pay a higher interest rate than large farmers when they borrow. When they borrow, it is often the case that they offer collateral (e.g., land). If so, since the left-hand side of Eq. (3) increases for small farmers, the marginal effect of $E[p_2|\Omega_1]$ on investments becomes smaller.

Another way to incorporate liquidity constraint is to impose the condition that $b \leq 0$. They can only save but cannot borrow. The modified Euler equation for b is given as:

$$u'(c_1) = \beta(1+r)E[v'(c_2)|\ \Omega_1]\ + \lambda, \qquad (4)'$$

$$\lambda \geq 0.$$

where λ is the Lagrangian multiplier associated with $b \leq 0$. Then, the condition (3) is modified as

$$(1+r) + \frac{\lambda}{\beta E[v'(c_2)|\Omega_1\ ]} = f'(k_2)\left[E[p_2|\Omega_1] + \frac{Cov(v'(c_2), p_2|\Omega_1)}{E[v'(c_2)|\Omega_1]}\right] \qquad (5)$$

Even in Eq. (5), our intuition remains the same: it potentially reduces the impact of $E[p_2|\Omega_1]$ on the investment, but we also observe asymmetry of the liquidity effect since the likelihood of facing the constraint ($\lambda > 0$ or $\lambda = 0$) depends on the realization of p_1.

Proposition 3 Effect of Liquidity Constraint: *In the presence of borrowing constraint (i.e., farmers cannot borrow), the marginal effect of $E[p_2|\Omega_1]$ will decrease.*

In the following sections, we describe our empirical strategies and data to verify the above theoretical predictions.

3. Empirical strategy

We use the IMDG data to test the implication of our theoretical model on the expectation formation and liquidity constraints. In our empirical model, we assume that farmers are price takers. Using the exogenous variations of food price shocks to households, we estimate the relationship between agricultural investment and food price using a first-differencing (FD) model.

We define food price variable ΔP as a growth rate of food prices between 2007 and 2009. The price index is constructed as follows. We start from the provincial capital producer prices of five main food items: rice ($c=1$), maize ($c=2$), cassava ($c=3$), estate plantation crops ($c=4$), and horticulture crops (c=5). We use an aggregate price measure of estate plantation crops which include major crops such as coffee, cocoa, and coconuts. Our price measure of horticulture crops also includes both vegetables and fruits. Since many farmers produce multiple crops in our sample, the price of each food item is weighted by the revenue share of each main crop among total revenues in 2007 (ϕ_{2007})[6], and the weighted prices are summed.

[6] Revenue shares are the proportions of production revenues of rice, maize, cassava, estate crops, and horticulture crops. If farmers do not market the crops and thus only report the volume of crop production, we imputed the production revenue using the median price of each crop at the village level.

This method provides household-level variations in the exposure to food price shocks, enabling the identification of food price shock impact.

$$\Delta P_{ij} = \sum_{c=1}^{5} \phi_{ijc,2007} (p_{cj,2009} / p_{cj,2007} - 1) \qquad (6)$$

For a household *i* in province (or village) *j*, we estimate:

$$\Delta \ln k_{ij} = \beta_1 \Delta P_{ij} + \beta_2 \Delta P_{ij}^2 + \beta_3 L_{0,ij} + \beta_4 A_{0,ij} + \beta_5 X_{ij,2007} + D_j + \Delta \varepsilon_{ij} \qquad (7)$$

where $\Delta \ln k$ is the log of gross investments in agricultural assets (in real term) between 2007 and 2010. Landholding size (production scale) L_0, the durable asset (initial wealth endowment) A_0, and a vector of household characteristics in 2007 (i.e., the age of the household head, the household's average years of schooling, and household size) X_{2007} are included. Depreciation of agricultural assets is not captured. The standard error is clustered at the village level.

In order to obtain causal effects of food price on investments, we use two-year panel data and difference out household-level fixed effects (time-invariant unobserved heterogeneity). We can difference out the risk aversion, which is the covariance term in the RHS of Eq. (5), and farmer's abilities and tastes which could affect their crop choice. These unobserved factors may be correlated with the production (revenue) weight of each crop in 2007 (ϕ_{2007}), which may bias our estimate of the effect of food price on the investment decision.

We have a concern that unobserved *time-varying* provincial factors, which affect the rise in food price, could also affect households' production decision. Different provinces have different natural endowments of land and resource, and the agro-climatic characteristics (e.g. soil quality) are also different, which affects actual realization of the food price changes. For example, Java and other provinces have very different levels of natural endowments, agricultural technologies, and market integration. We also expect that, over time, each province might have taken different policy measures to rising food prices. To account for the bias from the time-varying unobserved provincial attributes, we include provincial (or village) dummies (D_j) in Eq. (7).

If the food price had a dynamic impact on agricultural investments, we expect to see $\beta_1 > 0$ in Eq. (7). On the other hand, if the price change only had short-term impacts on the production level, we expect that the price variable does not have significant effect on investments but will only increase agricultural inputs.

3.1. Anticipated and unanticipated price shocks

To test Predictions 1 and 2 on the expectation formation, we use a similar empirical strategy as Paxon (1992) and Jacoby and Skoufias (1997) to distinguish between anticipated and unanticipated components of the price shock. In the theory, producers form the expectation of $E(p_2)$ based on Ω_1, which includes prior mean μ_1, price signal p_s, and noise variance $\sigma_\varepsilon^2(h)$. We assume that households have rational expectations concerning the future distribution of food prices, and their price expectation formation is based on the lagged price growth ΔP_{t-1}, a vector of initial crop shares in 2007 (rice, maize, cassava, estate crops, and horticulture crops) w_{2007}, household characteristics X_{2007}, and province dummies. The initial crop shares summarize the information set (containing price dynamics up to 2007, given household characteristics such as their risk aversion). Using the monthly price series of each crop and province from 2004 to 2007, we also compute the persistence and volatility measures (after removing linear trends), which are similarly weighted by the revenue share of each crop at the household level. We include the first-lag autocorrelation AR_{t-1} as the price persistence measure, the standard deviation SD_{t-1} as the volatility measure, and the price trend TR_{t-1}. We also include the interaction terms between initial crop shares in 2007 and average years of schooling (*H*) to allow heterogeneity in price expectation formation depending on households' human capital.

In the first stage, we regress ΔP_t on these variables as follows.

$$\Delta P_{ijt} = \alpha_1 \Delta P_{ijt-1} + \alpha_2 \mathrm{w}_{ij,2007} + \alpha_3 X_{ij,2007} + \alpha_4 \mathrm{w}_{ij,2007} H_{ij,2007} + \alpha_5 AR_{ijt-1} + \alpha_6 SD_{ijt-1} + \alpha_7 TR_{ijt-1} + D_j + e_{ijt} \tag{8}$$

The anticipated component is the projection of the price change based on information available to households in 2007, which is $\widehat{P^P}$.

$$\Delta \widehat{P_{ijt}^P} = \widehat{\alpha_1} \Delta P_{ijt-1} + \widehat{\alpha_2} \mathrm{w}_{ij,2007} + \widehat{\alpha_3} X_{ij,2007} + \widehat{\alpha_4} \mathrm{w}_{ij,2007} H_{ij,2007} + \widehat{\alpha_5} AR_{ijt-1} + \widehat{\alpha_6} SD_{ijt-1} + \widehat{\alpha_7} TR_{ijt-1} + D_j$$

We use the residual of the price shock $\Delta\widehat{P^{UP}} = \Delta P - \Delta\widehat{P^{P}}$ to represent the unanticipated component of the price shock (time index is removed for notational simplicity).

$$\Delta\widehat{P_{ij}^{UP}} = \Delta P_{ij} - \Delta\widehat{P_{ij}^{P}} \qquad (9)$$

Using Eq. (7) and Eq. (9), we estimate β 's in the following regression. This regression also controls for $Z = \{L_0, A_0\}$ and X_{2007}. Since the second stage estimator $\hat{\beta}$ depends in part on the first-stage estimator $\hat{\alpha}$, we use the two-step bootstrap estimation to adjust standard errors for generated regressors.[7]

$$\Delta\ln k_{ij} = \beta_1\Delta\widehat{P_{ij}^{P}} + \beta_2\widehat{\Delta P_{ij}^{UP}} + \beta_3\left(\widehat{\Delta P_{ij}^{P}}\right)^2 + \beta_4\left(\widehat{\Delta P_{ij}^{UP}}\right)^2 + \beta_5\Delta\widehat{P_{ij}^{P}} \times Z_{ij} + \beta_6\widehat{\Delta P_{ij}^{UP}} \times Z_{ij} + \beta_7 Z_{ij} + \beta_8 X_{ij,2007} + D_j + \Delta\varepsilon_{ij} \qquad (10)$$

To estimate Eq. (10), we consider the possibility that farmers' expectations on the future price may differ depending on the marketing arrangement of the products in 2007. In Indonesia, there exist traditional contractual arrangements such as *Tebasan* and *Ijon*[8] between farmers and traders, by which the purchasing prices of crops that traders offer differs from market

[7] In this specification, we only report the results with provincial-level fixed effects as the two-step bootstrap estimation cannot accurately estimate the standard errors with village-level fixed effects due to high dimensionality problem.

[8] *Tebasan* is a harvesting practice in which standing crops, mainly paddy and maize, are sold on area basis just before harvesting at prices close to normal market rates. In this way, farmers and traders avoid transaction costs. While *Ijon* is purchase of crops prior to the harvest at lower price, so that farmers can avoid harvest risks by paying risk premium to traders.

prices at the harvest time. Experiencing a smaller price risk through an informal contract with traders, farmers may perceive future prices differently. For this reason, we do not include households who used either the *Tebasan* or *Ijon* system in our analysis.

4. Data and context

4.1 Survey

The data come from two rounds of household surveys conducted in rural areas of Indonesia in 2007 and 2010 for 98 villages in seven provinces: Lampung, Central Java, East Java, West Nusa Tenggara (NTB), South Sulawesi, North Sulawesi, and South Kalimantan. The locations of surveyed villages are shown in Figure 1. In 2010, we revisited all the 98 sample villages to re-interview sample households and their splits of the 2007 survey households.

Over the three years, some household members split from the 2007 original households and became an independent family head (for marriage or other reasons). In our sample, household division occurred in 204 original households (9% of our sample). We use the 2007-survey original household as the unit for analysis to avoid bias that may arise from household splits. For instance, a new household head, who split from his original household, might share and jointly cultivate farm lands with his parents though the land remains still owned by his parents (vice versa). By aggregating original and split households in 2010, we minimize the split bias[9].

[9] It is possible that the 2007-08 food price crisis affected household split decisions, which will potentially cause an additional bias if we omit split households or do not aggregate original and split households. In this paper, we only report the results using the aggregated households. However, even when we use only households which did not experience split (excluding 204 split households), our empirical results remain the same.

The 2007 survey was designed to overlap with villages in the 1994/95 PATANAS survey conducted by ICASEPS to build household panel data. The 1994/95 PATANAS survey focused on agricultural production activities in 48 villages chosen from different agro-climatic zones in seven provinces. In 2007, we visited those villages to expand the scope of research as a general household survey under the IMDG survey. In the 2007 round, therefore, we added 51 new villages in the same seven provinces[10].

In the revisited villages in 2007, we re-sampled 20 households per village from the 1994/95 sample and followed the split households. In the new villages, we sampled 24 households from two main hamlets in each village. Since one of the 48 villages in the 1994/95 PATANAS was not accessible for safety reasons in the 2007 survey (in NTB province), we have the total of 98 villages. Among the total surveyed households (which include both agricultural and non-agricultural households), we use the 2007-survey original agricultural households (N=1,582) who reported crop incomes from agricultural activities in 2007.

4.2 Descriptive evidence

Agricultural production

The survey collected information on production activities in the past crop year. Therefore we have data on agricultural production in crop year 2006-07 and 2009-10. The survey was conducted in the second to third quarters in 2007 and 2010, which was the ideal timing to

[10] These new villages were selected with the following criteria. First we chose the same districts where PATANAS villages are located. We list villages that had received relatively large amounts of government infrastructure projects during the period of 1995 to 2005, funded by either the Japan Bank for International Cooperation or the World Bank. Finally, the new villages were randomly sampled from the list.

capture activities in crop cycles in the past agricultural year. Using the survey data, summary statistics provide descriptive information on our baseline agricultural households which made some amounts of farm investments in 2007 (N=762). The agricultural sector in Indonesia is characterized by smaller size of land (mean is 1.4 Ha in 2007) and multiple-crop farming. Many farmers cultivated three or four crops in Central and East Java.

There was a dramatic increase in agricultural production from 2007 to 2010, which seems to be accompanied by large investments in production capital. They include farm building, machineries such as tractor, thresher, sprinkler, irrigation pump, sprayer, and dryer, and others agricultural tools. See Table 1 for a detailed breakdown of investments.

Table 2 shows the regional variation of the average agricultural production revenues in 2007 for rice, maize, cassava, estate plantation crops, and horticulture crop from IMDG 2007. Based on food crop statistics by the Badan Pusat Statisti (BPS), Java is the major producing area of rice, maize, and cassava as well as farming multiple crops including various vegetables. In remote areas in South Kalimantan and NTB, farmers primarily produce rice, whereas farmers in Lampung, and North and South Sulawesi are specialized in estate plantation crops.

Household characteristics

Besides agricultural activities, the household module data of the IMDG shows that durable asset holding also increased from 2007 to 2010. In the table, durable asset holding is adjusted for household size (i.e. real values per household member). We use the provincial level consumer price index (2007=100) available online on the BPS website to calculate real values.

Also, we use trimmed data to remove outliers throughout the analysis of this paper. It is defined as the ownership of non-production assets (such as residential house and land; consumer electrical appliances such as TV, radio, satellite antenna, and telephone) and the value has increased by 12.3% from 2007 to 2010.

Local food price data

The wholesale price of agricultural products has started rising since 2004 and the price increased substantially after 2007. Figure 2 disaggregates the price dynamics into five crops in the capital cities of each province[11] based on the monthly price data available from the Indonesian Bureau of Logistics (Bulog) and BPS, which shows that prices of all crops increased quite fast between 2007 and 2010. The prices of rice, maize, and cassava were taken from Bulog statistics, while those of estate crops and horticulture crops are from BPS.

For the monthly raw price data of each crop, the Phillips-Perron test statistic (with time trend) does not reject the null hypothesis of unit root at any critical values, confirming that all price series are non-stationary. Table 3 shows that the first-order autocorrelations and standard deviations using the de-trended version of the monthly price series (which removes linear trends for each province and year). In general, the persistence of food price decreased (especially rice and horticulture crops) and the volatility increased (especially maize and cassava) from pre- to post-crisis period, which implies that the movements of food price have

[11] The capital cities in seven provinces are Banjarmasin (in South Kalimantan), Lampung (in Lampung), Makassar (in South Sulawesi), Mataram (in NTB), Menado (in North Sulawesi), Semarang (in Central Java), and Surabaya (in East Java).

become more uncertain in the post-crisis regime. This pattern was clearly observed in Java (i.e., Semarang and Surabaya), but it seems to follow somewhat different trends in the remote provinces such as NTB.

In the dynamics of local prices in each province, two features attract our attentions. First, due to the regional differences in the dynamics of food price in the post-crisis regime, the regional dispersions of prices have widened since 2007. Second, the prices of maize and cassava increased discontinuously with steps after 2007. In sum, the price level, the persistence, and the volatility seem to differ due to the different level of agricultural market integration.

5. Empirical Results

5.1 Capital investment decisions

In Table 4, we aim to empirically clarify the effects of price shock (including its non-linearity) and household characteristics on farm investments. The table shows benchmark specifications using the FD model of Eq. (7), which we also use with some modifications in other tables coming later. We use the sample of 762 agricultural households who made positive amounts of agricultural investments between 2007 and 2010. Note that, as we found the price effect was clearly concave in the preliminary analysis, all specifications include the square term of the price change.

In column (1), we assume identical investment responses to price shocks across all farmers. The negative estimate of the square term of ΔP indicates that the impact of food price shocks on households' investment decision was non-linear (concave), though the linear effect is insignificant. Both the initial wealth and the landholding size had significantly positive effects on agricultural investments. A large family size helps to expand agricultural activities by increasing investments, as they are endowed with larger family labor force.

In column (2), we allow heterogeneity in the price effect by including its interactions with the initial landholding size and wealth level. If land is used as a collateral, small farmers are likely to face borrowing constraint and, as a result, small farmers tend to invest less. It is also possible that large agricultural land owners have higher profitability per acre (scale economy) and the return to investment is scale-dependent.[12] Although we cannot perfectly separate borrowing constraint from the scale effect since land is a collateral as well as the most important factor determining the scale of production (thus, the efficiency of investments since, e.g., machines are more effectively used on large farms), we can test whether the size of land affected the effect of price shocks on the investment decision.

The theory also predicts that rich farmers invest more than poor farmers since their borrowing cost is lower. On the one hand, if this prediction is true, poor households will absorb the positive income shock by increasing savings and consumption. However, it could also be the case that poor farmers have a stronger incentive to invest since the marginal return to capital is higher than for rich farmers. It all depends on which activity – investment or consumption (current or future) – was constrained. With higher agricultural profit caused by the positive price shock, poor households might take this chance to invest since they do not have to

[12] Foster and Rosenzweig (2011) found the positive relationship between farm size and productivity using panel data in India.

borrow with a high interest rate. To test which hypothesis holds in our context, we interact the price change and durable assets in 2007 (A_0), a measure of the initial wealth level. This measure does not include agricultural land but include residential land.

Both linear and square terms of land size are positively signed, which implies that the effect of agricultural land on investment is increasing with convexity. Therefore, regardless of price shocks, large farmers tend to invest more. However, the interaction term of the price shock variable and farm land is insignificant, suggesting that the effect of price shocks on investment decisions does not depend on the size of farm land.

In the same column, the positive coefficient of durable assets implies that wealthier farmers could increase their agricultural investments even without food price shocks. However, the negative coefficient of the interaction term between the price shock and the initial wealth shows that the marginal effect of the price shock is greater for poorer farmers. Poorer farmers responded more to the price shock by investing, as it created an extra income gain, mitigating liquidity constraints for poor households. The negative marginal effect supports the conjecture that poorer households, which are likely to be liquidity constrained, had a greater incentive to invest due to higher returns to capital than wealthier farmers.

In column (4), we control for village-level fixed effects instead of provincial-level fixed effects. Even within village level, the above findings hold.

5.2 Decomposition of price shock variable

The above results indicate that farmers expected that an increased food price would sustain in the near future and therefore decided to increase their agricultural investments during the food price crisis. The marginal effect diminishes when the price shock became too high. To better understand the non-linear price effect on farm investments, we decompose ΔP in Eq. (7) into price changes from 2007 to 2008 (ΔP_1) and from 2008 to 2009 (ΔP_2). We also include the interaction term of ΔP_1 and ΔP_2.

We expect the diminishing return to price shocks (i.e., $\Delta P_1 \times \Delta P_2$ is negatively signed) since both utility and production functions are strictly concave. In addition, if we reply on a simple framework of Bayesian learning (described in Section 2), farmers put a higher weight on price signals p_s at the initial stage (that is, learning is fast) since the prior variance $\sigma_s^2(h)$ is the biggest in the beginning. As the learning speed is faster at the initial stage, farmers should respond more to initial price shocks ΔP_1. On the other hand, if farmers are uncertain about future price changes and are concerned about the expected payoff in subsequent years, they can increase their investments after observing the realization of ΔP_2. Figure 3 shows that farmers were exposed to larger positive price shocks in the initial stage compared to subsequent years.

The estimates in Table 5 show that the initial price shock ΔP_1 had a larger impact on investment decisions than ΔP_2, which supports our learning hypothesis as well as the diminishing returns. $\Delta P_1 \times \Delta P_2$ is negatively signed, which indicates that the impact of price shocks on investments has diminished over time. The results on the land size and the initial wealth are consistent with the results in Table 4. In column (2), we found that linear and square terms of land size are positive, showing that the scale effect remains positive and convex. In addition, we found that large land owners significantly increased their investments in response to ΔP_1 by 44.3%. In terms of the initial wealth, poorer farmers had a greater incentive to increase investments, but the marginal effect of the initial price shock ΔP_1 diminishes by 52.8% for wealthier farmers. As in section 5.1, we control for village-level fixed effects in column (3) instead of provincial-level fixed effects, and similarly confirm the robustness of our findings about the positive price effect on farm investments even within village level.

These results suggest that a higher food price did create a forward-looking incentive to invest, which can enhance productivity in the long run. However, Propositions 1 and 2 in Section 2 predict that investment decisions might differ by the nature of shocks whether anticipated or unanticipated, if household's expectations on price dynamics matter. If households perceived that the price shock is temporary (i.e. unanticipated shock), it will not have impacts on investments (from Proposition 1). On the other hand, if households changed their expectations based on a permanent change of the price distribution, we predict that the price shock will affect their investment decisions. In the next sub-section, we will examine whether farmers' expectation formation matters by distinguishing between anticipated and unanticipated price shocks.

5.3 Anticipated vs. Unanticipated shocks

In Table 6, we aim to incorporate the price expectation formation after the food price shocks by decomposing price changes into their anticipated and unanticipated components using the first-stage regression of Eq. (8). Table 7 reports the two-step bootstrap estimates of Eq. (10), which allows the anticipated and unanticipated components to have separate coefficients. Similar to Tables 4 and 5, land size, the initial wealth, and household characteristics are also controlled. We use 737 farmers, excluding those households using *Tebasan* or *Ijon* system.

In the first stage (Table 6), negative estimates of the lagged price growth ΔP_{t-1} and the pre-crisis trend TR_{t-1} imply that farmers anticipated a structural change in the future food price dynamics after 2007. As expected, the sign of the persistence measure AR_{t-1} is positive (significant at 10%) and the sign of the volatility measure SD_{t-1} is negative (significant at 1%).

In Table 7, we found that the two types of price shocks have different impacts on farm investments. Column (1) of the table shows that only the anticipated component of the price shock has a significantly positive effect on productive investments, while the effect of unanticipated component is insignificant. Farmers decide to invest in productive assets in response to the predicted component of the price change.

In column (2), we aim to check possible non-linearity in the effects of the two types of price shocks on farm investments. We find that that (i) the effect of the anticipated price shock on investments is concave as confirmed in the previous section, while the unanticipated shock had no significant effect, (ii) the marginal effect of the anticipated price shock is increasing as the land size becomes larger, and (iii) the marginal effect of the anticipated price shock is decreasing as the initial wealth increases. Less wealthier farmers have a greater incentive to invest when they anticipate an increase in price (the interaction term is significant at 5%). The result indicates that households' general wealth level (i.e. ownership of non-liquid wealth) is an important determinant of productive asset investments.

For the anticipated shock, the marginal effect is peaked at ΔP^P=0.15 for poor farmers and at ΔP^P=0.13 for rich farmers. In both groups, the effect diminishes as the anticipated shock increases beyond the above peaked price levels. As shown in the lower panel, for large land owners, the positive price effect becomes larger linearly with the anticipated price shock. The impact of the unanticipated shock on farm investments is always negative, regardless of the initial wealth and land sizes).[13]

Finally, in column (3), we examine whether households' risk aversion on future price volatility reduced their incentives to increase farm investments. For this purpose, we adopt the method used in Kazianga and Udry (2006) and investigate whether higher moments of future price shocks affected investment decisions by controlling for a price volatility measure in Eq.

[13] We note that the concavity of anticipated price shocks is partly driven by some outliers (i.e., those with anticipated price shocks above one), and therefore the concave relationship is not quite robust. However, even without the concave relationship, the impact of anticipated price shocks on farm investments will be peaked around the similar points even after trimming these outliers.

(10). We assume that farmers rationally expected the volatility of the post-crisis food prices based on the difference between realized prices P_t and the mean price level ($E_{t-1}(P_t)$), which they (we) can predict based on the pre-crisis food price data from 2004 to 2007. We include the prediction error of the standard deviation, defined as $SD_t - \widehat{SD_t}$ (re-scaled to 10^2), where SD_t is the realized standard deviation in the post-crisis regime.

$$\widehat{SD_t} = \sqrt{\frac{1}{36}\sum_{t=2007m1}^{2009m12}[P_t - E_{t-1}(P_t)]^2}$$

Figure 4 depicts the distribution of $SD_{prediction\ error}$. The mean (or median) of the prediction error is -0.932 (or -0.424), which means that farmers predicted a larger price volatility than the realized level of price volatility. There were, however, many farmers who experienced a larger price volatility than they expected. If the realized price is more volatile in the post-crisis regime than they expected, farmers should have a smaller incentive to increase investments in response to the food price spike and would increase pre-cautionary savings. The result in column (3) shows that $SD_{prediction\ error}$ has a negative sign but insignificant. Even in this specification, the results on anticipated and unanticipated shocks remain robust as we found in column (1) and (2).

This finding reinforces our arguments that not all farmers who anticipated a positive price shock invested in agricultural productive assets, but poorer farmers did.

5.3 Robustness check (1): Controlling for the initial production patterns prior to the food price crisis

As defined in Eq. (6), the household-level changes in prices are constructed as the product of household-level crop shares in 2007 (ϕ_{2007}) and provincial-level price changes. To check whether the initial crop shares are directly correlated with the subsequent investment decisions, we linearly add the revenue share of each crop ($\phi_{c,2007}$), where $c = 1, \dots, 5$.

Tables 8.A and 8.B report the robustness checks for the benchmark regressions in Eq. (7) including the crop shares. In Table 8.B, we decompose the price shock variable into the price changes in the initial period (in 2007-08) and the later period (in 2008-09). Although the magnitude of the price shock effect slightly decreases, the estimates remain significant and confirm our findings summarized in Table 4 and 5. That is, (i) the initial price spike (in 2007-08) had a strong positive effect on farm investments and (ii) poorer farmers increased investments more than richer farmers in response to the price spike.

In Table 9, we check robustness of our previous findings on anticipated vs. unanticipated price shocks reported in Table 7. Even when we control for the initial structure of production in Eq. (10), the estimates confirm that farmers (especially the poor ones) responded to the anticipated price shock, but they did not respond to the unanticipated price shock.

5.4. Robustness check (2): Sample selection

Finally, we are concerned about the selection bias that potentially arises from the omission of 635 farmers who did not make farm investments at all. We observed that, in the majority of our sample villages, the two groups of farmers are balanced, which justifies the use of village fixed effects in the estimation. In column (2) of Tables 8.A and 8.B, we show the estimates of a linear probability model, defined below:

$$I_{ij} = \beta_1 \Delta P_{ij} + \beta_2 \Delta P_{ij}^2 + \beta_3 Z_{ij} + \beta_4 \Delta P_{ij} \times Z_{ij} + \beta_5 X_{ij,2007} + D_j + \Delta\varepsilon_{ij}$$

where $I_{ij} = 1[k_{ij} > 0]$ and $Z = \{L_0, A_0\}$. To reinforce our findings based on the intensive margin, the new result shows that the price spike induced farmers (especially poor households) to make some levels of investments at the extensive margin too. In addition, the positive estimate of the interaction between the price variable and the land size suggests that those who owned larger farm lands were more likely to invest in farm equipment responding to the price spike. We also find that larger households with heads experienced in farming were more likely to make investments.

By excluding farmers who did not invest, there is a concern that our results in Tables 4 and 5 were overestimated due to the mentioned selection bias. In column (3) of Tables 8.A and 8.B, we use Tobit model defined as follows:

$$y_{ij}^* = \beta_1 \Delta P_{ij} + \beta_2 \Delta P_{ij}^2 + \beta_3 Z_{ij} + \beta_4 \Delta P_{ij} \times Z_{ij} + \beta_5 X_{ij,2007} + D_j + \Delta\varepsilon_{ij}$$
$$y_{ij} = \max(0, y_{ij}^*)$$

where $\Delta\varepsilon_{ij}$ is normally distributed with the variance of σ^2. The estimates in column (3) confirm our previous findings reported in Tables 4 and 5 on the intensive margin of investments. Therefore, the main findings on farm investments responding to price shocks qualitatively remain robust with and without the sample selection being controlled.

6. Conclusion

In this paper, we have examined farmers' investment decisions during the food crisis period using recent household panel data from Indonesia. The empirical analysis showed the positive price impact on farmers' investments during the food price crisis experienced in the period 2007 - 2008. Unlike the negative welfare impacts of higher food prices for consumers studied in the previous literature, we found that the anticipated component of the price shock created a forward-looking incentive for Indonesian farmers to invest in productive assets. The above effect was strong among poor farmers.

There are some interesting implications that deserve our attention. Whether the investment indeed had a dynamic positive impact on agricultural productivity is an important question. Our preliminary result suggests that investments undertaken between 2007 and 2010 have positively impacted productivity amid the global food price crisis, implying that the food price spike seemed to induce an upward shift in the production frontier in agriculture. However, the analysis on the micro-macro linkage is necessary to understand how the increase in farm investments significantly enhanced the aggregate productivity level.

Moreover, whether, in the long run, the food price crisis led to a divergence between rich and poor farmers is an important question to answer. Our results indicate that, though large landholders tend to invest in productive assets regardless of price shocks, small farmers capture the price spike as a good opportunity to relax their liquidity constraint and increased their investments.

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Summary statistics

	N	Mean	sd	p50	min	max
Ln(investment)	762	12.540	1.839	12.467	8.289	19.438
d_price	762	0.226	0.302	0.213	-0.226	2.12
d_price1	762	0.221	0.281	0.191	-0.2	1.8
d_price2	762	0.007	0.073	0.001	-0.355	0.333
Ln(asset)	762	16.918	1.162	17.056	11.336	22.790
Ln(land)	762	-0.626	1.250	-0.525	-5.809	2.197
Average years of schooling	762	7.569	2.926	7.225	0	16
Household size	762	5.328	2.067	5	1	16
Average age	762	35.292	5.703	35	20	55
AR_t-1	762	0.686	0.130	0.712	0.230	0.847
SD_t-1	762	187.642	183.419	111.824	10.679	718.735

(Note) d_price is the price changes from 2007 to 2009. In Table 5 and Table 8.B, we decompose the price shock variable into price changes from 2007 to 2008 (d_price1) and from 2008 to 2009 (d_price2). Durable asset holding is converted to real term, deflated by CPI index, and is adjusted for household size. AR_t-1 and SD_t-1 are household-level measures of autocorrelation and standard deviation of the pre-crisis food prices.

Table 1: Type of investment in agricultural asset

	N	Mean (1000Rp)	Min	Max
Farm equipment*	1,110	990.8	2.5	320,000
Sprayer	404	707.8	0	100,000
Farm building	223	3,294.3	50	120,000
Barn	43	482	0	9,900
Plow/Harrow	30	538	30	3,000
Tractor	21	8,561.9	100	20,000
Dryer	20	141.3	0	2,600
Machinery**	19	7,744.7	250	30,000
Thresher	17	9,700	0	70,000

*Farm equipment include agricultural tools such as shovel, hoe, sickle, jackknife, machete, crowbar and so on.
**Milling, feed processor, crumb rubber processor etc.

Table 2: Average share of production revenues (by provinces)

	All provinces	Each provinces						
		Central Java	East Java	Lampung	North Sulawesi	South Sulawesi	South Kalimantan	NTB
Rice	0.369	0.128	0.215	0.283	0.317	0.350	0.596	0.593
Maize	0.060	0.071	0.185	0.011	0.050	0.114	0.040	0.024
Cassava	0.047	0.099	0.024	0.133	0	0.008	0.015	0
Estate crops	0.336	0.151	0.108	0.549	0.598	0.489	0.261	0.108
Horticulture crops	0.189	0.550	0.275	0.024	0.035	0.039	0.088	0.275

Table 3: Persistence and Volatility of Commodity Prices (at province level)

1. Autocorrelations (1 month lag)

	Banjarmasin		**Lampung**		**Makassar**		**Mataram**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Rice	0.844	0.742	0.623	0.736	0.650	0.157	0.444	0.397
Maize	0.821	0.827	0.116	0.843	0.826	0.724	0.557	0.473
Cassava	0.864	0.76	0.471	0.476	0.671	0.768	0.788	0.807
Estate	0.713	0.731	0.734	0.792	0.821	0.850	0.510	0.585
Horticulture	0.652	0.510	0.604	0.741	0.729	0.250	0.362	0.547
Average	0.779	0.716	0.509	0.718	0.740	0.550	0.532	0.562

	Menado		**Semarang**		**Surabaya**		**All**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Rice	0.675	0.584	0.823	0.349	0.654	0.525	0.673	0.499
Maize	0.703	0.612	0.788	0.702	0.763	0.850	0.654	0.719
Cassava	0.772	0.857	0.847	0.842	0.758	0.802	0.739	0.760
Estate	0.712	0.805	0.756	0.873	0.841	0.821	0.727	0.780
Horticulture	0.607	0.572	0.675	0.554	0.687	0.537	0.617	0.530
Average	0.694	0.686	0.778	0.664	0.741	0.707	**0.682**	**0.657**

2. Standard deviations

	Banjarmasin		**Lampung**		**Makassar**		**Mataram**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Rice	718.735	202.156	290.385	363.887	244.257	95.094	215.805	167.721
Maize	95.490	354.976	217.241	729.643	80.842	533.299	224.583	127.499
Cassava	88.146	421.188	228.082	146.600	68.047	107.726	257.852	260.229
Estate	34.987	35.939	108.311	55.158	111.552	82.881	10.679	5.140
Horticulture	33.010	2.011	23.598	4.562	17.427	1.982	16.904	6.173
Average	194.074	203.254	173.523	259.970	104.425	164.197	145.165	113.353

	Menado		**Semarang**		**Surabaya**		**All**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Rice	257.152	197.888	249.636	86.973	190.629	178.155	309.514	184.553
Maize	147.204	264.117	85.064	173.756	147.852	240.060	142.611	346.193
Cassava	129.968	579.649	95.792	656.522	90.748	252.640	136.948	346.365
Estate	152.892	69.111	21.536	31.767	45.224	54.865	69.311	47.837
Horticulture	28.720	5.073	20.009	2.814	22.690	4.825	23.194	3.920
Average	143.187	223.168	94.407	190.366	99.429	146.109	**136.316**	**185.774**

Pre = Pre-food crisis period (from 2004m1-2006m12)
Post = Post-food crisis period (from 2007m1-2010m12)

(Note) Autocorrelations and standard deviations are computed based on the de-trended series of each crop and province using pre- and post-crisis monthly price data. We remove linear time trend to construct de-trended price series. Average is the simple average.

(Source) Bulog, BPS

Table 4: Positive price shock and investment decisions

VARIABLES	Ln(investment)			
	(1)	(2)	(3)	(4)
d_price = *x*	-0.425	7.218**	7.148**	4.601**
	(0.748)	(3.112)	(3.252)	(2.284)
x ^2	-0.567*	-0.582*	-0.529*	0.0726
	(0.301)	(0.306)	(0.306)	(0.245)
Ln(asset)	0.179**	0.284***	0.280***	0.279***
	(0.0756)	(0.0927)	(0.0935)	(0.0887)
x *Ln(asset)		-0.445***	-0.446**	-0.294**
		(0.167)	(0.175)	(0.126)
Ln(land)	0.222***	0.152*	0.276***	0.192*
	(0.0570)	(0.0810)	(0.0947)	(0.0972)
Ln(land)^2			0.0542***	0.0391*
			(0.0175)	(0.0206)
x *Ln(land)		0.364	0.400	0.269
		(0.246)	(0.254)	(0.215)
Average years of schooling	0.0128	0.0150	0.0155	0.0136
	(0.0272)	(0.0270)	(0.0268)	(0.0270)
Household size	0.0878**	0.0841**	0.0759**	0.0296
	(0.0334)	(0.0342)	(0.0347)	(0.0352)
Average age	-0.00242	-0.00311	-0.00330	-0.0122
	(0.0107)	(0.0107)	(0.0107)	(0.0102)
Constant	9.124***	7.346***	7.431***	7.048***
	(1.247)	(1.518)	(1.519)	(1.460)
Observations	762	762	762	762
Regional fixed effect included	Province	Province	Province	Village
R-squared	0.223	0.233	0.239	0.454

*** p<0.01, ** p<0.05, * p<0.1

Standard errors are heteroscedasticity robust and clustered at the village level, and are reported in the parentheses.

Table 5: Decomposed price shock and investment decisions

VARIABLES	Ln(investment)		
	(1)	(2)	(3)
d_price1 = *y1*	8.713***	8.612**	5.331*
	(3.267)	(3.351)	(2.891)
d_price2 = *y2*	5.702	5.100	10.29
	(14.63)	(14.11)	(14.77)
y1 * *y2*	-14.19**	-13.30**	-7.547
	(6.296)	(6.372)	(5.961)
y1^2	-0.106	-0.117	0.533
	(0.492)	(0.502)	(0.433)
y2^2	-14.80	-15.03	-6.584
	(12.39)	(12.39)	(12.36)
Ln(asset)	0.297***	0.291***	0.297***
	(0.0950)	(0.0956)	(0.0950)
y1 * Ln(asset)	-0.532***	-0.528***	-0.345**
	(0.178)	(0.183)	(0.165)
y2 * Ln(asset)	0.0302	0.0458	-0.418
	(0.799)	(0.768)	(0.851)
Ln(land)	0.151*	0.272***	0.184*
	(0.0852)	(0.0988)	(0.102)
Ln(land)^2		0.0542***	0.0377*
		(0.0167)	(0.0210)
y1 * Ln(land)	0.406*	0.443*	0.351
	(0.238)	(0.246)	(0.240)
y2 * Ln(land)	-0.368	-0.279	-0.404
	(0.556)	(0.510)	(0.434)
Average years of schooling	0.0147	0.0152	0.0121
	(0.0263)	(0.0262)	(0.0269)
Household size	0.0765**	0.0686**	0.0282
	(0.0339)	(0.0343)	(0.0351)
Average age	-0.00367	-0.00366	-0.0129
	(0.0103)	(0.0103)	(0.0103)
Constant	7.265***	7.360***	6.884***
	(1.554)	(1.554)	(1.541)
Observations	762	762	762
Regional fixed effect included	Province	Province	Village
R-squared	0.247	0.253	0.458

*** p<0.01, ** p<0.05, * p<0.1

Standard errors are heteroscedasticity robust and clustered at the village level, and are reported in the parentheses.

Table 6: Impact of anticipated vs. unanticipated price shocks

(first-stage regression on price expectation)

VARIABLES	d_price
d_price_t-1	-1.137***
	(0.257)
TR_t-1	-0.0106***
	(0.00206)
AR_t-1	0.642*
	(0.374)
SD_t-1	-0.000631***
	(0.000170)
Share of rice in 07	0.249**
	(0.101)
Share of maize in 07	0.777***
	(0.247)
Share of estate crop in 07	-0.492***
	(0.0713)
Share of horticulture crop in 07	-0.465***
	(0.0970)
Average age	-0.00116
	(0.000849)
Average years of schooling	0.00275
	(0.00196)
Househouse size	-0.00378*
	(0.00194)
Yrs of schooling x Share of maize	-0.0297
	(0.0214)
Yrs of schooling x Share of cassava	-0.00923
	(0.00955)
Yrs of schooling x Share of estate crop	-0.00956**
	(0.00381)
Yrs of schooling x Share of horticulture crop	0.00224
	(0.00444)
Constant	0.632**
	(0.296)
Observations	737
Provincial fixed effect included	YES
R-squared	0.843

*** p<0.01, ** p<0.05, * p<0.1

Standard errors are corrected by two-step bootstrap estimator with 2,000 replications, and are reported in the parentheses. Farmers with fixed price arrangement (*Tebasan* and *Ijon*) with traders are excluded from the sample.

Table 7: Impact of anticipated vs. unanticipated price shocks

(second-stage regression on price expectation)

VARIABLES	Ln(investment) (1)	(2)	(3)
Anticipated = *x*	7.513*	9.390**	10.01**
	(3.964)	(3.890)	(3.921)
x ^2		-0.973**	-1.258***
		(0.461)	(0.480)
Unanticipated = *y*	-3.507	0.417	-0.0391
	(8.176)	(8.255)	(8.219)
y ^2		4.440	4.775*
		(2.758)	(2.796)
Ln(asset)	0.283***	0.297***	0.304***
	(0.0905)	(0.0898)	(0.0896)
x * Ln(asset)	-0.504**	-0.566**	-0.576**
	(0.231)	(0.229)	(0.228)
y * Ln(asset)	0.0458	-0.124	-0.0866
	(0.484)	(0.489)	(0.487)
Ln(land)	0.298***	0.289***	0.293***
	(0.0991)	(0.0966)	(0.0964)
Ln(land) ^2	0.0636***	0.0594***	0.0603***
	(0.0223)	(0.0221)	(0.0222)
x * Ln(land)	0.468	0.506*	0.496*
	(0.291)	(0.282)	(0.283)
y * Ln(land)	-0.0443	0.207	0.203
	(0.467)	(0.466)	(0.465)
SD_prediction error			-0.0906
			(0.0702)
Average age	-0.000654	-0.00205	-0.00236
	(0.0110)	(0.0110)	(0.0110)
Average years of schooling	0.0279	0.0192	0.0179
	(0.0240)	(0.0243)	(0.0244)
Household size	0.0655**	0.0725**	0.0708**
	(0.0318)	(0.0318)	(0.0322)
Constant	7.325***	7.064***	6.891***
	(1.527)	(1.513)	(1.522)
Observations	737	737	737
Provincial fixed effect included	YES	YES	YES

*** p<0.01, ** p<0.05, * p<0.1

Standard errors are corrected by two-step bootstrap estimator with 2,000 replications, which are reported in the parentheses. Farmers with fixed price arrangement (*Tebasan* and *Ijon*) with traders are excluded from the sample.

Table 8.A: Robustness check 1 on benchmark regressions (Structure of production controlled)

VARIABLES	(1) OLS Ln(investment)	(2) Linear Pr Inv01	(3) Tobit Ln(investment)
d_price = *x*	4.361**	0.830***	16.37***
	(2.142)	(0.290)	(4.611)
x^2	-0.112	-0.123*	-1.984*
	(0.248)	(0.0663)	(1.101)
Ln(asset)	0.289***	0.0104	0.302
	(0.0889)	(0.0170)	(0.337)
x * Ln(asset)	-0.277**	-0.0315*	-0.689**
	(0.117)	(0.0160)	(0.271)
Ln(land)	0.208**	0.00384	0.232
	(0.0963)	(0.0174)	(0.341)
Ln(land)^2	0.0420**	-0.00226	-0.0209
	(0.0204)	(0.00563)	(0.108)
x * Ln(land)	0.231	0.0432**	0.853**
	(0.195)	(0.0208)	(0.434)
Average age	-0.0132	0.00485*	0.0904*
	(0.0101)	(0.00277)	(0.0521)
Average years of schooling	0.0117	0.000803	0.0695
	(0.0263)	(0.00554)	(0.108)
Household size	0.0292	0.0152**	0.327**
	(0.0346)	(0.00749)	(0.139)
Share of rice in 07	0.441	0.105	2.331
	(0.408)	(0.0917)	(1.501)
Share of maize in 07	0.846	-0.000622	0.546
	(0.716)	(0.110)	(2.130)
Share of estate crop in 07	0.0294	0.0301	1.182
	(0.427)	(0.0929)	(1.456)
Share of horticulture crop in 07	0.500	0.0876	2.092
	(0.445)	(0.0979)	(1.685)
Constant	6.852***	-0.182	-12.31**
	(1.564)	(0.308)	(5.928)
Observations	762	1,216	1,210
Village fixed effect included	YES	YES	YES
R-squared	0.459	0.290	0.0688
$\hat{\sigma}$			7.668

*** p<0.01, ** p<0.05, * p<0.1

Standard errors are heteroscedasticity robust and clustered at the village level, and are reported in the parentheses. In column (2), *Inv01* is a binary variable which is one if a farmer makes some levels of investments at the extensive margin.

Table 8.B: Robustness check 2 on benchmark regressions

VARIABLES	(1) OLS Ln(investment)	(2) Linear Pr Inv01	(3) Tobit Ln(investment)
d_price1 = *y1*	5.319*	0.903**	19.25***
	(2.713)	(0.407)	(6.701)
d_price2 = *y2*	4.934	-0.797	-25.63
	(16.51)	(3.332)	(61.84)
*y1 * y2*	-2.100	0.176	-0.0417
	(6.334)	(1.699)	(26.08)
y1^2	-0.0185	-0.136	-1.982
	(0.560)	(0.152)	(2.492)
y2^2	1.007	1.589	27.22
	(13.01)	(2.997)	(49.57)
Ln(asset)	0.302***	0.0106	0.317
	(0.0939)	(0.0173)	(0.340)
y1 * Ln(asset)	-0.332**	-0.0380*	-0.896***
	(0.155)	(0.0208)	(0.347)
y2 * Ln(asset)	-0.390	0.0479	1.504
	(0.927)	(0.184)	(3.416)
Ln(land)	0.196*	0.00348	0.215
	(0.0994)	(0.0175)	(0.341)
Ln(land)^2	0.0407*	-0.00220	-0.0231
	(0.0209)	(0.00554)	(0.106)
y1 * Ln(land)	0.321	0.0440	0.930*
	(0.221)	(0.0267)	(0.538)
y2 * Ln(land)	-0.507	0.0691	0.625
	(0.454)	(0.133)	(2.615)
Average age	-0.0132	0.00491*	0.0922*
	(0.0103)	(0.00278)	(0.0522)
Average years of schooling	0.0103	0.00100	0.0740
	(0.0260)	(0.00560)	(0.109)
Household size	0.0286	0.0151**	0.324**
	(0.0351)	(0.00753)	(0.140)
Share of rice in 07	0.475	0.176	3.602
	(0.375)	(0.151)	(2.486)
Share of maize in 07	0.820	0.0550	1.413
	(0.822)	(0.173)	(3.122)
Share of estate crop in 07	-0.0439	0.0885	2.190
	(0.495)	(0.148)	(2.433)
Share of horticulture crop in 07	0.538	0.162	3.421
	(0.551)	(0.163)	(2.718)
Constant	6.656***	-0.246	-13.70**
	(1.586)	(0.337)	(6.341)
Observations	762	1,216	1,210
Village fixed effect included	YES	YES	YES
R-squared	0.461	0.291	0.0689
$\hat{\sigma}$			7.665

Table 9: Robustness check on the price expectation regression

VARIABLES	Ln(investment)
Anticipated = *x*	8.939**
	(4.168)
x ^ 2	-0.718
	(0.764)
Unanticipated = *y*	-6.912
	(8.377)
y ^ 2	4.366
	(2.920)
Ln(asset)	0.298***
	(0.0909)
x * Ln(asset)	-0.595**
	(0.238)
y * Ln(asset)	0.293
	(0.498)
Ln(land)	0.345***
	(0.0970)
Ln(land)^2	0.0681***
	(0.0214)
x * Ln(land)	0.379
	(0.303)
y * Ln(land)	0.137
	(0.466)
SD_prediction error	0.0652
	(0.103)
Share of rice in 07	1.167**
	(0.494)
Share of maize in 07	1.690**
	(0.762)
Share of estate crop in 07	0.722
	(0.462)
Share of horticulture crop in 07	1.850***
	(0.458)
Constant	6.559***
	(1.579)
Observations	737
Provincial fixed effect included	YES

*** p<0.01, ** p<0.05, * p<0.1

Using the first stage regression of Table 6, this regression controls for the structure of production. Standard errors are corrected by two-step bootstrap estimator with 2,000 replications, which are reported in the parentheses. Farmers with fixed price arrangement (*Tebasan* and *Ijon*) with traders are excluded from the sample. Regressions also include other covariates such as average age, average years of schooling, and household size.

Figure 1: Locations of surveyed villages

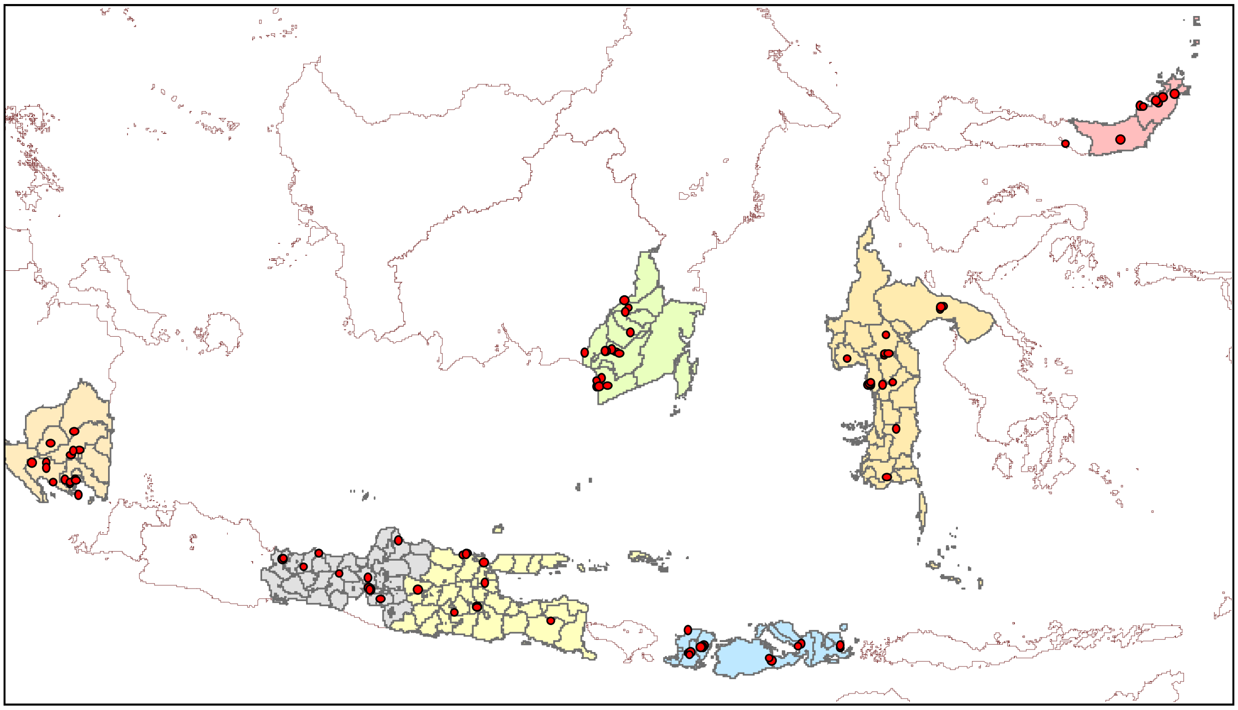
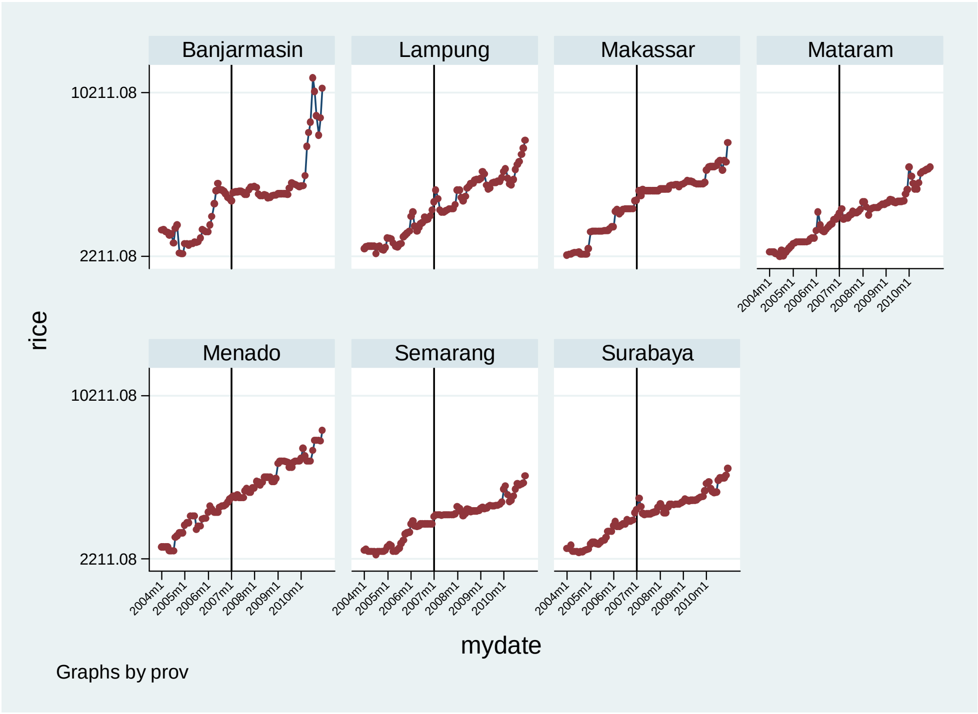
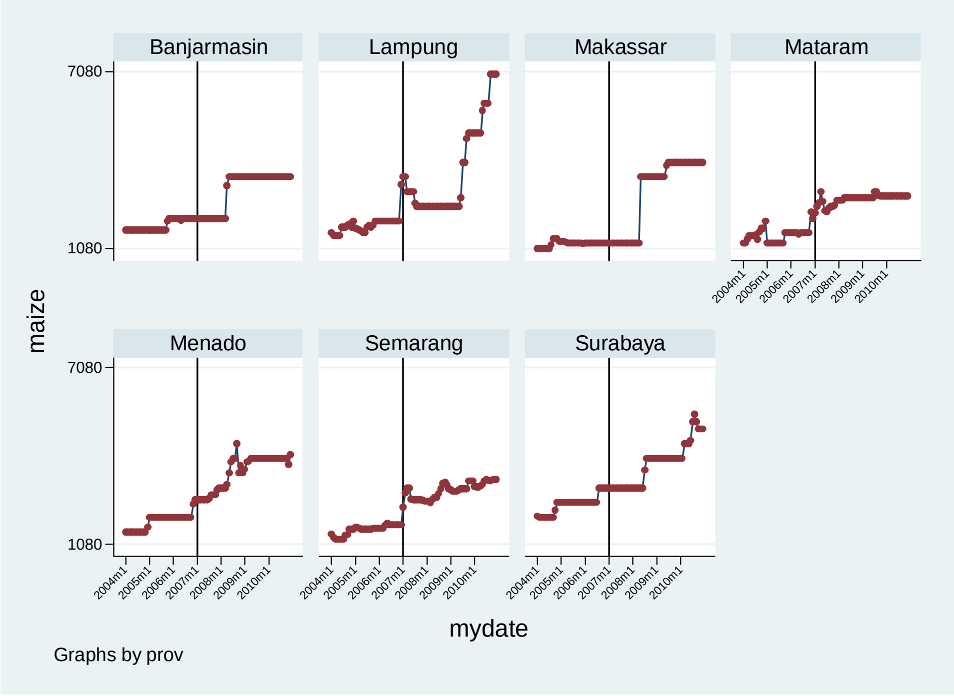


Figure 2: Prices of rice, maize, cassava, estate crop, and horticulture crop in Indonesia

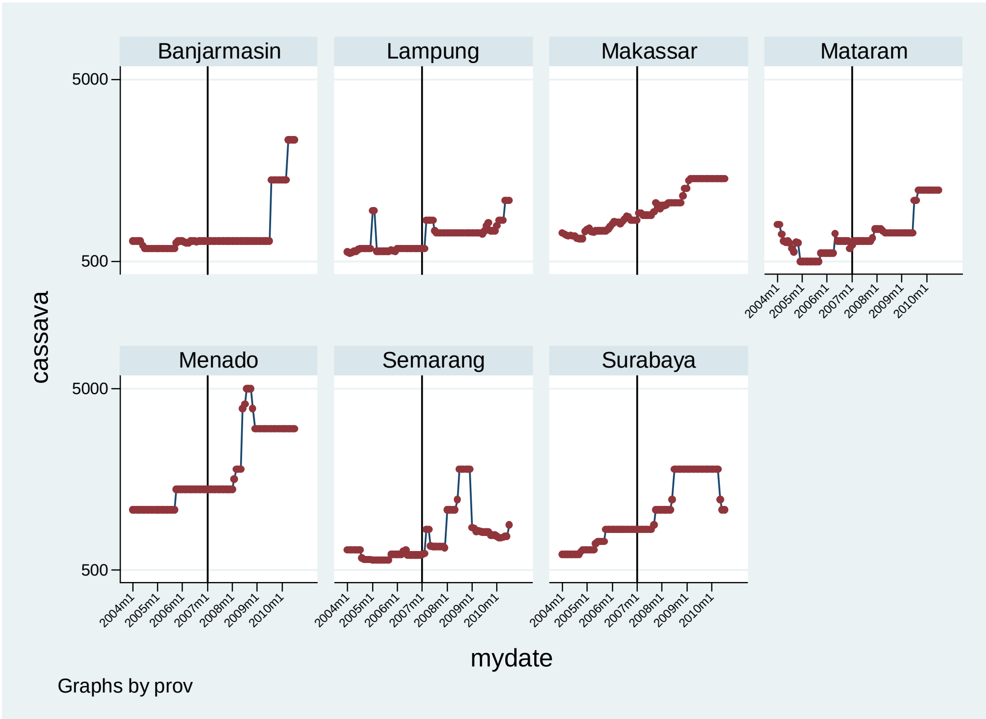
Dynamics of rice price



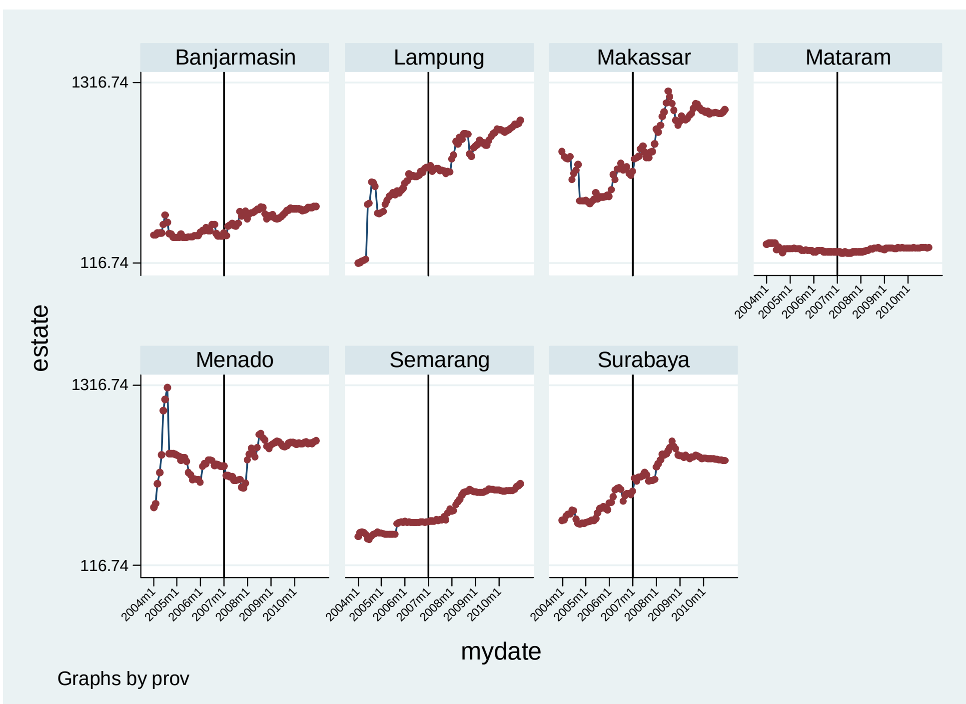
Dynamics of maize price



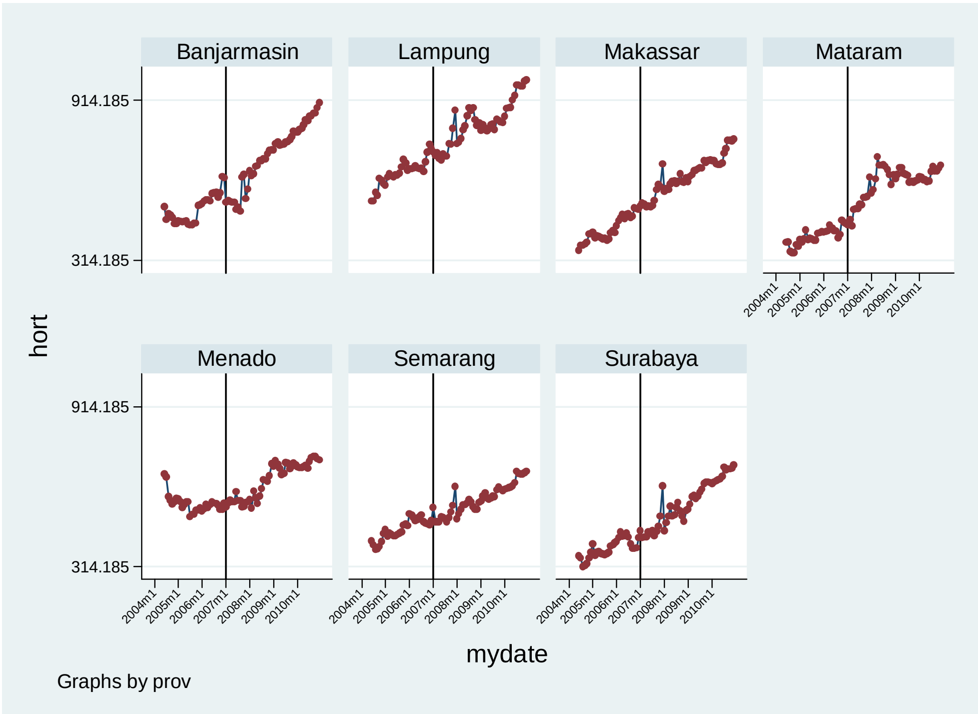
Dynamics of cassava price



Dynamics of price for estate plantation crop



Dynamics of price for horticulture crop



(Source) Bulog, BPS

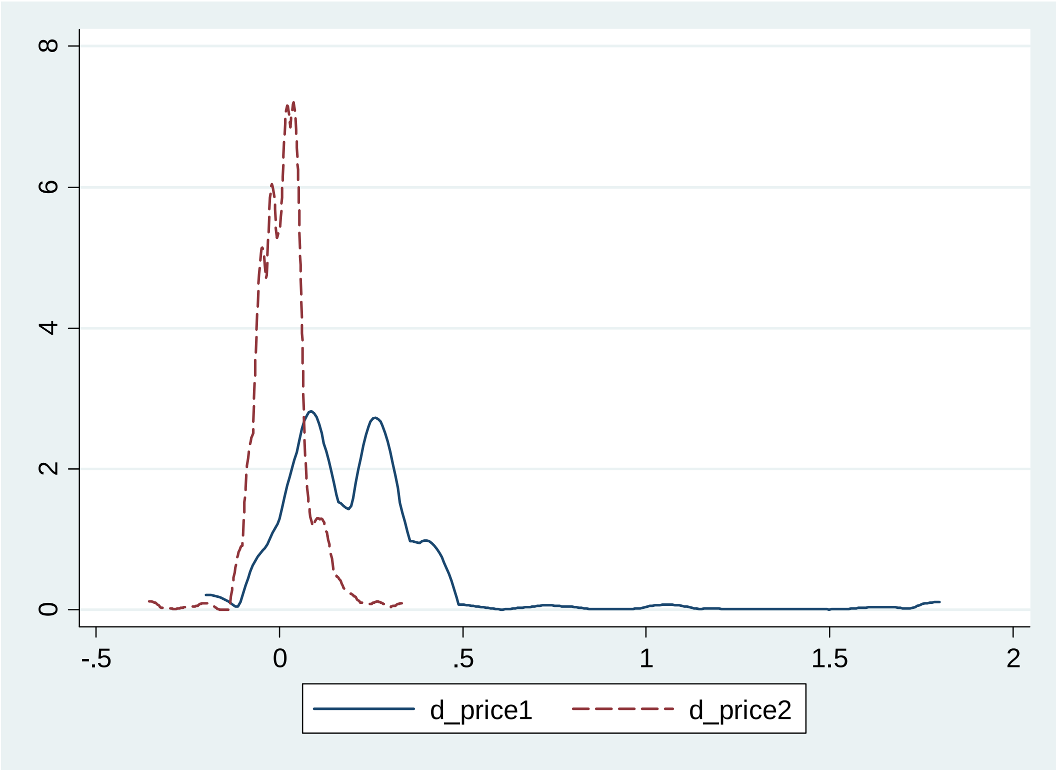


Figure 3: Distribution of food price variable (N=762)

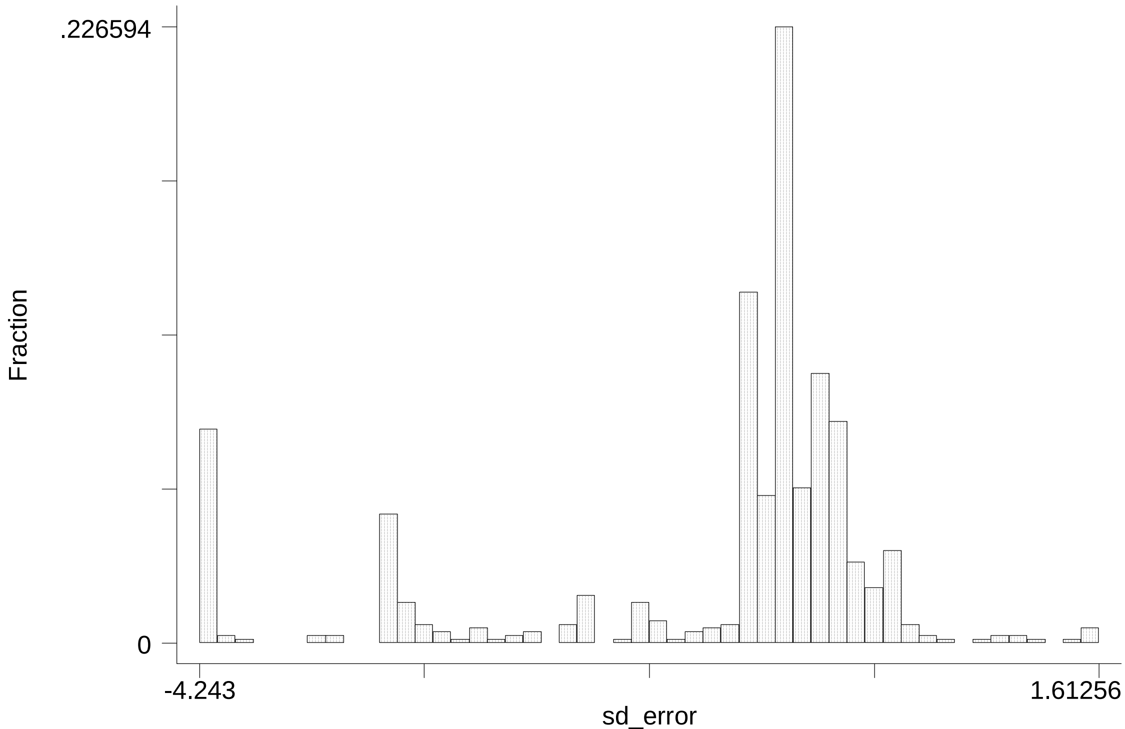


Figure 4: Distribution of $SD_{prediction\ error}$