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

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Abstract

This paper estimates farmers' investment response to food price spikes using household panel data collected before and after the 2007/08 food price crisis in Indonesia. We found that an increase in farmers' terms-of-trade allowed relatively large crop-producing farmers to increase their investments at both extensive and intensive margins. Food price spikes had a significant income effect among farmers whose production surplus is large for market sales. During the food price crisis, large farmers particularly increased machine investments, which saved some labor inputs, pointing to the importance of complementarities between land and machine investments.

Key Words: Food price crisis, Farm investment, Supply response, Indonesia
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1. Introduction

World food prices have suddenly and dramatically risen in late 2007. The global food price spikes were partially transmitted to the domestic market of Indonesia, where the share of agricultural sector is about 19% in GDP and 41% in total employment. The rising food prices, especially soybean, corn, and cooking oil, created a fear that such a spike can worsen household well-being in the short run, by suppressing their food consumptions, especially among the poor. Welfare impacts of food price inflation can potentially be large in Indonesia particularly for poor households who spend about two-thirds of their income on food (Dawe, 2009). On the other hand, higher food prices increased agricultural profits and created large income gains among agricultural households compared to non-agricultural households (Ravallion, 1990; Yamauchi and Dewina, 2012). The positive impacts on producers could have outweighed negative effects on consumer welfare in Indonesia as shown by World Bank (2011), especially for agricultural households in rural area who consume from self-production and/or sell production surplus to the local market.

In the literature, a large number of papers have investigated the short-term impact of food price shocks on poverty and welfare (e.g. Ivanic and Martin (2008); Ravallion (1990) for Bangladesh; Ferreira, Fruttero, Leite, and Lucchetti (2013) for Brazil; Vu and Glewwe (2011) for Vietnam; Friedman, Hong, and Hou (2011) for Pakistan) and distortions created by governments' trade restrictions that cope with volatile food prices (Do, Levchenko, and Ravallion, 2014; Martin and Anderson, 2012). In particular, Ferreira et al. (2013) estimated the overall welfare effect of the 2007/08 food price increase on consumer surplus in Brazil including its positive terms-of-trade shock for net producers, showing significant welfare loss

for the urban poor and market income gain for the rural poor. However, the effects of the recent 2007/08 food price crisis on agricultural production are still understudied in the literature.

If food price spikes create positive net gains to farmers, it is important to understand how farmers use the net gains and change their agricultural production activities. As output prices of food commodities increase, farmers in rural area may have an incentive to reallocate their resources from non-farming activities to farm investments. In this paper, we aim to answer the questions of (i) whether and, if the answer is positive, how farmers changed farm investments in response to food price spikes and (ii) what type of farmers were more responsive – do crops they produce (staple vs. cash crops), their landholding size and wealth matter?

We use two rounds of a household panel survey conducted in 2007 and 2010, covering rural agricultural households living in major agro-climatic zones in Indonesia. Since the first round was prior to the 2007/08 food price crisis and the second round was conducted in 2010 (before the 2010 food price crisis), we can examine the effect of the 2007/08 food price spikes on farm investment decisions. Details on the data will be described in Section 3.

In the empirical analysis, we found that the price elasticity of farm investments is higher for food crop producers than cash crop farmers at both extensive and intensive margins, especially if landholding size and production surplus for market sales are large. It is also important to note that mechanization is relatively easy in some crops but difficult in others. The terms-of-trade shock seemed to induce farmers to increase their investments when a large

portion of their produces is for market sales. Types of investments also matter. Farmers who operate on large farmland are more likely to respond to food crop price spikes by increasing investments in machines, while they appeared to reduce labor demands as a result of substitutions by machine investments. The above result highlights the importance of complementarities between land and machine investments and potential scale economies that may exhibit through machine investments.

This paper is organized as follows. The next section sets up a model to clarify our intuitions and empirical predictions. Section 3 describes survey design and data. Sections 4-7 carry out empirical analyses. Finally, Section 8 presents conclusions.

2. A Model

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 decides the investment for the next period and the proportion to sell their crops at the market. For simplicity, we assume out capital depreciation. The producer can borrow or save with an interest rate competitively determined in the credit market. Here the producer can consume directly from their own production or buy foods at the market.

Let A denote landholding, and $f(k)$ represent land productivity where 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: $c_1^1 = p_1\phi_1 Af(k_1) - \Delta kA + b$ and $c_2^1 = p_2\phi_2 Af(k_2) - (1+r)b$ where the subscript denotes time (*t=1,2*). Borrowing b is

allowed with gross interest rate $1 + r$. If the producer saves ($b < 0$), there are positive returns in the next period $(1 + r)b$. The producer can also directly consume what they produced. Let c^2 denote direct consumption from production. That is, $c_1^2 = p_1(1 - \phi_1)Af(k_1)$ and $c_2^2 = p_2(1 - \phi_2)Af(k_2)$ where ϕ_t is the proportion of output supplied to market (*t=1,2*). Since home food consumption has an upper bound, ϕ_t depends on the sale of production. The type of crops produced also matter in ϕ_t. The producer decides $c_1, \phi, \Delta k$ and b at the end of period 1.

With the investment $I = A\Delta k$, the next period capital stock is determined as

$$K_2 = Ak_2 = A(k_1 + \Delta k) \tag{1}$$

The producer maximizes the discounted sum of current and future utilities over $c, \phi, \Delta k$ and b: $\max u\,(c_1^1, c_1^2) + \beta E v(c_2^1, c_2^2)$, subject to the budget constraints and Eq. (1). At this stage, we do not impose any constraints on b. Note that ϕ_2 is determined at period 2 (therefore, c_2^1, c_2^2).

The Euler equations are:

$$1 + r = f'(k_2)\left[E[p_2\phi_2^*|\Omega_1] + \frac{Cov(v_1, p_2\phi_2^*|\Omega_1)}{E[v_1|\Omega_1]}\right] \tag{2}$$

$$p_1 u_1 = u_2 \text{ and } p_2 v_1 = v_2 \tag{3}$$

where $\Omega_1$is the initial information set, u_s denotes $\frac{\partial u}{\partial c_s}$ (*s=1,2*) and similarly for v_s. Since $E[p_2\phi_2^* v_1|\ \Omega_1]\ = E[v_1|\Omega_1]E[p_2\phi_2^*|\Omega_1] + Cov(v_1, p_2\phi_2^*|\Omega_1)$, we can derive the following condition from the Euler equations:

$$(1+r) \leqq f'(k_2)E[p_2\phi_2^*|\Omega_1]$$

where the last inequality holds since

$$\frac{Cov(v'(c_2), p_2\phi_2^*|\Omega_1)}{E[v'(c_2)|\Omega_1]} \leqq 0.$$

The equality holds when there is no uncertainty in p_2 or the producer is risk neutral. The covariance term also reflects the fact that the capital investment increases the variance of the future production value.

The proportion of outputs supplied to market ϕ_t (*t=1,2*) reflects the possibility that they can directly consume their produces, which varies across commodity types. For example, farmers who produce staple crops and vegetables can consume those commodities, but those who produce estate (cash) crops such as coconut, coffee, etc. largely sell their produces and, in exchange, buy their food commodities as rice and vegetables. Assume that $\phi_t = 1$ among estate (cash) crop farmers (in other words, $u_2 = v_2 = 0$). The first order conditions (3) implies that ϕ_t can either increase or decrease when p_t increases (since p_1u_2 and p_2v_2 may increase or decrease when p_t increases).

Assume that the producer observes a price shock θ at the end of period 1 when the period-1 production was completed (say, a price spike experienced in the 2007/08 food price crisis), which affects the expectation of p_2 and therefore the investment decision. For simplicity, from now on, we assume out price uncertainty, $p_2 = p_1 + \theta$ where $\theta > 0$. That is,

$$1 + r = f'(k_2) p_2 \phi_2^* \qquad \text{(2)'}$$

For example, if $f(k_2) = k_2^\alpha$ where $\alpha < 1$, we have $k_2^* = \sqrt[1-\alpha]{\frac{\alpha p_2 \phi_2^*}{1+r}}$. That is, an increase in $p_2\phi_2^*$ also increases k_2^*.

The price effect on the investment $(\frac{\partial k_2^*}{\partial p_2})$ is conditional on change in ϕ_2^*. In general, the response of k_2^* depends on:

$$\frac{\partial p_2 \phi_2^*}{\partial p_2} = \phi_2^* + \frac{\partial \phi_2^*}{\partial p_2}$$

which can be greater than ϕ_2^* if $\frac{\partial \phi_2^*}{\partial p_2} > 0$ (that is, farmers sell more from their production as the price rises). In the case of cash crops, $\frac{\partial p_2 \phi_2^*}{\partial p_2} = \phi_2^* \approx 1$ as all outputs are sold to the market $(\phi_t = 1)$. In general, it is possible that $\frac{\partial p_2 \phi_2^*}{\partial p_2} > 1$, i.e., farmers who have relatively large surplus to sell before a positive price shock increase their market sales even more positively responding to the price shock.

The observed investment is positively related to landholding since $I = A\Delta k$. Moreover, if there is a liquidity constraint, it is even more likely that the investment is a positive function of land holding size. Assume that the $(1 + r)$ 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. The requirement of collateral is a good example. If so, since the left-hand side of Eq. (2) increases for small farmers, the marginal effect of $p_2\phi_2^*$ on the investment becomes smaller. Alternatively, we may impose the condition that $b \leq 0$ if A (or asset-holding in general) is small. Small farmers can only save but cannot borrow. The modified condition (2) is

$$(1 + r) + \frac{\lambda}{\beta v_1} = f'(k_2)p_2\phi_2^* \qquad (2)''$$

where λ is the Lagrange multiplier associated with the condition that $b \leq 0$. Other conditions being equal, the investment is predicted to be larger among large holders or wealthy producers.

3. Data

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) under the study on effects of Infrastructure on the Millennium Development Goals in Indonesia (IMDG).[1] The locations of surveyed villages are shown in Figure 1. In 2010, we revisited all the 98 sample villages to re-interview the 2007-survey sample households and their splits.

Among the total surveyed households (which include both agricultural and non-agricultural households), we use the 2007-survey original agricultural households who reported crop incomes from agricultural activities in 2007.

[see Figure 1]

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[2].

For our key food price variable, we use growth rate of terms-of-trade (TOT) index during 2007-09 for three commodity groups: staple, estate, and horticulture crops, available from *Badan Pusat Statistik* (BPS). The TOT index is the ratio of agricultural producer price index (farm-gate price) to the index of production costs paid by farmers, computed by the BPS for each province using the 2007 consumer price index.[3] The TOT index captures an increase in farm-gate prices of produced crops sold at the market relative to an increase in production costs of each crop. Estate crops include major crops such as coffee, cocoa, and coconuts, etc., and horticulture includes both vegetables and fruits.

Summary statistics in Table 1 show the magnitude of the TOT shock in each commodity as well as basic household characteristics at the initial round in 2007. During 2007-09, the average change in the TOT index was 2.9% for staple crop, smaller than estate and horticulture crops whose TOT indices increased by 4.7% and 5.4%, respectively. A rapid increase in farm-gate prices in Indonesia, largely driven by a surge in international food prices, outpaced an increase in production costs which resulted in an increase of the TOT index. The movement of real farm-gate price index has been highly correlated with real global food price index (taken from IMF's primary commodity price data) during 2006-10 (the correlation is about 0.86), although the impact of global food price spikes was mitigated during the peak time in 2007-09 by the government's food subsidies and trade restrictions (World Bank, 2011).

In general, the global food price shock was transmitted into domestic food prices but unevenly, depending on the way markets work, the degree to which domestic markets are integrated into international market and price policies the government implements. In the context of Indonesia with large spatial dispersions, remoteness from the capital of Jakarta and transportation infrastructure quality determine the level of market integrations (Valera, Aldaz-Carroll, and Iacovone, 2012). Our sample includes some remote provinces (see Figure 1) where agricultural markets are not fully integrated into the central market and both levels and changes in food prices deviate from those of the national average.

The characteristics of agricultural households in Table 1 and 2 show large differences in wealth, land endowments and agricultural activities. The average value of the logarithm of real durable assets owned by agricultural households was 16.8 with relatively large inequality

in the initial wealth endowments (ranging from 10.6 at the minimum and 22.8 at the maximum) in the sample.[4] The average size of total agricultural land is small, but the endowment shows large variations both across and within provinces. In Panel A of Table 2, we found that Indonesian farmers generally had larger farm land in outer Java provinces where staple and estate crops were mainly produced. In Java, the average farm size was less than 0.5 hectare in 2007. Panel B shows the share of production revenues by province (in proportions). In Indonesia, multiple crops are commonly harvested especially in Central and East Java in our sample over a year, similar to others Asian countries. Estate crops were mainly planted in Lampung, North Sulawesi, and South Sulawesi.

[see Table 1 and 2]

4. Empirical Analysis

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

4.1 Baseline Specification

As described in Section 3, the international food price crisis has impacts differentiated across provinces and types of farmers defined by their wealth and land endowments. Like Friedman and Levinsohn (2002) and Ferreira et al (2013), we exploit disaggregated province-level TOT shock measures to reflect variations in price shocks specific to each province to analyze the effect of food price crisis at the household level.[5]

In the sample, farm equipment and machinery were two major investment items.[6] Among 1,441 agricultural households, 61% of them made new investments. By excluding farmers who did not invest, OLS estimates could be biased due to the sample selection bias and therefore, we use the Tobit model for the whole sample to estimate the level of investments at the intensive margin. For a household *i* in province (or village) *j*, we estimate:

$$lnI_{ij}^{*} = \beta_1 \Delta TOT_{c,j} + \beta_2 Z_{ij} + \beta_3 \Delta TOT_{c,j} \times Z_{ij} + \beta_4 X_{ij,2007} + D_j + \varepsilon_{ij}$$

$$lnI_{ij} = \max(0, lnI_{ij}^{*}) \tag{4}$$

where *c* denotes commodity groups. In Eq. (4), I_{ij} is the aggregate value of farm investments made during 2007-10, in which depreciations of farm assets are not accounted for, the initial landholding size L_0 (defined in each crop type) and the initial durable asset endowment A_0 are included as part of covariates Z. Note that the effect of crop-type specific price changes on farm investments depends on the amount of lands allocated to the specific crops. Therefore, we interact the crop-specific province–level TOT changes and crop-specific landholding size. X_{2007} is a vector of household characteristics in 2007 (i.e., the average age, the household's average years of schooling, and household size, all defined with household members aged 20 to 55).

In regression tables, we also report the estimates from the linear probability model that examines investment decisions at the extensive margin, defined below:

$$\Pr(Y_{ij} = 1) = \beta_1 \Delta TOT_{c,j} + \beta_2 Z_{ij} + \beta_3 \Delta TOT_{c,j} \times Z_{ij} + \beta_4 X_{ij,2007} + D_j + \varepsilon_{ij} \tag{5}$$

where $Y_{ij} = 1[lnI_{ij} > 0]$.

Unobserved provincial factors, which potentially affect changes in food prices, could also affect households' production decisions. Each province has different natural endowments of land and resources, different agro-climatic characteristics (e.g. soil quality), and different degrees of market integration, all of which potentially affect actual realizations of food price changes. For example, Java and outer-Java provinces have very different natural endowments, agricultural technologies, and market integration. In short, price spikes can be province specific. To account for potential bias from unobserved provincial attributes, we include province dummies (D_j) in the above regression equations. In the appendix, we further consider possible bias due to omitted farmer characteristics which can affect farmers' choices and potentially affect the province-level TOT index at the same time. As the survey covers relatively small farmland holders who are mainly price takers, the effect of omitted farmer characteristics on the TOT index is likely to be marginal. However, we may potentially underestimate the true effect as omitted variables and ΔTOT are likely to be negatively correlated. Following methods developed by Altonji, Elder, and Taber (2005) and Oster (2015), we incorporate bias adjustments to evaluate the magnitude and direction of omitted variable bias which show that our main results remain robust after correcting potential omitted variable bias.

4.2 Baseline Results

In Table 3 and 4, we first present results with the linear term of the TOT shock and its interaction terms with the logarithm of assets and land size by each commodity (in Columns (1), (4), and (7)). In this specification, we do not include province dummies. Then, province

dummies are included in Columns (2), (5), and (8). To check non-linear effect, we also present results with the TOT shock interacted with dummies which identify farmers holding relatively large farmland (above 0.6 hectare for staple and estate crops, and above the average land size for horticulture crop) and wealthier farmers (whose asset value is above the median).[7] We use durable assets in 2007 as a measure of the initial wealth level, which exclude agricultural land but include residential land. The entire sample of 1,441 agricultural households is used to analyze price responses at both extensive (Table 3) and intensive margins (Table 4).

[see Table 3 and 4]

At the extensive margin in Table 3, the terms-of-trade shock of each commodity does not significantly induce farmers to start new investments if province dummies not included. However, when province dummies are included in Columns (2), (5), and (8), the interaction term of the TOT shock with the logged size of farmland becomes positive and significant for staple and horticulture crops. The result remains robust when asset and farm size dummies are used in Columns (3), (6), and (9). This means that an increase in the TOT index for staple and horticulture crops significantly increases the probability of new farm investments among farmers who hold relatively large farmland. The marginal effect becomes larger as landholding size increases. When the linear terms of assets and land size are replaced by wealth and farm size dummies, the result remains robust. For other variables, the linear term of farm size has a positive effect but the negative effect of the square term implies diminishing effects, as commonly observed in many developing countries.

The Tobit estimates in Table 4 demonstrate the average marginal effect of the TOT shock on farm investments at the intensive margin which are broadly consistent with the previous results at the extensive margin. The results in Columns (2) and (8) suggest relatively large price elasticity of investments only for relatively large farmers. An increase in the TOT index for staple and horticulture crops significantly increases farm investments by a large margin. This result remains robust when dummies of assets and farm size are used in Columns (3) and (9).

When province dummies are included, the interaction term between the TOT shock and the initial wealth remains insignificant at both extensive and intensive margins, which implies that a price increase did not significantly weaken liquidity constraints among relatively poor farmers. That is, even though price spikes created an extra income, relatively poor farmers did not increase farm investments. As liquidity constraint tends to bind relatively poor farmers, they cannot still invest enough in productive assets even under the circumstances where they can expect the subsequent realization of a higher price in the coming period. They convert the positive income shock into savings and consumptions.

5. Would Price Responsiveness Differ by Types of Investment?

Table 5 shows price elasticities by investment types. Panels A, B, and C demonstrate results for investments in machines, storage facility, and land purchase. Columns (1)-(4) are for the TOT shock in staple crop; Columns (5)-(8) for estate crop; Columns (9)-(12) for horticulture separately. Like Tables 3 and 4, the TOT shock is interacted with linear terms of assets and

farm size, and also interacted with dummies which identify relatively wealthy farmers and large holders. Machine investments include purchases of tractors, threshers, pump, and other machines which, in principle, function to substitute for farm labor. We show estimates at both extensive and intensive margins for three different food commodities. At the extensive margin, only 25.4% of farmers invested in new machines, and fewer farmers invested in farm buildings to expand their storage capacity (13%) and purchased new land (9.9%) (see Table 1).

[see Table 5]

For machine investments (Panel A), farmers whose scale of operations is relatively large, especially above the threshold land size of 0.6 hectare, tend to install new machines in response to a positive TOT shock in staple crop at both extensive and intensive margins. This result implies complementarities between mechanization and farm size, especially among relatively large farmers.

In Panel B, the interaction term of the TOT shock and assets is positively signed and significant, whereas the interaction term with farm size is weaker. Relatively wealthy farmers expand their storage capacities in response to an increase in the TOT index at both extensive and intensive margins, implying that only those farmers can afford to build a new storage facility to minimize quality deterioration of their farm products.

The result on land transactions (Panel C) shows that an increase in the TOT index did not significantly induce farmers to buy new farmland. The interaction terms of the TOT shock

with assets and land size are mostly insignificant and are negative in some cases. In general, farmers spent the windfall income on investments in machines and storage facility, and not on purchasing new farmland. This is perhaps because the windfall income was not sufficiently large for farmers to purchase new farmland because farmland is generally quite expensive.

6. Heterogeneity in Price Responsiveness by Amount of Marketed Surplus

The above results indicate that farmers tended to increase their investments in machines or storage facility during the food price crisis, and their responsiveness is larger and statistically significant among food crop farmers. The price responsiveness would, however, be stronger if farmers experience a large increase in crop income (hereinafter "*income effect*").[8] The 2007 survey provides information on production surplus, i.e., the proportion of outputs sold to local markets out of total production through marketing arrangements with local traders. The exposure to output price changes also depends on whether commodities are cash crops or not. Cash crop producers sell most of their productions to markets and receive cash incomes, while food crop farmers can directly consume from their own productions.

In Table 6, a change in food crop prices is interacted with the share of marketed surplus of each commodity to understand heterogeneities in the response of farm investments. Panel A is for total farm investments; Panel B is for machine investments. A change of the TOT index for staple crop, once interacted with the share of marketed surplus, is positively signed and significant for both total and machine investments. For households with the average share of marketed surplus in staple crops, i.e., households who sell 25.4% of total productions to market (Table 1), a unit change of the TOT shock in staple crops induced farmers to increase

total investments by 29% (=1.152×0.25) at the extensive margin. The average marginal effect of the TOT shock on the logarithm of total investments is 17.3 at the intensive margin for those who have the average share of marketed surplus. The effect will exponentially go up as the proportion of marketed surplus increases. A unit change of the TOT shock in horticulture is also likely to significantly increase machine investments at both margins. The results confirm that the magnitude of the price effect critically depends on the amount of farm production surplus sold to local markets both at extensive and intensive margins, which is consistent with our theoretical predictions.

[see Table 6]

7. Did Farmers Substitute for Labors by Machine Investments?

The results above suggest that a higher food price appeared to create an incentive to invest among food crop producers who have relatively large marketed surplus, which can enhance farm productivity in the long run. However, it is also possible that the change in input prices, e.g., real wages of hired labors, also altered the conditions of factor and product markets during the crisis period. In our context, Yamauchi (2016) found that the food price spike increased real agricultural wage of hired labors, which might induce farmers to substitute for labor by machines.

In Table 7, we use the linear probability model (all with province dummies) to examine whether farmer's labor demand for hired and family labors changed in response to the price changes in staple crop (Panel A), estate crop (Panel B), and horticulture (Panel C). The

outcome variable is one if farmers increased demand for hired labor (Column (1)-(2)), family labor (Column (3)-(4)), and total labor (Column (5)-(6)) between the two survey rounds, and zero otherwise. Farmers who did not demand any labors for both survey rounds are excluded from the sample. Columns (1), (3), and (5) show the estimates for the TOT shock interacted with linear terms of assets and farm size, while Columns (2), (4), and (6) provide the estimates of the TOT shocks interacted with wealth and farm size dummies.

For staple crop (Panel A), the interaction terms of the TOT shock variable with the logarithm of farm size and the farm size dummy are negatively signed and mostly significant, implying a reduction in the use of hired and family labors in staple crop. For non-staple crops (Panels B and C), the TOT shock similarly has negative effect on the use of labors for farmers who hold larger farmland although the marginal effect and the significance level vary by specifications. For food crop producers (staple crop and horticulture), the interaction terms of the TOT shock with the logarithm of assets and the wealthy farmer dummy are also negative and significant in Columns (3) and (4), implying that wealthier farmers tended to reduce family labors as farming became less labor-intensive. The introduction of machines and rising agricultural wages induced farmers to save hired labor inputs. Family labors are intensively used on small farms but will also be substituted by machines for relatively large holders because they could benefit from scale economy to reduce production costs. In sum, a higher food price could also induce the substitution from labors to investments in agricultural assets, although this is found mainly among those who owned relatively large farmland because mechanization was relatively easier for them.

[see Table 7]

8. Conclusions

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 that the effect of the terms-of-trade shock on investments differs by farmer type (in terms of wealth and farm size) and crop type (staple, estate, or horticulture crops). During the food price crisis, spikes in the terms-of-trade appeared to have a positive impact on farm investments for Indonesian farmers at both extensive and intensive margins in general, but the effect is significant only among food crop producers who operate on relatively large farmland. The price elasticity of investments is found to be particularly large for those who have relatively large production surplus to sell at markets. The empirical results also show that an increase in food prices induced the substitution of labor by machines among relatively large farmers in Indonesia, especially among food crop producers.

There are some interesting implications that deserve our attention. The issue of whether the investment indeed had a dynamic positive impact on agricultural productivity needs a careful assessment. Moreover, whether the food price crisis led to a divergence in production frontier between rich and poor farmers and/or between large and small farmers in the long run is an important question to investigate. Our results indicate that, although large landholders tend to invest in productive assets regardless of terms-of-trade shocks, smaller farmers with greater marketed surplus could also find the price spike as an opportunity to increase their investments, as their liquidity constraints are relaxed.

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Endnotes

[1] 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 by adding 51 new villages in the same seven provinces. These new villages were randomly sampled from the list of 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. In the revisited 48 PATANAS villages, we re-sampled 20 households per village from the original 1994/95 PATANAS 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.

[2] 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. This paper aggregates the original and their split households in 2010. However, even

when we use only households which did not split (excluding 204 split households), our empirical results remain the same.

[3] Each province is represented by one city in the terms-of-trade data. Farm-gate price is computed based on the rural producer price survey, where farmers are the respondents. Farmers' consumer price is computed based on the rural consumer price survey, where retail traders in rural markets are the respondents. In calculating the TOT index, values of the producer price and the consumer price index are computed using the Laspeyres index method.

[4] The total value of durable assets is computed by summing the value of each non-production asset owned by households in 2007, which includes assets such as a residential house and land, and consumer electrical appliances such as TV, radio, satellite antenna, and telephone.

[5] Friedman and Levinsohn (2002) noted the wide dispersion of price changes across provinces and similarly used provincial price data from the BPS to identify the distribution impact of 1997 financial crisis on the welfare of Indonesian households. de Janvry and Sadoulet (2008) reviewed the methodological approaches used in the literature to analyze the impact of the food crisis on the poor, and proposed to apply disaggregated food price data to measure its welfare impact as the transmission of international food prices to domestic prices varies greatly by region. Recently, Ferreira et al (2013) also used local food price data in Brazil to analyze the welfare impact of the 2007/08 food price crisis.

[6] Farm machinery investments include the purchase of tractor, pump, and other machines (such as thresher, sprinkler, sprayer, dryer, milling, feed processor, and crumb rubber processor). Farm equipment includes the purchase of agricultural tools such as shovel, hoe, sickle, jackknife, machete, crowbar, plow, farrow, and equipment for fermentation.

[7] Following Yamauchi (2016), we use 0.6 hectare as the threshold size to check whether small and larger farmers responded differently to the TOT shock. Given that the average land size of horticulture crop is much smaller than 0.6 hectare, we use the average land size as a threshold value to define a dummy of large landholder for horticulture crop.

[8] As implied by agricultural household model (Singh, Squire, and Strauss, 1986), farmers still purchase foods while selling their produced crops to the market. Besides positive income effect from marketed surplus, negative consumption effect (i.e., negative impacts of the food price increase on consumption) may potentially interfere with the benefit of higher food prices to producers. As we only observe the value of weekly food consumption during the survey period, the survey data only provide a snapshot of farmers' status of self-sufficiency at the time when each round of survey was conducted either in

2007 or 2010. This prevents us from classifying farmers into “net seller” and “net buyer” for the entire period as usually defined in the literature. Nevertheless, our estimate of the price effect will not be significantly affected by the consumption effect because (i) our TOT index already accounts for an increase in consumer prices of each crop and (ii) the negative consumption effect would be limited for crop producers in rural villages of Indonesia because the positive income effect tends to dominate for rural farmers while the negative income effect is critical for the urban poor as similarly found by Ferreira et al. (2013) in the case of Brazil. We also conducted a robustness check by excluding farmers who consumed foods by purchasing from the market, which confirmed that our main results remain qualitatively the same. Therefore, we focus on analyzing heterogeneities in the price effect on investment decisions through the income effect.

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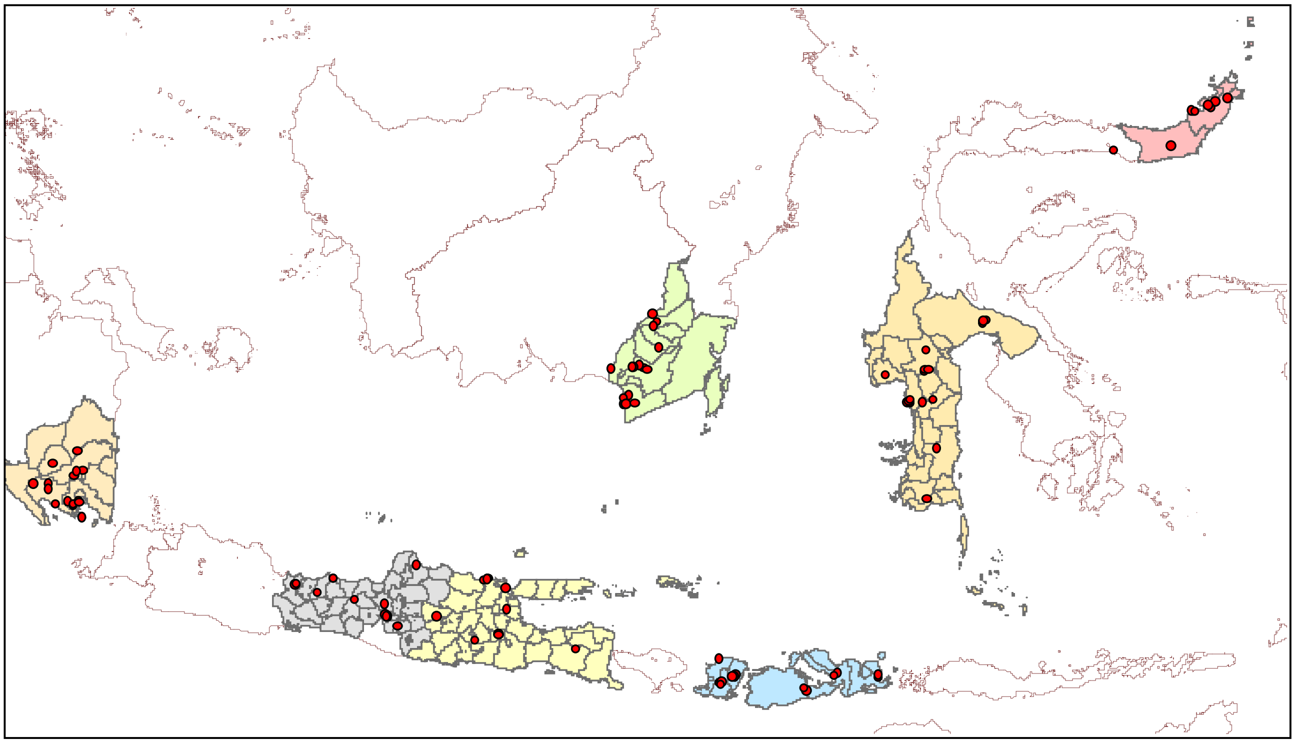

Figure 1. Locations of surveyed villages

Table 1. Summary statistics

	N	*Mean*	*Std. dev*	*Median*	*Min*	*Max*
At extensive margin						
Invest	1441	0.607	0.488	1	0	1
Machine invest	1441	0.254	0.435	0	0	1
Storage invest	1441	0.130	0.336	0	0	1
Land invest	1441	0.099	0.298	0	0	1
At intensive margin						
Ln(investment)	1441	7.715	6.374	11.156	0	19.659
Ln(machine investment)	1441	3.301	5.696	0	0	18.064
Ln(storage investment)	1441	1.779	4.635	0	0	19.427
Ln(land investment)	1441	1.661	5.038	0	0	20.292
Other variables						
ΔTOT shock (staple crop)	1441	0.029	0.107	-0.011	-0.094	0.232
ΔTOT shock (estate crop)	1441	0.047	0.081	0.041	-0.090	0.182
ΔTOT shock (horticulture)	1441	0.054	0.092	0.009	-0.049	0.241
Increase in hired labors	908	0.755	0.430	1	0	1
Increase in family labors	1205	0.347	0.476	0	0	1
Increase in total labors	1237	0.400	0.490	0	0	1
Ln(asset) 1/	1441	16.776	1.285	16.961	10.627	22.775
Ln(staple land size)	1441	0.421	0.473	0.288	0	3.199
Ln(estate land size)	1439	0.317	0.462	0.030	0	3.000
Ln(horticulture land size)	1441	0.080	0.251	0	0	2.429
Share of marketed surplus (staple crop)	1376	0.254	0.357	0	0	1
Share of marketed surplus (estate crop)	1376	0.338	0.457	0	0	1
Share of marketed surplus (horticulture)	1376	0.161	0.357	0	0	1
Average years of schooling	1441	7.481	2.982	7	0	16
Household size	1441	4.603	1.804	4	1	13
Average family age	1441	35.031	5.964	35	20	55

Source: Authors' calculations using the IMDG survey

1/ Durable asset holding is converted to real term, deflated by CPI index (2007=100) available from the BPS website.

Table 2. Initial landholding and production patterns by provinces

	A. Farm land size (hectare)						***B. Share of production revenues***		
Commodity type	*Staple crop*		*Estate crop*		*Horticulture*		*Staple*	*Estate*	*Horticulture*
Statistics	*Mean*	*Max*	*Mean*	*Max*	*Mean*	*Max*	*Proportions*		
Lampung	0.39	6.50	0.69	9.25	0.03	4.00	0.27	0.69	0.03
Central Java	0.24	8.51	0.12	4.46	0.23	4.43	0.30	0.32	0.38
East Java	0.22	3.00	0.08	2.50	0.28	10.35	0.40	0.13	0.47
West Nusa Tengarra	0.65	10.05	0.10	4.00	0.02	2.00	0.67	0.24	0.09
South Kalimantan	0.62	23.50	0.45	8.75	0.03	6.00	0.56	0.38	0.06
North Sulawesi	0.62	21.00	0.88	19.09	0.05	3.60	0.28	0.66	0.05
South Sulawesi	0.70	10.20	0.41	14.00	0.08	4.81	0.41	0.52	0.06
All provinces	0.51	23.50	0.40	19.09	0.09	10.35	0.40	0.47	0.13

Source: Authors' calculations using the IMDG survey

Table 3. Baseline regression: extensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Dependent variable : Invest				
					Linear Probability Model				
VARIABLES		***A. Staple crop***			***B. Estate crop***			***C. Horticulture***	
ΔTOT shock	-0.206			-3.124*			0.360		
	(1.113)			(1.539)			(2.127)		
x Ln(asset)	-0.004	0.004		0.208*	-0.118		-0.047	0.029	
	(0.073)	(0.097)		(0.107)	(0.145)		(0.135)	(0.116)	
x Ln(land size)	0.495	0.697**		-0.798*	0.035		0.619	0.848***	
	(0.311)	(0.235)		(0.369)	(0.545)		(0.476)	(0.216)	
x Dummy: wealthy farmers			-0.092			-0.142			-0.068
			(0.203)			(0.309)			(0.197)
x Dummy: large land holders			0.710***			-0.372			0.807*
			(0.183)			(0.653)			(0.341)
Ln(asset)	0.016	-0.002	-0.001	0.006	0.006	0.002	0.019	-0.002	0.001
	(0.022)	(0.016)	(0.015)	(0.018)	(0.016)	(0.016)	(0.025)	(0.019)	(0.017)
Ln(land size)	0.180**	0.219**	0.219**	0.193**	0.224**	0.241***	0.196**	0.224**	0.223**
	(0.072)	(0.069)	(0.070)	(0.058)	(0.061)	(0.057)	(0.064)	(0.065)	(0.065)
Ln(land size)^2	-0.070	-0.065	-0.066	-0.059	-0.072	-0.074**	-0.083**	-0.073*	-0.072*
	(0.040)	(0.034)	(0.035)	(0.038)	(0.041)	(0.028)	(0.033)	(0.030)	(0.030)
Average years of schooling	-0.009	-0.003	-0.003	-0.008	-0.003	-0.003	-0.012*	-0.003	-0.003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Household size	0.002	0.000	0.000	0.002	-0.001	-0.001	-0.001	0.000	0.000
	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.011)	(0.010)	(0.010)
Average family age	0.001	0.004	0.004	0.002	0.004	0.004	0.001	0.004	0.004
	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)
Constant	0.311	0.374	0.400	0.422	0.520	0.384	0.304	0.418	0.385
	(0.366)	(0.255)	(0.333)	(0.374)	(0.340)	(0.359)	(0.436)	(0.355)	(0.389)
Observations	1441	1441	1441	1439	1439	1439	1441	1441	1441
Provincial dummies included	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are heteroscedasticity robust and clustered at province level, and are reported in parentheses.

Table 4. Baseline regression: intensive margin

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
	Dependent variable : ln(investment)								
	Tobit regression (average marginal effect)								
VARIABLES	***A. Staple crop***			***B. Estate crop***			***C. Horticulture***		
ΔTOT shock	0.420			-50.902*			-3.989		
	(19.697)			(26.202)			(36.389)		
x Ln(asset)	-0.297	0.137		3.462*	-1.060		-0.069	1.259	
	(1.295)	(1.355)		(1.800)	(2.087)		(2.285)	(1.776)	
x Ln(land size)	9.532**	11.214***		-11.287*	2.034		9.299	11.245***	
	(4.299)	(3.625)		(6.199)	(8.923)		(6.685)	(2.838)	
x Dummy: wealthy farmers			-0.903			-0.789			0.106
			(2.730)			(4.348)			(2.915)
x Dummy: large land holders			10.367***			-3.632			11.883***
			(2.703)			(10.430)			(4.357)
Ln(asset)	0.373	0.032	0.047	0.190	0.115	0.078	0.387	-0.003	0.069
	(0.391)	(0.252)	(0.241)	(0.302)	(0.263)	(0.260)	(0.455)	(0.296)	(0.276)
Ln(land size)	2.658***	3.520***	3.533***	2.940***	3.618***	3.790***	2.906***	3.603***	3.597***
	(1.016)	(1.036)	(1.057)	(0.859)	(0.882)	(0.808)	(0.911)	(0.963)	(0.958)
Ln(land size)^2	-0.927	-0.924*	-0.952*	-0.835	-1.083*	-1.069**	-1.131**	-1.050**	-1.048**
	(0.657)	(0.547)	(0.558)	(0.601)	(0.646)	(0.446)	(0.549)	(0.474)	(0.476)
Average years of schooling	-0.148*	-0.041	-0.037	-0.126	-0.041	-0.036	-0.177**	-0.043	-0.043
	(0.082)	(0.070)	(0.072)	(0.081)	(0.071)	(0.072)	(0.083)	(0.072)	(0.075)
Household size	0.047	0.037	0.026	0.050	0.022	0.023	0.01	0.028	0.03
	(0.149)	(0.134)	(0.130)	(0.132)	(0.134)	(0.133)	(0.159)	(0.132)	(0.130)
Average family age	0.015	0.058	0.057	0.025	0.061*	0.062*	0.016	0.062*	0.06
	(0.039)	(0.036)	(0.037)	(0.038)	(0.036)	(0.037)	(0.039)	(0.037)	(0.037)
Observations	1441	1441	1441	1439	1439	1439	1441	1441	1441
Left-censored observations	567	566	566	567	566	566	567	566	566
Provincial dummies included	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$; Standard errors are heteroscedasticity robust and clustered at province level, and are reported in parentheses. Average marginal effects of each covariate are presented in this table.

Table 5. Heterogeneity by type of investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Linear Pr.	*Tobit*	*Linear Pr.*	*Tobit*	*Linear Pr.*	*Tobit*	*Linear Pr.*	*Tobit*	*Linear Pr.*	*Tobit*	*Linear Pr.*	*Tobit*
	Invest	*ln(investment)*	*Invest*	*ln(investment)*	*Invest*	*ln(investment)*	*Invest*	*ln(investment)*	*Invest*	*ln(investment)*	*Invest*	*ln(investment)*
						A. Machine investment						
VARIABLES	***I. Staple crop***				***II. Estate crop***				***III. Horticulture***			
									0.161	1.992		
ΔTOT shock x Ln(asset)	0.029	0.037			0.040	-0.281			(0.088)	(1.250)		
	(0.067)	(1.022)			(0.121)	(1.791)			0.916	7.945***		
x Ln(land size)	0.831***	7.133***			-0.129	-1.133			(0.495)	(2.461)		
	(0.137)	(1.173)			(0.539)	(5.470)						
x Dummy: wealthy farmers			-0.091	-2.080			0.046	-0.665			-0.028	-0.710
			(0.164)	(2.442)			(0.401)	(5.809)			(0.177)	(2.449)
x Dummy: large land holders			0.530***	4.762***			-0.237	-2.608			0.533	4.057
			(0.111)	(1.154)			(0.546)	(5.888)			(0.585)	(5.652)
Observations	1441	1441	1441	1441	1439	1439	1439	1439	1441	1441	1441	1441
Left-censored observations	…	1075	…	1075	…	1074	…	1074	…	1075	…	1075
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
						B. Storage						
ΔTOT shock x Ln(asset)	0.092	1.336*			0.216	1.968*			0.028	0.682		
	(0.071)	(0.738)			(0.145)	(1.054)			(0.096)	(1.511)		
x Ln(land size)	0.294*	3.497**			0.254	1.540			-0.477*	-4.649***		
	(0.148)	(1.402)			(0.597)	(4.735)			(0.216)	(1.641)		
x Dummy: wealthy farmers			0.315**	5.037***			0.453*	5.267**			0.137	2.681*
			(0.105)	(1.285)			(0.186)	(2.486)			(0.106)	(1.372)
x Dummy: large land holders			0.194	2.634			0.186	1.008			0.024	1.218
			(0.159)	(1.856)			(0.554)	(5.107)			(0.208)	(2.049)
Observations	1441	1441	1441	1441	1439	1439	1439	1439	1441	1441	1441	1441
Left-censored observations	…	1253	…	1253	…	1252	…	1252	…	1253	…	1253
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
						C. Land purchase						
ΔTOT shock x Ln(asset)	-0.084**	-1.727***			-0.078	-2.507***			-0.032	-0.975*		
	(0.028)	(0.499)			(0.047)	(0.812)			(0.039)	(0.559)		
x Ln(land size)	-0.001	-0.036			0.089	2.106			0.714	5.268*		
	(0.049)	(0.562)			(0.368)	(4.455)			(0.663)	(3.024)		
x Dummy: wealthy farmers			-0.027	-1.188			-0.138	-3.864			0.142	0.807
			(0.099)	(1.680)			(0.220)	(4.044)			(0.085)	(1.257)
x Dummy: large land holders			0.034	0.433			0.023	0.214			0.376	3.213
			(0.047)	(0.589)			(0.242)	(3.423)			(0.416)	(3.801)
Observations	1441	1441	1441	1441	1439	1439	1439	1439	1441	1441	1441	1441
Left-censored observations	…	1299	…	1299	…	1297	…	1297	…	1299	…	1299
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are heteroscedasticity robust and clustered at province level, and are reported in parentheses. The regression also includes the logarithm of assets and farmland size owned by households, the square term of farmland size, average years of schooling, household size, and average age of the age 20-55 household members. For Tobit regression at the intensive margin, average marginal effects of each covariate are presented in this table.

Table 6. Heterogeneous effect due to marketed surplus

	(1)	(2)	(3)	(4)	(5)	(6)
	Linear Pr.	*Tobit*	*Linear Pr.*	*Tobit*	*Linear Pr.*	*Tobit*
			A. Total investment			
VARIABLES	*Invest*	*In(investment)*	*Invest*	*In(investment)*	*Invest*	*In(investment)*
ΔTOT shock x Share of marketed surplus (staple crop)	1.152***	17.284***				
	(0.206)	(3.092)				
ΔTOT shock x Share of marketed surplus (estate crop)			-0.064	-0.257		
			(0.593)	(9.124)		
ΔTOT shock x Share of marketed surplus (horticulture)					0.424	6.722
					(0.601)	(8.223)
Observations	1376	1376	1376	1376	1376	1376
Left-censored observations	…	543	…	543	…	543
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes
			B. Machine investment			
ΔTOT shock x Share of marketed surplus (staple crop)	0.474**	4.904***				
	(0.151)	(1.830)				
ΔTOT shock x Share of marketed surplus (estate crop)			-0.376	-4.099*		
			(0.245)	(2.352)		
ΔTOT shock x Share of marketed surplus (horticulture)					1.024***	10.532***
					(0.205)	(3.508)
Observations	1376	1376	1376	1376	1376	1376
Left-censored observations	…	1022	…	1022	…	1022
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors are heteroscedasticity robust and clustered at province level, and are reported in parentheses. The regression also includes the logarithm of assets and farmland size owned by households, the square term of farmland size, average years of schooling, household size, and average age of the age 20-55 household members. For Tobit regression at the intensive margin, average marginal effects of each covariate are presented in this table.

Table 7. Responsiveness of farm's labor demand

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
			A. Staple crop			
VARIABLES	*Increase in hired labors*		*Increase in family labors*		*Increase in total labors*	
ΔTOT shock x Ln(asset)	0.000		-0.202*		-0.139	
	(0.153)		(0.084)		(0.092)	
x Ln(land size)	-0.397*		-0.584**		-0.248	
	(0.203)		(0.228)		(0.279)	
x Dummy: wealthy farmers		0.016		-0.547**		-0.400*
		(0.348)		(0.181)		(0.206)
x Dummy: large land holders		-0.449***		-0.675**		-0.584**
		(0.119)		(0.256)		(0.169)
Observations	896	896	1187	1187	1218	1218
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes
			B. Estate crop			
ΔTOT shock x Ln(asset)	-0.348		-0.076		0.042	
	(0.194)		(0.126)		(0.134)	
x Ln(land size)	-0.229		-0.990		-1.313*	
	(0.347)		(0.561)		(0.634)	
x Dummy: wealthy farmers		-0.584		-0.081		0.035
		(0.496)		(0.360)		(0.279)
x Dummy: large land holders		-0.190		-0.909**		-1.283**
		(0.284)		(0.337)		(0.402)
Observations	894	894	1186	1186	1216	1216
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes
			C. Horticulture			
ΔTOT shock x Ln(asset)	-0.173		-0.438***		-0.379**	
	(0.223)		(0.112)		(0.144)	
x Ln(land size)	-1.078**		-0.976***		-1.300**	
	(0.360)		(0.249)		(0.445)	
x Dummy: wealthy farmers		-0.220		-0.729***		-0.726**
		(0.259)		(0.193)		(0.226)
x Dummy: large land holders		-0.543		-0.558		-0.605
		(0.304)		(0.330)		(0.645)
Observations	896	896	1187	1187	1218	1218
Provincial dummies included	Yes	Yes	Yes	Yes	Yes	Yes

Notes: ** p<0.01, ** p<0.05, * p<0.1; Standard errors are heteroscedasticity robust and clustered at province level, and are reported in parentheses. The regression also includes the logarithm of assets and farmland size owned by households, the square term of farmland size, average years of schooling, household size, and average age of the age 20-55 household members.

[On-line material: Not for publication]

Appendix: Bias adjustment of the effect of terms-of-trade shock

This note estimates the degree of potential bias due to omitted farmers' unobservable characteristics by applying methods proposed by Altonji, Elder, and Taber (2005) and Oster (2015). This approach uses the bias arising from multiple observed controls to identify the bias that arises from unobservables, assuming the unobservables share same covariance properties as the observables (*proportional selection assumption*). Following Oster (2015), both coefficient stability and movements in R-squared values are considered to identify omitted variable bias.[1]

The bias-adjusted effect of terms-of-trade (TOT) shock is computed by bounding two parameters: (i) R-squared from a hypothetical regression of farm investments on full set of controls (both observables and unobservables), denoted as $\boldsymbol{R_{max}}$ and (ii) a coefficient of proportionality between observed and unobserved controls, denoted as $\boldsymbol{\delta}$. As proposed by Oster (2015), true effect (which adjusts for omitted variable bias) can be approximated by bounding the proportionality coefficient by one ($\delta = 1$) and R_{max} by 1.3*R*, where *R* is the R-squared from an actual regression model which only includes observed controls. We check the sensitivity of our results (Tables 3-7) to bias-adjustment assuming $\delta = 1$ and $R_{max} = 1.3R$.

1. Sensitivity of Baseline Results

Table A.1 summarizes the sensitivity of the effect of the TOT shock which is interacted with the logarithm of land size (both linear term and the dummy). Column (1) presents unadjusted effects β^0 based on equations (4) and (5) which correspond to the results in Table 3 (at the extensive margin) and Table 4 (at the intensive margin). Column (1) presents bias unadjusted effect β^0 using ordinary least squares. Column (2) presents bias-adjusted effects β^1 using the method described above.[2] Column (3) shows the ratio of bias adjustment (β^1/β^0). If $\beta^1/\beta^0 > 1$

[1] The bias adjustment is conducted using STATA code (**psacalc**).

[2] This validation test can be implemented only with linear model. Therefore, β^0 is OLS estimates at the intensive margin which are not identical to Tobit estimates in the Table 3 and 4.

(or $\beta^1/\beta^0 < 1$), our results in the main text are found to underestimate (or overestimate) the true effect. If β^1/β^0 is close to one, the size of bias is marginal. In the sensitivity check of the TOT shock on farm investments, we focus on the TOT shock on food crops (staple and horticulture) as they are found to have significant effect in Table 3 and 4.

At the extensive margin (Panel A of Table A.1), the ratio of bias adjustment is greater than one for the TOT shock of staple crops and is close to one for horticulture crops. At the intensive margin (Panel B), the ratio of bias adjustment is always greater than one. This result suggests that true effect of the TOT shock is likely to be even larger (or close to the unadjusted effect) when omitted variable bias is corrected.

Table A.1 Bias-adjustment for main results in Tables 3 and 4

	Staple crop			Horticulture		
	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio
Effect on total investment						
A. Extensive margin (Table 3)						
ΔTOT shock x Ln(land size)	0.697	0.838	1.20	0.848	0.734	0.87
--- x Dummy: large land holders	0.710	0.839	1.18	0.807	0.778	0.96
B. Intensive margin (Table 4)						
ΔTOT shock x Ln(land size)	10.830	13.123	1.21	10.174	12.534	1.23
--- x Dummy: large land holders	9.410	10.977	1.17	11.060	14.032	1.27

Note: Column (2) presents the effect of the TOT shock when omitted variable bias is adjusted assuming $\delta = 1$ and $R_{max} = 1.3R$, while column (1) presents unadjusted effects. Color code: Red ($\beta^1/\beta^0 \geq 1$), Orange ($\beta^1/\beta^0 < 1$).

2. *Sensitivity of Results by Investment Types*

In Table A.2, we implement same sensitivity check when dependent variable is replaced with investment in machines and storage facility, which corresponds to Panels A and B of Table 5 respectively. The parameter stability of the TOT shock interacted with land size is tested for machine investments in Panel A, while same exercise is implemented for the interaction term of the TOT shock with assets for storage investments in Panel B.[3] Results both at the extensive and the intensive margins are presented by investment types. The result similarly points that true

[3] Throughout this appendix, we present results only for key variables which stand significant in main tables. The estimates of other variables are also stable and the results are available upon request.

effect is likely to be larger due to downward bias (i.e., $\beta^1/\beta^0 \geq 1$) or is close to unadjusted estimates. This shows that the bias adjustment will not alter our main results.

Table A.2 Bias-adjustment for main results in Table 5

	Staple crop			Horticulture		
	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio
A. Effect on machine investment						
Extensive margin						
ΔTOT shock x Ln(land size)	0.831	0.706	0.85	0.916	0.908	0.99
--- x Dummy: large land holders	0.530	0.347	0.65	0.533	0.538	1.01
Intensive margin						
ΔTOT shock x Ln(land size)	10.953	10.479	0.96	11.178	13.437	1.20
--- x Dummy: large land holders	6.626	5.093	0.77	6.368	9.277	1.46
B. Effect on storage investment						
Extensive margin						
ΔTOT shock x Ln(asset)	0.092	0.130	1.41	0.028	0.045	1.61
--- x Dummy: wealthy farmers	0.315	0.466	1.48	0.137	0.218	1.59
Intensive margin						
ΔTOT shock x Ln(asset)	1.015	1.493	1.47	0.239	0.423	1.77
--- x Dummy: wealthy farmers	3.940	6.525	1.66	1.535	2.354	1.53

Note: Column (2) presents the effect of the TOT shock when omitted variable bias is adjusted assuming $\delta = 1$ and $R_{max} = 1.3R$, while column (1) presents unadjusted effects. Color code: Red ($\beta^1/\beta^0 \geq 1$), Orange ($\beta^1/\beta^0 < 1$).

3. Sensitivity of Heterogeneous Effect due to Marketed Surplus

Table A.3 tests the robustness of the results in Table 6 by checking the parameter stability of the TOT shock interacted with the share of marketed surplus for food crops. Panel A is for total farm investments; Panel B is for machine investments. This test similarly finds that the magnitude of potential omitted variable bias is marginal or true effect is likely to be even larger, which supports the robustness of our main results in the main text.

Table A.3 Bias adjustment for main results in Table 6

	Staple crop			Horticulture		
	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio
A. Effect on total investment						
Extensive margin						
ΔTOT shock x Share of marketed surplus	1.152	1.398	1.21	0.424	0.592	1.40
Intensive margin						
ΔTOT shock x Share of marketed surplus	15.753	18.589	1.18	6.486	7.389	1.14
B. Effect on machine investment						
Extensive margin						
ΔTOT shock x Share of marketed surplus	0.474	0.387	0.82	1.024	1.233	1.20
Intensive margin						
ΔTOT shock x Share of marketed surplus	6.222	5.464	0.88	13.676	15.683	1.15

Note: Column (2) presents the effect of the TOT shock when omitted variable bias is adjusted assuming $\delta = 1$ and $R_{max} = 1.3R$, while column (1) presents unadjusted effects. Color code: Red ($\beta^1/\beta^0 \geq 1$), Orange ($\beta^1/\beta^0 < 1$).

4. Sensitivity of Responsiveness of Farm's Labor Demand

Finally, Table A.4 tests the robustness of negative effects of the TOT shock on the probability of increasing three types of labor demand. We focus on staple crops although similar results can be obtained for non-staple crops (estate and horticulture crops). The result in Table A.4 also shows that the reduction in the use of labors could be even larger than the unadjusted results in Table 7 when omitted variable bias is corrected. This supports that those with large farmland and wealth tended to substitute labors with farm investments in response to higher food prices.

Table A.4 Bias adjustment for main results in Table 7

	A. Effect on increase in hired labors			B. Effect on increase in family labors			C. Effect on increase in total labors		
	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio	(1) Unadjusted	(2) Bias-adjusted	(3) Ratio
Interaction term with land size									
ΔTOT shock x Ln(land size)	-0.397	-0.624	1.572	-0.584	-0.927	1.587	-0.248	-0.544	2.194
--- x Dummy: large land holders	-0.449	-0.626	1.394	-0.675	-0.975	1.444	-0.584	-1.020	1.747
Interaction term with assets									
ΔTOT shock x Ln(asset)	-0.0005	-0.010	20.408	-0.202	-0.384	1.901	-0.139	-0.424	3.050
--- x Dummy: wealthy farmers	0.016	-0.106	>1 #	-0.546	-0.980	1.795	-0.400	-1.105	2.763

Note: Column (2) presents the effect of the TOT shock when omitted variable bias is adjusted assuming $\delta = 1$ and $R_{max} = 1.3R$, while column (1) presents unadjusted effects. Color code: Red ($\beta^1/\beta^0 \geq 1$), Orange ($\beta^1/\beta^0 < 1$). #: Bias-adjustment provides a larger negative estimate than the unadjusted effect (which is positively signed).

The results in Tables A.1-A.4 indicate that the effect of the TOT shock on farm investments and on labor demand as we found in the main text will be valid after correcting the bias due to omitted farmer characteristics. Although this bias correction is not perfect as it relies on proportional selection assumption and linearity of the model, the magnitude of omitted variable bias is found to be marginal. The true effect of the TOT shock on investments and labor demand are likely to be even larger as discussed in the main text.

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