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Crop choices in Indian agriculture: Role of market access and price policy

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Abstract

Following recent innovations in methodology for measuring market access, this paper assesses the influence of market access and price policy on crop choices in Indian agriculture. It finds that locations with greater market access specialize in less risky crops, away from pulses and oilseeds towards cereals and vegetables. Further, it establishes, a widely discussed but not empirically probed relationship, that cereal-centric price policy attenuates the effects of market access on crop choices.

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1. Introduction

What drives crop choices in agriculture? This is a key question in development literature, given increasing recognition of the role of crop diversification in agricultural transformation. Several studies have shown that diversification into high-return, low-risk crops is an important path to improving productivity, sustainability and resilience of agriculture, and for enhancing income and reducing poverty (Govereh and Jayne 2003; Weinberger and Lumpkin 2007; Birthal *et al*. 2015; Michler and Josephson 2017; Birthal and Hazrana 2019). In fact, structural transformation in agriculture is a precursor to a larger structural change in economy, i.e, a shift towards non-farm sectors (Johnson 2002; Timmer 2009; Gollin *et al*. 2002; Foster and Rosenzweig 2004; Emran and Shilpi 2012; Bustos *et al*. 2016). Timmer (1988) argues that a sequence of progressively broader diversification steps underlies the successful agricultural transformation as part of the economywide structural transformation, and it is not possible to move to the stage of rapid productivity growth if the diversification phase in agriculture is postponed.

This paper investigates the role of market access (suitably measured at the sub-district *tehsil* level) in determining the crop choices. Traditionally, the role of market access in agricultural production decisions has been seen through the vonTheunen model in which the nearness to an urban center is considered an effective measure of market access, and the causation of influence is unidirectional from cities to producing areas. It is, however, not grounded in theory. There is a problem of indeterminacy when there are multiple market centers. Also, the economic entities exist in a complex trade network, formed endogenously by the relevant market size and trade costs. With a highly spatially disaggregated unit of analysis as *tehsil* in this paper, it means that in measuring market access, each tehsil can trade with a large set of other locations depending upon the whole matrix of bilateral trade costs between the origin and the potential destinations, a structure that cannot be handled in a vonTheunnen model-based framework.

The recent innovations, as in Donaldson (2018) and Donaldson and Hornbeck (2016), provide a toolkit for measuring market access in a theoretically consistent manner. Following Donaldson and Hornbeck (2016), this paper constructs a measure of market access based on the general equilibrium model of trade with a complete matrix of trade costs, i.e., a reduced-form expression of the general equilibrium Ricardian trade theory based on Eaton and Kortum (2002) structure.

A priori 'how market access determines crop choices' is not clear. It can induce a shift away from low-value to higher-value crops, but it may also bring greater volatility in production that can steer crop choices towards low-risk cereals (Allen and Atkins 2016). Apart from market access, the policies can also play a complementary role. Agriculture is highly prone to market risks, and the public policy as the crop-specific minimum support prices (MSP) and the procurement of produce at MSP can accentuate risk differences across crops. Moreover, agriculture is influenced by climatic conditions, endowments of land, labor and capital, market access, and policies. Thus, the profitability and risk profile of crops differ significantly across geographical locations.

The procurement of paddy and wheat at MSP is a notable feature of India's agri-food policy, and it has a role in crop choices and may overshadow the effect of market access in production decisions. Our results show that market access causes a shift in crop choices away from riskier pulses and oilseeds towards staple cereals. The insurance provided by MSP and procurement of cereals reinforces this effect. Note that the marketed surplus ratio is higher for non-staple food crops (see, https://www.ceicdata.com/en/india/memo-items-agriculture-marketed-surplus-ratio).

2. Data

(i) Agricultural and infrastructural data

We use data on crops' acreage from Agricultural Census 2011-12 for 4199 tehsils from 517 districts of 20 states. Information on infrastructure and other controls is extracted from the 'village amenities database' of 2011 Population Census. As this information is binary, i.e., presence or absence of an amenity in a village, we aggregate it to *tehsil* level using the village population as weight.

(ii) Gridded data on market size and natural endowments

Data on income are extracted from Ghosh *et al*. (2010) who generated spatially disaggregated $one\ km^2$ maps of the economic activity using the night-time lights satellite imagery and LandScan population grids. FAO-GAEZ data provides indicators of a location's crop suitability for each grid point of $100\ km^2$. It assigns a score from 0 to 7 to each grid cell; 0 to unsuitable and 7 to highly suitable soils. It also provides information on temperature, rainfall, slope and altitude that serve as controls in our model.

(iii) General equilibrium measure of trade costs

Road transport costs are extracted from the 'operational efficiency of freight transportation report', of the Transport Corporation of India Limited, and the Indian Institute of Management, Calcutta. We use Open Source Routing Machine (OSRM) and Open Street Map to find the shortest optimal road distance between two *tehsils* (based on latitude and longitude of centroids). This procedure is implemented using *osrmtime* command in STATA 15. We calculate bilateral transport costs (BTC) between 18 million origin-destination *tehsil* pairs.

3. Methodology

Tehsils can trade with one another, but the realized network of trading partners depends upon the matrix of BTC. Following Donaldson and Hornbeck (2016), we construct a reduced form equation for market access specifying how market access of each *tehsil* is influenced by the national matrix of BTC.

$$MA_o = \kappa_3 \sum_d \tau_{od}^{-\theta} MA_d^{-\frac{(1+\theta)}{\theta}} N_d \qquad (1)$$

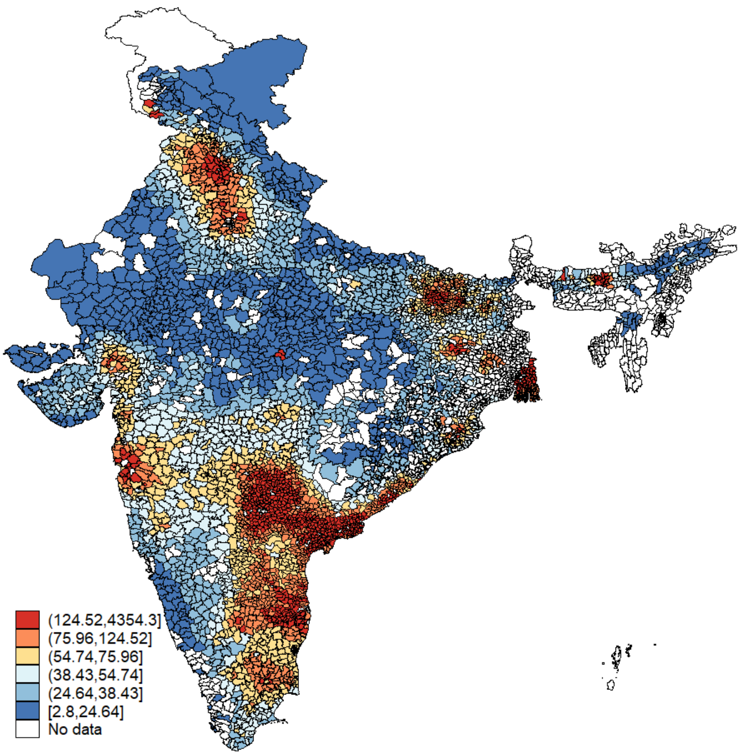
Where MA denotes market access and *N* population (market size). *o* and *d* denote origin and destination of trade respectively, and $o \neq d$. τ_{od} is BTC, and is assumed symmetric between *o* and *d*. MA is a function of BTC between a *tehsil* and all other *tehsils*, and all other *tehsils*'s access to other markets. The first-order approximation of MA is:

$$MA_o \approx \sum_d \tau_{od}^{-\theta} Y_d \qquad (2)$$

Where θ is the trade elasticity parameter. We replace population (*N*) with per capita income (*Y*) — a more relevant indicator of demand. Donaldson and Hornbeck (2016) show that results are not sensitive to approximation in Equation (2), and are highly correlated with the numerical estimate of MA from Equation (1).

The tedious task in calculating MA is to estimate τ_{od}. Following Donaldson and Hornbeck (2016), we first estimate unit cost of transportation from one state to another. We consider road-based BTC as the main mode of transportation of agricultural produce, and it is assumed that unit transport cost does not vary between *tehsils* within a state. In the data, the transport cost varies significantly, from INR 2.21/km/ton in Andhra Pradesh to 4.24/km/ton in Uttar Pradesh. Then, we calculate the shortest route between *tehsils*. MA is estimated using Equation (2) assuming $\theta = 2$, and we check its robustness at $\theta = 3$ (in supplementary material).

Figure 1: Variation in *tehsils*'s market access



Notes: Out of 5135 tehsils, 4199 were matched accurately. Blank areas show either unmatched or tehsils with missing data.

Figure 1 shows *tehsil*-level MA; red color represents greatest MA, and the blue color, the least MA . To assess the effect of MA on crop choices we specify the following equation:

$$A_{ij} = \alpha_j + \delta \ln(\text{MA})_{ij} + X_{ij}\beta + \varepsilon_{ij} \qquad (3)$$

Where A_{ij} is the proportion of area under a crop in *tehsil* i of state j. X is a vector comprising electricity, irrigation, and mechanization, telephones, banks, schools, hospitals, share of marginal holdings (less than equal to one hectare) in the total holdings and measures of crop suitability.[1] There are both theoretical and empirical reasons for non-inclusion of the relative prices at *tehsil* level. The equilibrium trade is determined by equalization of prices based on demand, supply, and trade costs. The relative prices of crops in *tehsils* are embedded in MA itself. Ideally, Equation (3) should include other control variables like storage facilities for high-value commodities (HVC) and consumption patterns, income classes. But such variables are not available at this level of analysis. We resort to using state fixed effects α_j to control for such and other omitted variables.

4. Results and discussion

Table 1: Market access and crop choices

	Rice	Wheat	Pulses	Sugarcane	Oilseed-Fibers	Vegetables	Fruits-Plantation
Panel A: Benchmark MA with shortest road distance and state varying BTC							
Ln(MA)	4.12**	1.16**	-2.25***	1.39***	-5.61***	1.24***	-1.81*
	(2.03)	(0.54)	(0.83)	(0.45)	(1.95)	(0.44)	(0.96)
Panel B: Benchmark MA and controls including railway connectivity							
Ln(MA)	0.66	-0.45	-1.11	0.92*	-4.36***	2.07***	-0.37
	(1.65)	(0.52)	(0.80)	(0.55)	(1.48)	(0.43)	(0.84)
Panel C: Tobit regressions							
Ln(MA)	2.42	-0.89	-1.97**	1.73*	-6.21***	2.35***	-0.67
	(1.72)	(0.98)	(0.95)	(0.93)	(1.68)	(0.51)	(1.04)

Notes: All regressions include state fixed effects. The number of observations on which these regressions are estimated is 4199. Standard errors are robust to intra-district correlation. ***, **, and * indicate significance at 1%, 5%, and 10% respectively.

Table 1 presents results of Equation (3). Panel A in the Table excludes controls. In this specification, MA shifts acreage from pulses, oilseeds-fibers and plantation crops to rice, wheat, sugarcane, and vegetables. Adding controls, the results for pulses and oilseeds acreage remain unchanged (Panel B). Note, pulses and oilseeds are grown mostly under rainfed conditions, and are covered under MSP but rarely procured. Thus, when MA brings more volatility, preferences move away from comparatively risky crops like pulses and oilseeds. Rice, wheat, and sugarcane in contrast are procured at MSP. Vegetables are not covered under MSP, but because of their short duration, higher value and lower risk, these are positively impacted by MA.

There are several robustness checks that we implement. First, with MA solely based on road network the BTC measure may not be adequate if other means of transport are also used. To

[1] See supplementary material for control variables and their sources.

account for this possibility, Panel B reports estimates conditional on a *tehsil*'s railway connectivity and other control variables. The same pattern of effects of MA holds.

Further, we address some potential econometric issues. First, some crops exhibit concentration at zero, in terms of acreage. Therefore, we estimate a Tobit model (Panel C). Moreover, geographical data and cropping patterns may exhibit spatial correlation. To test for spatial or neighborhood effects, we also estimate spatial autoregressive model and find similar effects of MA.[2] Second, road-based BTC may be endogenous due to non-random road placement. As an additional robustness check, we estimate MA considering the linear distance between *tehsils* and major urban centers. Finally, *tehsil*-level unobserved heterogeneity may be of concern, for which possible solution is an instrumental variable (IV) strategy. Perhaps the main empirical concern remains that the road construction may occur in *tehsils* with certain crop choices. Most variation in road construction in India is perhaps driven by politics, topography, or a drive to connect large cities as through the Golden Quadrilateral Project, and crop acreage might play only a minimal role, if any. To address endogeneity concerns, we estimate Lewbel's (2012) instrumental variable strategy. Results are presented in Table 2.

Table 2: Lewbel IV estimates

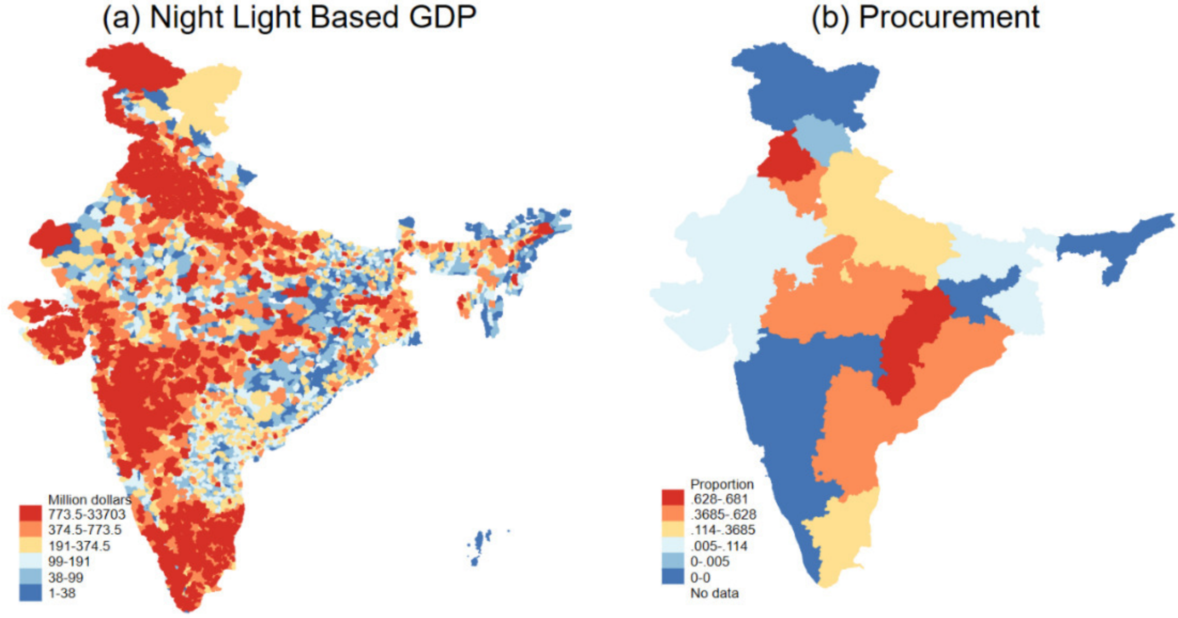
	Rice	Wheat	Pulses	Sugarcane	Oilseed-Fibers	Vegetables	Fruits-Plantation
Ln (MA)	6.75***	-0.27	-2.10***	-0.31**	-3.15***	0.77***	-0.70*
	(1.15)	(0.34)	(0.53)	(0.15)	(0.72)	(0.26)	(0.40)
Breusch-Pagan heteroscedasticity test							
$\chi 2(1)$				38.26***			

Notes: All regressions include controls. The number of observations on which these regressions are estimated is 4138. Omitted exogenous variables as instruments: altitude, slope index, temperature, rainfall, and crop suitability index. Robust standard errors in parenthesis.

Even without procurement, MSP plays an anchoring role for farmgate price. Where markets are thin, MSP helps in price discovery reducing informational asymmetry (between buyer and seller) on price. Yet, MSP as a floor in selected crops may hinder farmers' response to market signals. Figure 2 shows estimates of local GDP (for market size) and procurement of cereals at MSP. Regions with comparatively big market sizes are also where cereal-centric policy is more entrenched.

[2] See supplementary material.

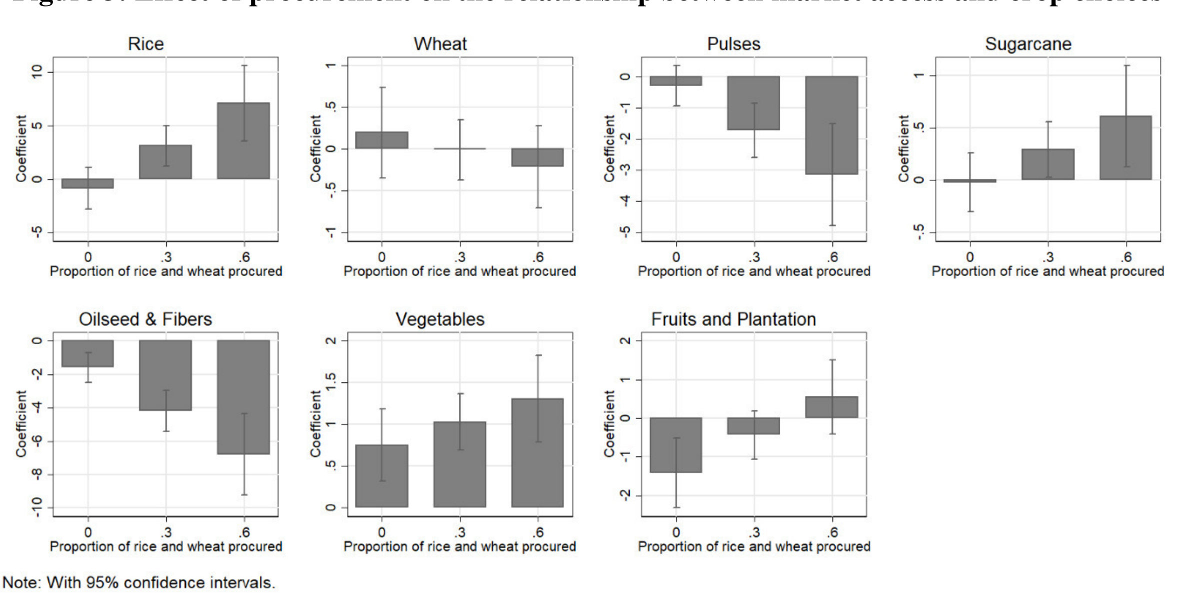
Figure 2: Map of nighttime light-based GDP, and government procurement of cereals at MSP



Notes: Panel (a)-*Tehsil*-level GDP estimates in million dollars. Panel (b)-state-level proportion of rice and wheat procured at MSP.

Generally, 25-30% of rice and wheat outputs are procured to different degrees across states. MSP with procurement un-levels the playing field and impedes non-cereal crop choices. We re-estimate Equation (3) including an interaction between MA and state-wise proportion of rice and wheat procured. Figure 3 plots marginal effects. Our results show that the positive relationship between MA with cereals, and an inverse relationship between MA and pulses and oilseeds-fibers may be driven by procurement, i.e., due to insurance provided by MSP with procurement.

Figure 3: Effect of procurement on the relationship between market access and crop choices



Notes: Marginal effects are estimated from a regression of cropped area on MA and its interaction with procurement. Includes state fixed effects. Standard errors are robust to intra-district correlation of residuals.

5. Conclusions

This paper has assessed crop choices as a function of general equilibrium based measures of MA at a highly disaggregated geographical level in India. We use novel data on local GDP and construct measures of MA. Our results show that after controlling for endogeneity, using Lewbel's (2012) estimator, MA leads to a choice for comparatively low-risk crops, cereals, sugarcane, and vegetables. Along with relative production risk that varies by crops, support prices and procurement of cereals attenuate the impacts of MA on crop choices. Pulses and oilseeds, which are low-yielding and riskier, and India is in deficit in these, are displaced with MA.

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