Impact of credit constraints on profitability and productivity in U.S. agriculture

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Abstract

This study examines industry-level impacts of possible credit constraints on farm profitability and productivity. We theoretically show that binding credit-constraints negatively affects profits as they inhibit acquisition of the optimal scale and mix of inputs for profit maximization. However, the impact of credit constraints on productivity is ambiguous and depends on the farm's production region (IRS or DRS). Empirically, current debt-to-asset ratio has a positive effect on TFP and a negative effect on profit.

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There has been a structural shift in U.S. agricultural production over the years as more and more labor has been substituted by technology. This has been induced, in part, by rising labor cost and increased investment in R&D which has facilitated continuous technological improvement. Consequently, agricultural productivity has responded as expected – rising steadily over the past century, despite some evidence of slowdown in recent years (e.g. Ball, Schimmelpfenning and Wang 2013). However, fixed costs in technology adoption are generally large. The challenge for farmers is to be able to adopt these advanced technologies while also catering to other farm financial needs. As O'Donnell (2012) finds, technical change has been the main driver of U.S. agricultural productivity growth. This implies that the ability to adopt suitable technology is an integral part of farm performance. Thus, borrowing to finance technology adoption and other farm related expenses/investments is very common.

While external financing is very common, there are numerous reasons why farmers may not be able to obtain the external financing (credit) they may require, thereby rendering them credit constrained. For instance, external financing is more costly than, say, internal financing and potentially unaffordable for some of the small family farms which may require it. [1] Additionally, increase in credit demand may result in disequilibrium

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[1] Girante, Goodwin and Featherstone (2008) note that external financing is more costly than internal financing due to capital market imperfections precipitated by informational asymmetries between borrowers and lenders. This results in adverse selection, moral hazard or costly state verification. These unresolved problems of contemporary contract theory constitute the theoretical foundation for the existence of credit constraints. Additionally, obtaining external financing is confounded by the risky nature of agricultural production since return is highly dependent on factors that are independent of the farmer's actions or managerial capability, such as weather.

between credit demand and supply resulting in some farms being credit constrained.[2]

Kauffman and Akers (2015) note that crop prices plummeted to their lowest in five years in the fourth quarter of 2014 resulting in lower profit margins and a surge in borrowing to finance short-term operating expenses. Thus, external financing remains a major source of agricultural production financing, a scenario likely to perpetuate as the agricultural sector continues facing volatile cash flows, fluctuating commodity prices and yields, and high production costs. However, credit supply is conditional on the overall macroeconomic conditions with a negative economic shock likely to spillover and have an impact on agricultural credit supply. This further makes credit constraints in agricultural production a credible threat and warrants investigation, in order to come up with new and/or reinforce current policies to tackle this issue.

The question we seek to answer in this study is what impact being credit constrained has on farm profitability and productivity. We regard the inability to obtain credit as being credit constrained. This encompasses either obtaining partial credit or none altogether, while the credit is desired. We hypothesize that being credit constrained negatively affects total profit. This is because credit constrained farms may not be able to acquire the optimal scale and mix of inputs for profit maximization. Nevertheless, the impact of credit constraints on productivity is ambiguous, assuming that farmers exhibit profit-maximizing behavior. While farmers pursue the profit-maximizing quantity of

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[2] A potential response to credit supply and demand disequilibrium would be a rise in interest rates. However, this response is unlikely as Stiglitz and Weiss (1981) show that raising interest rate lowers the return on projects which succeed and as the interest rate rises, the average riskness of those who borrow increases, possibly lowering the bank's profits. Further, higher interest rates induce firms to undertake projects with lower probabilities of success but higher payoffs when successful Thus, raising interest rates changes the borrower's behavior and those who perceive their probability of success to be low are willing to borrow at high interest rates.

inputs, profit maximizing input mix is not necessarily productivity maximizing. It is productivity maximizing when perfectly competitive firms are in long-run equilibrium, a state unlikely to ever be fully achieved. The potential impact of credit constraints on productivity emanates from its potential to reduce technical change, increase technical inefficiency, and/or constrain adjustments for scale and input mix efficiency.

Our objective is to determine industry-level impacts of possible credit constraints on agricultural profitability and productivity. Findings from micro-level analysis, a common feature of prior related studies, do not necessarily carry over to the macro-level. The only study we are aware of that is closely related to ours is Calomiris, Hubbard, and Stock (1986). They use state-level panel data spanning twenty-four states from 1977 to 1984. They consider change in collateral value, debt service burdens, and the availability of commercial bank credit as measures of credit constraints to examine impacts of agricultural credit market imperfections on farm output. However, no study has examined the impact of credit constraints on farm profitability and overall productivity for U.S. agriculture. We use a richer dataset covering all 48 contiguous states for a longer period of time (1961-2003) and improved measures of farm performance in examining the aggregate impact of credit constraints on U.S. agricultural production.

Micro-level studies use survey data and typically include questions on the survey to elicit information on whether farm households are credit constrained or not. At the aggregate level, previous studies use debt-to-asset ratio which is also known as leverage or measure of solvency (Calomiris, Hubbard, and Stock 1986; Chavas and Aliber 1993; Bierlen and Featherstone1998; Lambert and Bayda 2005; Blancard, Boussemart and Kerstens 2006; Mishra, Moss, and Erickson 2008; Rahaman 2011) or debt-to-equity ratio (Bhaumik,

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Das and Kumbhakar 2012).[3] High/low debt-to-asset (or equity) ratio imply low/high creditworthiness. Creditworthiness is the major factor that determines whether credit is granted or denied. Cagetti and Nardi (2006) and Barry, Baker and Sanint (1981) highlight that lenders evaluate a borrower's (farmer's in our case) creditworthiness by considering the farmer's assets which act as collateral, credit history, experience such as age, education level, income, and repayment expectations. The lenders' objective is to minimize default risk. If the assurance provided by the farmer is insufficient to convince the lender that he/she will be able to repay the amount being sought, the farmer either gets partial credit or no credit which makes him/her credit constrained.

This study uses debt-to-asset ratio, total assets, off-farm income (for robustness checks) as measures of credit-constraints. These measures are indicators of a farm's creditworthiness, as they impact the farm's ability to get credit. Further, this study also includes farm size, extension and public research as measures of shocks to agricultural production through their influence on input usage.

An important question in regards to credit constraints is whether they are binding, and thus affect profitability and/or productivity. Lee and Chambers (1986) address this question and they conclude that credit constraints are binding in U.S. agriculture. Prior literature examining the impact of credit constraints mostly finds that they have an impact on farm efficiency (Chavas and Aliber 1993), lower value of agricultural production (Ciaian and Swinnen 2009; Briggerman, Towe and Morehart 2009), and reduce the amount of inputs used (Karlan, et al. 2012; Kumar, Turvey and Kropp 2013). On the contrary, removal of credit constraints has been shown to improve farm performance and farm acreage

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[3] Assets = equity + liability(debt). Debt-to-assets = debt/assets and debt-to-equity = debt/equity.

(Blancard, Boussemart and Kerstens 2006; Girante, Goodwin and Featherstone 2008; Dong, Lu and Featherstone 2010; Kumar, Turvey and Kropp 2013).

We examine both constrained and unconstrained profit and productivity maximization problems and show that the optimal outcomes of both depend on whether or not the constraint is binding. If the credit constraint is binding in both the profit and productivity maximization problems, it will decrease both profit and productivity. However, if the credit constraint is binding in the profit maximization problem and non-binding in the productivity maximization problem, it will decrease profit and may increase productivity. Finally, we use the aforementioned measures of credit constraints to empirically examine the impact of credit constraints on farm profit and productivity, based on a state-level panel dataset from 1961-2003. We find a negative impact of lagged debt-to-asset ratio on productivity, and a positive impact of current debt-to-asset ratio on productivity. We also find a positive impact of lagged debt-to-asset ratio on profit and a negative impact of current debt-to-asset ratio on profit. On the other hand, we find a negative impact of farm assets on productivity and profit.

The rest of the paper is organized as follows: In Section II we provide the theory and empirical model. In Section III we discuss the data and estimation approach followed by empirical results in Section IV. Section V concludes.

Theory and Empirical Model

Theory

O'Donnell (2008) shows that TFP for state i in period t can be expressed mathematically as:

$TFP_{it} = Y_{it}/X_{it}$, where $Y_{it} \equiv Y(\boldsymbol{y}_{it})$ is aggregate output, $\boldsymbol{y}_{it} \in i_+^M$ is a vector of output quantities, $X_{it} \equiv X(\boldsymbol{x}_{it})$ is aggregate input, and $\boldsymbol{x}_{it} \in i_+^N$ is a vector of input quantities.

Output quantities are measures of quantities sold plus on-farm consumption and net changes in inventories, and input quantities are measures of purchased inputs and those inputs provided on the farm (O'Donnell 2012). The functions $Y(\cdot)$ and $X(\cdot)$ are aggregators required to be nonnegative, nondecreasing and linearly homogeneous.

Profit is calculated as $\pi_{it} = p_{it}Y_{it} - w_{it}X_{it}$, where p_{it} and w_{it} are output and input prices, respectively. O'Donnell (2012) shows that the point of maximum profit will coincide with the point of maximum TFP if and only if the level of maximum TFP equals the reciprocal of the slope of the isoprofit line. This, as he notes, is a characteristic of perfectly competitive markets where profits are zero. Conversely, inequality between maximum TFP point and maximum profit point is characteristic of competitive markets not being in long-run equilibrium and of non-competitive markets, in which cases profits are strictly non-zero. Thus, the economically feasible region of production in the short run for competitive firms is the region of locally-decreasing returns to scale. In this region, productivity falls and profits rise as rational efficient firms move from TFP maximizing point to profit maximizing point and the reverse, triggered by deteriorations in output prices and/or increases in input prices, is true.

Introducing credit constraint and how this might be affecting farm profitability and productivity, we model this as a simple individual farm problem. Consider an agricultural economy where $Y_{it} = f(X_{it})$. Assuming perfectly competitive input and output markets and letting the farm be credit-unconstrained, the farm chooses optimal X_{it} that solves:

$$\max \pi_{it} = p_{it}f(X_{it}) - w_{it}X_{it},$$

$$X_{it}^* \text{ solves } \frac{\partial \pi_{it}}{\partial X_{it}} = 0 \Rightarrow p_{it}f'(X_{it}) - w_{it} = 0 \Rightarrow p_{it}f'(X_{it}) = w_{it}.$$

This implies that under unconstrained profit maximization, optimal X_{it}^* is when marginal value product of inputs is equal to the marginal cost of inputs. Unconstrained productivity maximization problem will be:

$$\max \frac{f(X_{it})}{X_{it}},$$

$$\tilde{X}_{it}^* \text{ solves } \frac{\partial f(X_{it})/X_{it}}{\partial X_{it}} = 0 \Rightarrow \frac{f'(X_{it})}{X_{it}} - \frac{f(X_{it})}{X_{it}^2} = 0 \Rightarrow f'(X_{it}) = \frac{f(X_{it})}{X_{it}}.$$

That is, marginal product (MP) is equal to average product (AP), and AP is a maximum. Following Ciaian and Swinnen (2009) and allowing for constant returns to scale (CRS) and decreasing returns to scale (DRS), we model the credit constraint problem as follows. Letting the amount of credit a farm can borrow (B) depend on C_{it} which is a measure of creditworthiness, the farm profit maximization becomes:

$$\max \pi_{it} = p_{it} f(X_{it}) - w_{it} X_{it},$$

$$s.t. w_{it} X_{it} \le B(C_{it}).$$

Forming the Lagrange we have:

$$\mathcal{L} = p_{it} f(X_{it}) - w_{it} X_{it} - \lambda_{it} (w_{it} X_{it} - B(C_{it})).$$

where λ_{it} is the shadow price of credit constraints. The Kuhn-Tucker conditions are:

$$\frac{\partial \mathcal{L}}{\partial X_{it}} = p_{it} f'(X_{it}) - w_{it}(1 + \lambda_{it}) = 0, \qquad X_{it} \ge 0,$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_{it}} = \lambda_{it}[w_{it} X_{it} - B(C_{it})] = 0, \qquad\qquad \lambda_{it} \ge 0.$$

If the credit constraint is non-binding ($\lambda_{it} = 0$), optimal input under credit constraints $\bar{X}_{it}^* = X_{it}^*$. That is, we revert back to the optimal input level obtained from the unconstrained problem. If however, the constraint is binding ($\lambda_{it} > 0$), $p_{it} f'(X_{it}) = w_{it}(1 + \lambda_{it})$ which shows that the marginal value product of inputs is higher than the

marginal cost of inputs. By increasing input use, the farm could increase profits, but it cannot use more inputs due to credit constraints. Assuming that the production function exhibits positive and diminishing marginal product and technical complementarity, i.e., $f_i > 0$, $f_{ii} < 0$ and $f_{ij} > 0$, being credit constrained also affects the use of other inputs.

Considering the productivity maximization problem under credit constraints we have:

$$\max \frac{f(X_{it})}{X_{it}},$$

$$s.t. w_{it}X_{it} \leq B(C_{it}).$$

Forming the Lagrange and the Kuhn-Tucker conditions we have:

$$\mathcal{L} = f(X_{it})/X_{it} - \bar{\lambda}_{it}(w_{it}X_{it} - B(C_{it})).$$

$$\frac{\partial \mathcal{L}}{\partial X_{it}} = \frac{f'(X_{it})}{X_{it}} - \frac{f(X_{it})}{X_{it}^2} - \bar{\lambda}_{it}w_{it} = 0, \quad X_{it} \geq 0,$$

$$\frac{\partial \mathcal{L}}{\partial \bar{\lambda}_{it}} = \bar{\lambda}_{it}[w_{it}X_{it} - B(C_{it})] = 0, \qquad \bar{\lambda}_{it} \geq 0.$$

Similarly, when the credit constraint is non-binding ($\bar{\lambda}_{it} = 0$), we revert back to the optimal input level obtained from the unconstrained problem where MP is equal to AP and TFP is maximized. However, when credit constraints are binding, ($\bar{\lambda}_{it} > 0$), MP>AP>0. In this case, credit constraints lead to suboptimal input level which does not maximize AP.

Although in the long-run competitive equilibrium, profit-maximizing level of inputs and productivity-maximizing level of input will coincide, in other cases there will be a difference between optimal input amounts that maximize profit and those that maximize TFP (average product). Since we assume the farm's objective is profit maximization, it is clear from the above analysis that binding credit constraints will lower farm profits, since

they will push the farm below the profit-maximizing level in the DRS region. However, the effect of credit constraints on productivity is ambiguous. If credit constraints are binding such that they move production into the increasing returns to scale (IRS) region, relaxing credit constraints will increase both farm profits and productivity. If credit constraints are binding in the profit maximization problem but not in the productivity maximization problem (so that the firm is operating in the DRS region), relaxing the credit constraints will increase only farm profits but may decrease farm productivity.

Empirical Model

We use a two-step approach similar to Zhengfei and Lansink (2006). In the first step farm performance measures are calculated – profit and productivity indices. In the second step we regress the farm performance measures from step 1 on various predictor variables which include measures of credit constraints and other variables which have been found to affect farm performance such as public research investments.

The model we estimate in step 2 is:

$$FP_{it} = \beta_0 + \beta_1 FP_{it-1} + \beta_2 DebtR_{it} + \beta_3 DebtR_{it-1} + \beta_4 Assets_{it}$$

$$+ \beta_5 Assets_{it-1} + \beta_6 Farmsize_{it} + \beta_7 Ext_{it} + \beta_8 Res_{it} + +\beta_9 Spill_{it} + \delta_r + \varepsilon_{it}.$$

where FP is TFP or profit; β_ι, $\iota=1,\ldots,9$ are parameters to be estimated; δ_r denote regional fixed effects; ε_{it} is a random disturbance term with expected mean of zero; $DebtR$ denotes debt-to-asset ratio; $Assets$ denotes farm assets; Ext denotes stock of public extension investments; Res denotes stock of public agriculture research investments and $Spill$ denotes stock of public agricultural research spill-in.

　　Zhengfei and Lansink (2006) argue that there is an intertemporal serial correlation in the farm performance measures. Current year productivity is influenced by previous

year's productivity, either positively or negatively, while a high earning capacity in the previous year tends to push up the current year's earnings. We capture this dynamic performance by estimating a dynamic panel data model above which includes 1 lag of the dependent variable. Additionally, credit constraints potentially have an impact not only on current year farm performance but in subsequent years. We include just one lag for each of our credit constraint measures as explanatory variables in our dynamic model.

Similar to prior literature, and as noted previously, our first measure of credit constraints is debt-to-asset ratio. Debt-to-asset ratio is a financial indicator used by lenders in evaluating the borrower's creditworthiness. A higher debt-to-asset ratio implies that farmers are more exposed to failure risk. As such, lenders would be either unwilling to give them credit or ration the amount of credit they give them, both of which imply that they are credit constrained. Though having a lower debt-to-asset ratio is necessary, it is not sufficient.

The major challenge faced by lenders in providing credit to farmers is asymmetric information. The farmer possesses superior information in terms of the project(s) he/she plans to undertake. This information imbalance potentially results in adverse selection (lack of complete prior information on the lender's side). Also since the lender does not typically monitor the farmer's use of the loan, there is no guarantee that the loan is used according to the loan contract agreement. This results in a moral hazard problem (inability of the lender to control the farmer's behavior after the deal). In order to hedge against the above problems and minimize loss risk due to delinquency, lenders require collateral. In the event the farmer fails to meet the loan repayment obligations, the lender will be able to recuperate the loaned amount plus interest through foreclosure.

Collateral mitigates both agency and information problems. Calomiris, Hubbard, and Stock (1986) note that farmland (as an asset measure) makes up the majority of the farmers' collateral and this remains the case as shown in the farm balance sheet data. The assets measure used in this study is comprised largely of real estate with farmland making up most of the real estate. Barry, Baker and Sanint (1981) note that credit is positively correlated with net value of assets and Bierlen and Featherstone (1998) highlight that farms with high asset levels are expected to have better access to credit than farms with lower asset levels. This is echoed by Weber and Key (2014) who note that capital gains from land appreciation may have increased access to credit by making more collateral available for loans. This implies that farms with low asset levels are likely to be more credit constrained than farms with higher asset levels.

In evaluating creditworthiness of the farmer, lenders also consider the repayment potential of the farmer. Farm income is highly volatile due to fluctuating output prices induced, in part, by natural production shocks. As a cushion against this volatile farm income, there has been an increase in off-farm work with off-farm income contributing a higher percentage of household farms' income since the early 1980s (Barry and Robinson 2001). Thus, off-farm income could be considered as a reserve that could be used to cover debt payments in the event of any negative externality to production or if output prices plummet to unprofitable levels. In fact, Briggerman (2011) notes that most farmers rely on off-farm income to pay, at least partially, their debt. Without off-farm income, many farmers would not be able to service all their debt. Having another external source of income which is nonvolatile could serve as a lubricant to ease credit constraints. We use

off-farm income as a robustness check measure including only years 1961-1984, the period we have the off-farm income data available.

Farm size, extension, public research, and public research spill-in are found in prior literature as having a positive relationship with productivity (e.g. Huffman and Evenson 2006a; Sheng, et al. (2014). We use regional fixed effects for the 10 farm production regions (Appalachia States; Corn Belt; Delta States; Lake States; Northeast States; Northern Plains; Mountain States; Pacific States; Southeast States; and Southern Plains States) used by the Census of Agriculture. These regions have generally similar agricultural patterns and similar weather conditions. Including region and year dummies enables us to eliminate region and year specific effects (Greene 2008, p.191).

Data and Estimation

Data

This study uses a balanced panel dataset for 48 contiguous states over the period 1961-2003 with 2016 observations. TFP indices are calculated by O'Donnell (2012) using an annual state-level panel dataset of prices and quantities for three outputs (crops, livestock and other outputs) and four inputs (land, labor, capital and materials) taken from the USDA/ERS website. Profit is measured as the returns to operators and divided by quality-adjusted land quantity indices all taken from the USDA/ERS website. Nominal farm assets values, also available at the USDA/ERS website, are deflated to 2003 dollars using the BEA chain-type GDP deflator, accessed from the St. Louis Fed's Alfred service, also used by the USDA/ERS.

Average farm size for each state is measured as the real gross value of farm assets per farm. Yee and Ahearn (2005) argue that this measure is preferred to acreage since it

accounts for the productive capacity of land. Public agricultural extension and public agricultural research stock data are from Liu et al. (2009) for 1961-1976 and updates from 1977-2003 from Huffman (2014). The stock of public agricultural extension is calculated as a stock of full-time-equivalent professional extension staff based on a 5-year exponentially declining weight. The stock of public agricultural research is calculated using state-level expenditure data for agricultural research on agricultural productivity. The stock variable is the sum of expenditures based on a 35-year trapezoidal knowledge decay function (Wang et al. 2013). Public research spill-in is calculated using spatial weights derived by Huffman (2009). The spatial weights were calculated as a share of the value of agricultural production for each state in the geo-climatic region relative to the value of all agricultural production for all states in the region. Public research spill-in for state *i* was then calculated as the sum of the weighted public agricultural research stock for all other states, except state *i,* in the same geo-climatic region.

Results

Results from the profit and TFP models are presented in Table 2. For the regional fixed effects, we leave the Corn Belt region out of the estimation, as a baseline for comparison with the other regions. From the profit model, current debt-to-asset ratio has a negative and statistically significant impact on profit as hypothesized. A unit increase in debt-to-asset ratio decreases profit by $32,806.50.This makes sense, intuitively. As the farmer takes out a loan to finance farm expenses, his/her debt-to-asset ratio increases. The higher the debt-to-asset ratio, the more credit constrained the farmer is and the less profit the farmer can make due to inability to use optimal scale and mix of inputs for profit maximization. However, lag debt-to-asset ratio is positive and statistically significant. A plausible

explanation could be that the loan obtained by the farmer in the previous year goes towards future expenses, and while it decreases current year profits, it increases profit in the following year.

On the contrary, debt-to-asset ratio has an opposite impact on TFP. Lag of debt-to-asset ratio has a negative impact on TFP, but current debt-to-asset ratio has a positive impact on TFP. This implies that increase in debt-to-asset ratio might be pushing farmers to be more productive, by for instance becoming more efficient, in order for them to be able to pay back the debt that they may have. As Blancard et al. (2006) argue, indebted farmers are motivated to improve their efficiency to ensure their repayment capabilities.

The other measure of credit constraints, farm assets, is insignificant in the profit model. Current assets have a smaller negative impact while the lag has a small and positive impact on TFP. Farm size, public research investment and public research spill-in are all insignificant in the profit model but have positive and statistically significant impact on TFP.

Due to limited data availability on off-farm income (another measure of credit constraints) we perform robustness check using off-farm income and lag of off-farm income as independent variable by truncating the dataset to include only years 1961 – 1984 (for which we have off-farm income data). Results of the robustness check are reported in Table 3. Off-farm income does not have a significant effect on TFP, but has a positive significant impact on profit. Off-farm income has an impact on profit similar to the farm assets impact on profit. Excluding off-farm income from the estimation yields similar results.

Conclusions

This study examines industry-level impact of credit constraints on U.S. agricultural profitability and productivity. We use debt-to-asset ratio (a measure of creditworthiness) and total farm assets (measure of collateral) as measures of credit constraints. We show, theoretically, that binding credit constraints have a negative impact on farm profits. However, impact of binding credit constraints is ambiguous and depends on the farm's production region (IRS or DRS). Empirically, our measures of credit constraints have an opposite effect on profit and TFP. Lag debt-to-asset ratio has a negative impact on profit and a positive impact TFP. On the other hand, current debt-to-asset ratio has a positive effect on TFP and a negative effect on profit. The net effect of debt-to-asset ratio is positive in both cases. We find a negative impact on farm assets on both profit and TFP.

For robustness check, we use off-farm income as another measure of credit constraints. Due to limited data on off-farm income, we re-estimate the models for the period we have off-farm income data available (1961-1984) with and without off-farm income. Off-farm income has a similar effect as farm assets and results are robust to inclusion of off-farm income.

These findings have important policy implications for both profit and TFP. While the first is desirable from the farmers' standpoint, the latter is desirable from the society standpoint. One implication is that increasing credit availability to farmers is instrumental in increasing farm profits while it is less effective in increasing total factor productivity.

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Table 1. Summary Statistics

Variable	Unit	Mean	Standard Deviation	Minimum Value	Maximum Value
Total Factor Productivity	index	0.982	0.301	0.401	2.155
Profit	$1,000	762,054	662,000	-555,017	5,549,656
Debt to asset ratio	index	15.883	4.198	3.6	31.6
Farm assets	$1,000	25,939,228	560,696	276,555	160,000,000
Extension	$1,000	137.157	97.077	0.028	562.310
Public research investment	$M	15.349	13.775	1.040	101.167
Public research spillin	$M	63.947	34.027	5.960	171.737

Table 2. Base Model Estimates

	Profit Model	TFP Model
TFP (*t-1*)		0.903***
		(0.0197)
Profit (*t-1*)	0.792***	
	(0.0439)	
Debt-to-Asset Ratio	-32806.5***	0.00581***
	(7561.7)	(0.00118)
Farm Assets	0.00204	-1.73e-09***
	(0.00252)	(4.98e-10)
Debt-To-Asset Ratio (*t-1*)	37994.3***	-0.00495***
	(7791.7)	(0.00123)
Farm Assets (*t-1*)	-0.00290	1.30e-09**
	(0.00232)	(4.37e-10)
Farm size	-1.725	0.0000281***
	(25.10)	(0.00000694)
Extension	96.78	0.0000603
	(327.7)	(0.0000459)
Public Research Investment	0.00175	1.18e-09**
	(0.00140)	(4.05e-10)
Public Research Spillin	-0.0000307	4.79e-10***
	(0.000328)	(1.02e-10)
Region 1	1348.2	-0.00520
	(62026.6)	(0.0107)
Region 2	79297.9	0.00385
	(51101.8)	(0.0105)
Region 3	-4516.1	-0.0352***
	(34504.7)	(0.0107)
Region 4	-23696.3	-0.0217**
	(30113.8)	(0.00718)
Region 5	86240.7*	0.0151
	(43791.3)	(0.00918)
Region 6	-72051.9	0.00523
	(42581.1)	(0.00968)
Region 7	-101967.1*	-0.0189
	(49539.2)	(0.0122)
Region 8	4130.6	0.00982
	(67171.6)	(0.0124)
Region 9	-91932.2*	-0.00520
	(45596.7)	(0.00751)
Intercept	67131.2	0.0373*
	(58963.1)	(0.0159)
Number of observations	2016	2016

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3. Robustness Check Results

	Off-farm Income Included		Off-farm Income Excluded	
	Profit Model	TFP Model	Profit Model	TFP Model
Off-farm income	0.0829*	-4.45e-09		
	(0.0372)	(5.61e-09)		
Off-farm income (*t-1*)	-0.0753*	9.01e-09		
	(0.0361)	(5.57e-09)		
TFP (*t-1*)		0.865***		0.865***
		(0.0293)		(0.0296)
Profit (*t-1*)	0.687***		0.686***	
	(0.0420)		(0.0419)	
Debt-to-Asset Ratio	-31565.9**	0.0114***	-31775.4**	0.0111***
	(10875.8)	(0.00209)	(10984.3)	(0.00206)
Farm Assets	0.00854***	-1.09e-09	0.00931***	-1.06e-09
	(0.00251)	(6.35e-10)	(0.00259)	(6.18e-10)
Debt-To-Asset Ratio (*t-1*)	38218.6**	-0.00942***	38482.8**	-0.00910***
	(12449.5)	(0.00186)	(12624.0)	(0.00184)
Farm Assets (*t-1*)	-0.00920***	8.10e-10	-0.00984***	8.64e-10
	(0.00257)	(6.24e-10)	(0.00263)	(6.13e-10)
Farm size	-57.59	0.0000304*	-62.26	0.0000289*
	(50.65)	(0.0000122)	(50.97)	(0.0000123)
Extension	1.330	0.0000503	35.52	0.0000789
	(592.1)	(0.0000588)	(507.9)	(0.0000493)
Public Research Investment	0.00211	9.49e-10	0.00211	9.37e-10
	(0.00308)	(6.59e-10)	(0.00313)	(6.84e-10)
Public Research Spill-in	0.000384	1.30e-10	0.000227	1.08e-10
	(0.00114)	(1.63e-10)	(0.00114)	(1.60e-10)
Region 1	-35065.6	-0.00823	-38973.2	-0.00918
	(72630.6)	(0.0111)	(75055.1)	(0.0111)
Region 2	28903.1	0.0127	25430.1	0.0102
	(70683.5)	(0.0123)	(65607.8)	(0.0119)
Region 3	23130.6	-0.0179	23423.6	-0.0185
	(53980.8)	(0.0111)	(54012.0)	(0.0111)
Region 4	8543.4	-0.0227**	8829.5	-0.0224**
	(40129.8)	(0.00795)	(40391.5)	(0.00782)
Region 5	94324.6	0.00526	83316.8	0.00207
	(71196.5)	(0.00992)	(69590.0)	(0.00978)
Region 6	-80189.7	-0.0115	-93405.1	-0.0155
	(85241.8)	(0.0130)	(84383.0)	(0.0125)
Region 7	-143842.0	-0.0337	-153176.7	-0.0360
	(93437.6)	(0.0197)	(93240.2)	(0.0194)
Region 8	5728.4	-0.00112	920.2	-0.00244
	(111050.3)	(0.0183)	(112363.3)	(0.0187)
Region 9	-170390.6*	-0.0304*	-162438.7*	-0.0263*
	(79467.8)	(0.0120)	(79732.6)	(0.0109)

Intercept	123501.5	0.0574**	144884.1*	0.0620***
	(73726.3)	(0.0176)	(69140.3)	(0.0171)
Number of observations	1104	1104	1104	1104

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$