Market Access and Plant Productivity in Indian Agriculture

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Abstract

Agricultural markets have been found to significantly affect aggregate productivity. Several studies covering a wide range of countries and agro climatic conditions have quantified direct (specialization) and indirect (intensification) effects of market access on farms' productivity, using data from one-shot surveys (cross-sectional data collected from farms randomly selected in villages purposively chosen at different distances from input/output markets). These studies show significant relationships of productivity increasing with better market access (VON OPPEN AND GABAGAMBI, 2003). However, the causality cannot be proven. Markets might have developed in response to better productivity.

A data set from India provides the opportunity for studying agricultural change over a long time and across a wide diversity of districts. Statistical information available from 1966 to 1994 (29 years) for a total of 235 districts provides a time-series-cross-section data set containing 6815 observations. These observations include information for every district on area and production of 22 crops (food crops, oil seeds, commercial crops, pulses) and their prices; also data on inputs used (fertilizer, high yielding varieties), resources (irrigated area, farm size, credit, literacy, population), and market access (road and market densities) are available.

These data allow testing several hypotheses on market access affecting productivity. In this paper, the data are tested with a model for South India estimating a set of equations separately using panel (longitudinal) analysis approach which permits sorting out time-series-related, cross-section disturbances and the combination of both. Total productivity is expressed as a function of market access, inputs and resources; and also inputs as a function of market, access, productivity and resources.

Results indicate that the lag with which productivity responds to market access is around three years.

1. Background and Objectives of the Study

Given the importance of agricultural sector in India in providing both food security and social stability to the population, extensive work has been carried out addressing manifold areas of the fundamental and applied agricultural research. Productivity in agriculture, in particular that of plant production, was and remains a subject of many studies. Those studies, delivering quite interesting results, based their conclusions, however, on analyses which used data from one-shot surveys. In our opinion, a regression based on cross-section has certain limitations. Though it can in principle take into account any scale of economy a particular district (state, region), it cannot account for any increased productivity that may occur over time as the infrastructure gets improved. The separation of the impact of technological change from the impact of scale of economies, would give policy makers useful insights in designing policy measures in agriculture.

The study, therefore, sets the following specific objectives:

(1) Trace back the direct effects of market access on agricultural productivity over time and cross-section units in South India.

(2) Sort out direct (specialization) and indirect (intensification) effects of the improvement of road and market infrastructure on agricultural productivity.

2. Data Set on Indian Agriculture

A data set was made available by ICRISAT and Indian government including information for every district on area and production of 22 crops (food crops, oil seeds, commercial crops, pulses) and their prices, on inputs used (fertilizer, high yielding varieties), resources (irrigated area, farm size, credit, literacy, population), and market access (road and market densities).
Statistical information covering a longe period from 1966 to 1994 (29 years) for a total of 235 districts provided a time-series-cross-section data set containing 6815 observations and more than 120 variables.
The data set provides an opportunity for a representative study of agricultural change over a long time and across a wide diversity of districts in India.
As a first step in analyzing this data the authors take the case of South India as an example of modeling with panel data set. The subset of data includes 51 districts from Karnataka, Tamil Nadu and Andhra Pradesh states over 29 years.

3. Econometric Modeling with Panel Data

A panel data set can be useful because it allows to sort out economic effects that cannot be distinguished with the use of either cross-section or time-series data alone (PINDYCK & RUBINFELD, 1998). Further, PINDYCK and RUBINFELD (1998) point to the increased number of data points when using panel data set, which in turn generates additional degrees of freedom. Another advantage of a panel data set is that incorporating information relating to both cross-section and time-series variables can substantially diminish the problems that arise when there is an omitted-variables problem (HSIAO, 1986) which is otherwise present in OLS procedure.
Different techniques can be used for analysing a panel data set.
The first technique for panel data use simply combines, or pools, all the time-series and cross-section data and then estimates the underlying model by utilising ordinary least squares.
A second procedure involves the recognition that omitted variables may lead to changes in the cross-section and time-series intercepts. Models with *fixed effects* add dummy variables to allow for these changing intercepts.
A third technique improves the efficiency of the first least-squares estimation process by accounting for cross-section and time-series disturbances. The *random-effects* model is a variation of the generalised least-squares estimation process.
Finally, we consider techniques which account for the fact that the error term may be correlated over time and over cross-section units. Once again a variation of generalised least-squares estimation provides a useful solution to the problem.

In general form, the equations specified for the model will be:

$$TP_t = f(IN_t, RE_t, MA_{t-3})$$
$$IN_t = f(RE_t, MA_{t-3}, TP)$$

Where

TP	=	the aggregate plant productivity in monetary terms per ha
IN	=	inputs (fertilizer, high yielding varieties)
RE	=	resources (irrigated area, farm size, credit, literacy)
MA	=	market access (road and market densities)
t	=	time in years

The detailed specification would be then:

$$TP_t = f(IR, HYV, FERT, CR, RF, RFSQ, RD_{t-3}, RDSQ_{t-3}, MD_{t-3}, MDSQ_{t-3})$$
$$HYV_t = f(FERT, CR, RD_{t-3}, RDSQ_{t-3}, MD_{t-3}, MDSQ_{t-3})$$
$$FERT_t = f(TP, IR, CR, RF, RFSQ, RD_{t-3}, RDSQ_{t-3}, MD_{t-3}, MDSQ_{t-3})$$

4. Results

The description of variables in the model with their respective units of measure and mean values is presented in Table 1. The aggregate productivity is expressed in monetary terms (rupees) per land unit (hectare) derived by multiplying production volumes per crop with their respective average prices and then summing them up and dividing by the total cultivated area in the particular district.

Model Equations

As mentioned earlier, three equations were specified and tested separately using panel analysis approach. The regression coefficients are presented in Table 2. The equation for total productivity (TP) appears as a function of inputs and resources (IR, HYV, FERT, CR, and RF), and market access (road and market densities, RD and MD respectively).

Table1: List of variables in the model

Variables	Variable Description	Units	Mean Values
TP	Aggregate Productivity of major crops	Rs/ha	257.82
FERT	Quantity of Fertilizer	kg/ha	63.52
HYV	Area under High Yield Variety	% of land	24.61
CR	Amount of Credit	Rs/ha	473.71
IR	Area under Irrigation	% of land	28.80
RF	Amount of Rainfall	mm	1070.27
LT	Level of Literacy	No/100 000	31.61
FS	Farm Size	ha	2.08
RD	Road Density	$km/100\ km^2$	5.73
RD_{t-3}	RD with three-year lag	$km/100\ km^2$	3.09
MD	Market Density	$no/1\ 000\ km^2$	5.06
MD_{t-3}	MD with three-year lag	$no/1\ 000\ km^2$	8.93

The variables RFSQ, $RDSQ_{t-3}$, and MD_{t-3} are the squared values of rainfall, and three-year-lag variables for road density and market density. The square terms are to account for the non-linear character of the increase of these variables saying the marginal rate of return is diminishing[1].

Analogically, we specified two more equations for HYV and FERT whereby they have, among others, market access variables on their right hand side (Table 2).

As previously mentioned, panel model analysis is based on subsequent estimation of simple OLS, fixed-effects (FE) and random-effects (RE) models. First, we compare FE with OLS looking closely at the residual sum of squares. Since the OLS model includes more parameter restrictions than does the fixed-effects model (the intercepts are restricted to be equal over time and over districts) it was to be expected that SSE (error sum of squares) of the fixed-effects model would be lower. We have SSE for FE equal 3 059 917.854 compared to that of OLS model with 8 260 011.504, therefore opting for the fixed-effects model. Also, the Hausman specification test (Fixed vs. Random Effects = 120.21) favors the FE over RE model. Hence, the following regression coefficients refer to those obtained from FE model analysis.

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[1] To show this on the example of $RDSQ_{t-3}$: $TP = b_1 RD_{t-3} + b_2 * RDSQ_{t-3}$.
The elasticity calculation in this case will be: $\varepsilon_{TP} = \partial TP/\partial RD_{t-3} * (RD_{t-3}/TP) = (b_1 + 2\ b_2 * RD_{t-3}) * RD_{t-3}/TP$

The examination of Table 2 shows all the variables have expected signs, except in HYV equation road density variable carries a negative sign (though statistically insignificant), and credit variable has a negative sign as well, this time however significant for which no immediate explanation is available.
Irrigated area (IR), as well as areas under high yielding variety (HYV), fertilizer use (FERT) and amount of credit taken (CR) significantly influence (linear relationship) the level of aggregate productivity. The effect of road (RD) density on the productivity follows a parabolic pattern with an optimum 325 km/100 km^2, which is far above the mean value. Similarly, market (MD) density has a parabolic shape showing an optimum at 27 markets per 1000 km^2 which is 3 times the mean value.

Table 2: Panel Model Coefficients

N=1326			
Variable	Endogenous Variables		
	TP	**HYV**	**FERT**
	Eq. 1	Eq. 2	Eq. 3
TP	**DEP**		.174*** (11.578)
IR	1.85*** (5.286)		
HYV	.886*** (5.196)	**DEP**	
FERT	.45*** (8.817)	.062*** (7.436)	**DEP**
CR	.033*** (10.198)	-.003*** (-4.927)	.011*** (6.008)
RF	.026*** (2.486)		
RFSQ	-.21E-05 (-.818)		
RD_{t-3}	6.49*** (3.517)	-.136 (-.431)	11.979*** (12.284)
$RDSQ_{t-3}$	-.01 (.113)	-.022* (-1.571)	-.369*** (-7.914)
MD_{t-3}	2.84*** (2.648)	.695*** (4.188)	2.611*** (4.337)
$MDSQ_{t-3}$	-.053*** (-2.718)	-.013*** (-4.397)	-.026*** (-2.335)

Note: *** = significant at 1%, ** = significant at 5%, * = significant at 10%. In brackets are t-values.
Source: Own calculations. Equations are estimated separately.

Almost all variables are significant at 1% and justify the calculation of elasticities which measure the importance of these factors. The more the roads and markets are developed the higher will be the level of total agricultural productivity, the more fertilizer will be applied and more land planted with high yielding variety seeds.

Elasticities allow sorting out the so-called direct (specialization) and indirect (intensification) effects of market access parameters on aggregate productivity and comparing the extent of the impact they exercise. Table 3 presents the calculations of partial elasticities from the coefficients of respective equations[2].

Elasticity gives the weighted effect of the explanatory variables without the influence of their unit measurement allowing a direct comparison (HAU AND VON OPPEN, 2001). Those standing for market access factors in the first equation reflect the direct impact of 1% change of these parameters on total agricultural productivity. If, for example, we build 1% more roads, aggregate productivity is supposed to increase by 0.08%.

Table 3: Elasticities

	TP	**HYV**	**FERT**
TP			0.71***
IR	0.21***		0.67***
HYV	0.08***		
FERT	0.11***	0.16***	
CR	0.06***	-0.06***	0.08***
RD_{t-3}	0.08***	-0.03	0.47***
MD_{t-3}	0.07***	0.17***	0.30***

Note: *** = significant at 1%, ** = significant at 5%, * = significant at 10%.
Source: Own calculations.

Market access will also have indirect effect on the level of total productivity, as already stated, through the increased use of inputs. Thus, 10 % increase in number of markets per 1000 km^2 will bring about 1.7 percentage point increase of in HYV areas and 3 % increase in fertilizer use. Hence, the intensification effect of market density on productivity will be 0.3 % via fertilizer and 0.1% through HYV when market density to rise by 10%. The total effect of road and market densities observed will be the arithmetic summation of both specialization and intensification effects for each parameter (Table 4).

Table 4: Impact of a 10% improvement in road and market density on agricultural productivity

Effect	**Road Density**	**Market Density**
Specialization effect (%)	**0.8**	**0.7**
Intensification effect (%):	**0.5**	**0.4**
Fertilizer	0.5	0.3
HYV	ns	0.1
Total effect (%)	**1.3**	**1.1**

Note: ns = not significant.

[2] In general, a partial elasticity $\square_Y = \square Y/\square X * (X/Y)$ where Y and X are mean values of dependent and independent variables in question. For example, for IR in the TP equation we proceed as follows: 1.85 (from Table 2) * 28.80/ 257.82 (from Table 1) = 0.21

Conclusions

The findings of this study in South India indicate that the market access determinants have significant effect on total agricultural productivity.

Increase of 10% in road lengths will contribute to 1.3% increase in aggregate productivity whereby specialization effect appears to be stronger than that of intensification (0.8 vs. 0.5%). Increase of 10% in number of market in given area will improve aggregate productivity by 1.1% which comprises of 0.7 for specialization and 0.4% for intensification effects. Again, the direct component weighs more than indirect effect.

We can conclude therefore that aggregate productivity may be largely improved merely through prompting states (districts, farmers) to allocate their resources in a more efficient way even without using more inputs. However, it is evident that increased used of inputs would be adding to that positive effect considerably.

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