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Keywords: Crop diversification, Market access, Policy distortion, India

JEL Code: O13, Q18, R14

Market Access, Price Policy and Diversification in Indian Agriculture

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Abstract

This paper provides empirical evidence of a causal relationship between the access to markets and the crop partial policies on the pattern of specialization or diversification in Indian agriculture. We uniquely combine highly spatially disaggregated data on cropping patterns, amenities, and market size at a granular level, and construct a measure of market access using indicators from both the supply and the demand side of trade. We employ the heteroscedasticity based two-stage Lewbel (2012) estimator to address the possible endogeneity of market access and also test for non-linearity between market access and crop diversification. Our results show that locations connected with bigger markets are more diversified into vegetables, and cash crops like oilseeds and cotton. However, the effect of market access moderates after a threshold level of diversification probably because of the non-market constraints. Nonetheless, the policy-induced distortions in agri-food markets, the nucleus of policies in the form of procurement of cereals mainly rice and wheat at the government-determined pre-announced minimum support prices, significantly attenuates the effect of market access on crop diversification.

1. Introduction

Owing to the dominance of small landholdings and excessive employment pressure on agriculture, enhancing farmers' income remains a prime concern for policymakers in India. Inter alia, diversification of agriculture in favor of high-return, low-risk crops away from the widely grown staple cereal crops is considered an important pathway for sustainable improvements in agricultural productivity and farmers' incomes. Several studies show that such a transformation in the agricultural sector helps not only improve farmers' incomes but also induces agricultural growth and contributes to reducing poverty and nutrition insecurity (Jayne and Govereh 2003; Barghouti et al. 2004; Birthal, Roy, and Negi 2015; Michler and Josephson 2017). Not only that, but it also improves the resilience of agriculture and smoothens households' livelihoods against climatic shocks of deficit rainfall and excess temperature (Amare et al. 2018; Birthal and Hazrana 2019).

The structural transformation in an economy is often preceded by diversification-led productivity growth triggered by the commercialization of agriculture (Johnston 1970; Gollin, Parente, and Rogerson 2002; Foster and Rosenzweig 2004; Emran and Shilpi 2012; Bustos, Caprettini and Ponticelli 2016). Profitability of agriculture depends on the extent of diversification of production portfolio into the crops and livestock that generate higher returns and have better demand prospects compared to the widely grown staple cereals, and into the production for agri-business sector that can add value through processing and enhanced consumer appeal (Timmer 2009; Reardon and Timmer 2007). Timmer (1988) shows that a sequence of progressively broader diversification steps defines a successful agricultural transformation as a part of the process of broader structural transformation of the economy. An alternative approach followed to boost agricultural productivity or enhance farm incomes is the provision of input subsidies and output price support as in India. Nonetheless, Timmer (2009) argues that it is impossible to move on to the stage of rapid productivity growth and integration into the overall economy if the diversification phase in agriculture is postponed.

Economists have long recognized the importance of markets in land (re)allocation or crop diversification decisions. However, there are only a few studies that have investigated the relationship between market access and crop diversification at a spatially disaggregated level, the exception being Emran and Shilpi (2012) who study this relationship using household survey data from Nepal. We use highly spatially disaggregated data to analyze product diversification as a function of market access as well as food policy emblematic of the developing countries with the centrality of cereals for food security. In analyzing the relationship between market access and diversification, we consider several nuances of agriculture that may matter more in Indian agriculture than elsewhere. Beyond size differences, Indian agriculture is quite heterogeneous in several other aspects, including topography, climate and cropping systems; and we account for this heterogeneity in our analysis using the highly spatially disaggregated tehsil (an administrative unit below the district) level data. Accordingly, we build our measure of market access basing on the distance of tehsils from urban centers and the differences in the income levels of urban centers. Another important characteristic of Indian agriculture is the inequity in the distribution of landholdings. Over 86% of the farm households possess landholdings of size less than or equal to two hectares. We conjecture significant differences in the cropping patterns across different farm classes even if there is equal market access. Thus, we also quantify the effect of market access on crop diversification for different farm classes, besides analyzing it for the overall pool of farm households. Finally and more importantly, we introduce policy dimension to the diversification-commercialization landscape to know how the government interventions in food grain markets influence the agricultural land-use or crop diversification even amidst the market access.

While analyzing land-use decisions, it is important to bear in mind that diversification and commercialization of agriculture are influenced by a number of factors. Inter alia, poor access to markets is one of the most important impediments to diversification in smallholder agriculture (Barrett 2007; Gulati et al. 2007; Hellin, Lundy, and Meijer 2009; Shiferaw, Hellin, and Muricho 2011; Fafchamps and Shilpi 2003). Lack of transport infrastructure and asymmetric information cause imperfections in agri-food markets, leading to the higher cost of trade and poor price realization by producers (de Janvry, Fafchamps and Sadoulet 1991; Kydd and Dorward 2004; Dorward et al. 2004; Meenakshi and Benerjee 2005; Poulton, Kydd, and Dorward 2005; Shiferaw, Hellin, and Muricho 2011, Negi et al. 2018).

Notwithstanding infrastructural and market constraints, the effect of output price policy on crop diversification amidst the market access has been overlooked in the empirical literature. No other country, but India is an ideal case to study the role of price policy in fostering or encumbering crop diversification. Historically, to attain self-sufficiency in food grains, India has been providing both the price and non-price incentives to farmers for the adoption of improved biochemical technologies (seeds, fertilizers, and agrochemicals). Often, such incentives are not crop-neutral and cause distortions in agricultural land-use or cropping patterns and income distribution.

Ever since the introduction of biochemical technologies in the mid-1960s, India’s pricing policy has been cereal-centric. To protect farmers (and also consumers) from the significant price fluctuations, the government of India annually fixes minimum support prices (MSP) for food as well as non-food crops and assures their procurement in case their prices in open market fall below the MSP. This policy, however, is effective only for rice and wheat, that are procured in large quantities by the government for public distribution system (PDS) and buffer stocking. No doubt, policies did help in achieving self-sufficiency in cereals, but have also acted as a disincentive to private investment in markets and associated infrastructure critical to diversification and commercialization of agriculture (Rashid, Cummings and Gulati 2005; Gulati et al. 2007).

With this background, in this paper we address the following questions:

(i) Does market access lead to diversification in the cropping systems?

(ii) How does government intervention in food grain markets influence the effect of market access on crop diversification?

The paper makes the following contributions to the empirical literature:

(i) The studies that attempt to quantify the causal impact of diversification on farm incomes, agricultural growth and rural poverty do recognize market as an important channel but have rarely established and quantified the causal links between market access and product diversification. Combining granular data on agricultural land-use from the Agricultural Census, and on indicators of market access from the Population Census, we quantify the effects of market access on product diversification in agriculture. We conceptualize market access both from the demand and the supply sides of trade. Our measure of market access is constructed at a granular level considering the distance to urban centers and the market size of the urban centers.

This paper, for the first time, provides empirical evidence on the relationship between crop diversification and market access at a highly spatially disaggregated level (tehsil i.e. sub-district) combining data from multiple sources. Further, taking farm heterogeneity seriously, it also looks into this relationship across farm classes.

(ii) Another issue that has received little attention in the empirical literature relates to the spatial dimensions of agricultural land-use, which besides the household or regional resource endowments is also influenced by the market forces. In a frictionless economy, characterized by a free flow of resources, commodities, and services, each location is expected to realize almost a similar change in the agricultural land-use in response to any change in the market forces. This, however, is not the case. The potential for diversification of different locations, inter alia, is influenced not only by the market size and trade costs but also by the farm and farm household characteristics. We assess a location's diversification potential through market size and trade costs conditional upon its natural resource endowments and agro-ecological conditions.

(iii) Finally, we investigate the role of government interventions in agri-food markets in the diversification process amidst market access. The cereal-centric policies are often blamed for limiting the realization of the diversification potential in general discussions, but their effects have not been formally quantified. This paper shows how cereal-centric policies offset the impact of greater market access on crop diversification.

The paper is organized as follows. Section 2 describes in detail the multiple datasets that we have combined to construct our measures of diversification, crop suitability, and market access, and to assess their relationships. Section 3 illustrates the construction of the indices of diversification and market access and provides descriptive statistics of the key variables. Section 4 describes the empirical strategy for assessing the effect of market access and government interventions in food markets on crop diversification. Section 5 discusses the results, and the conclusions and policy implications are given in the final section.

2. Data Sources

Most studies that examine the effect of market access on crop diversification rely either on a highly spatially disaggregated household-, or village-level datasets (e.g., Emran and Shilpi 2012) or on spatially aggregated state-, or district-level datasets (Joshi et al. 2004; Rao, Birthal, and Joshi 2006). The household-level data although it can capture several nuances of the local farming systems (that otherwise are difficult to capture at higher levels of spatial aggregation), their findings cannot be generalized for policy actions because of their being based on small location-specific samples. Further, it is possible that even with equal market access, some households in a village or some villages in a region may follow a highly specialized cropping system.

The other line of research that relies on the spatially aggregated data usually has low granularity and cannot unpack the heterogeneity in cropping systems and market channels available at lower geographical and administrative levels. In our analysis, the unit of observation is tehsil that represents an intermediate level of spatial aggregation. No study in India has attempted examining diversification and commercialization in agriculture at this level of spatial disaggregation.

For our analysis, we use data from the following sources:

Agricultural Census

The Ministry of Agriculture and Farmers' Welfare, Government of India conducts a quinquennial census of agricultural activities, generally with a focus on the size distribution of landholdings, acreage allocation and irrigation status by crop. This is the only source of information on cropping patterns aggregated at the level of a tehsil, district, and state. We rely on the latest available Agricultural Census conducted in 2011-12. Although this dataset is in public domain (https://agcensus.nic.in), the format in which it is provided is not user-friendly. It takes considerable time and effort in downloading data for each tehsil, their compilation, and processing for use in econometric analysis. Our final dataset includes area allocations to crops or group of similar crops by farm size for 5135 tehsils in 517 districts of 20 states in the country.

Population Census

The Agricultural Census although rich in information on agricultural land-use, but does not contain information on markets, infrastructures, and institutions that matter in agricultural land-use decisions. What is novel in this paper is that for such variables we rely on the 'village amenities database' provided in the Population Census, which is conducted at a decadal interval by the Ministry of Human Resource Development, Government of India. Incidentally, the latest Population Census also pertains to 2011, which is also the reference year for the Agricultural Census. Besides demographic contents, the Census contains information on infrastructure and other amenities available at the village level. This is a comprehensive source of data on general amenities and infrastructures for this level of spatial disaggregation. Surprisingly, it has not been utilized much in economic analysis as a data source for amenities for a locality.

The information on most village-level amenities in the Population Census is binary, indicating either the presence or absence of an amenity in the village. We aggregate village-level variables to tehsil-level, the unit of observation in our analysis, using the village population as weight. Since infrastructures and other village level amenities are weighted by the village population, these essentially reflect the proportion of the population in a tehsil exposed to these amenities.

Further, we identify tehsils that are common in the Agricultural Census and the Population Census. We could accurately match 4707 (92%) tehsils from the two Censuses.

Gridded data on market size and natural endowments

To construct an effective measure of market access we need data on both the demand and supply sides of trade. Accordingly, we consider distance to the urban/market centers and their market size for constructing an index of market access. From the Population Census, we identify 494 cities that have a population of more than 100 thousand. At one level, the population itself can serve as a proxy for market size, but more adequately it is captured by the income of the urban center.

The income or gross domestic product is not officially estimated for spatial units below the district. With the need for a measure of economic activity at high-resolution, we draw block-level night-time lights satellite imagery data from Ghosh et al. (2010). Ghosh et al. (2010) generate spatially disaggregated one square kilometer maps of the total economic activity using the night-time lights satellite imagery and the LandScan population grids. From this dataset, we estimate gross domestic product for 494 identified cities.

A few studies have used the night time light data to estimate income and poverty at the state and district levels. Such data are often used to augment measures of output and output growth and to generate estimates for the areas or periods for which the official data are unavailable (Henderson, Storeygard, and Weil 2012). This is the case for the level (i.e., tehsil) for which we are scouting for information on economic activities. To the best of our knowledge, except Gibson et al. (2017), no other study has used the night time light data to generate estimates of incomes for major cities of India.

For information on natural endowments, we rely on gridded data provided in the Food and Agriculture Organization Global Agro-Ecological Zones (FAO-GAEZ) project. This dataset includes several indicators of suitability of a location for growing a particular crop. It provides data for each grid point of 100 square kilometers and assigns each grid cell a score, ranging from 0 for the soils unsuitable for cultivation of a specific crop to 7 for the soils highly suitable for that crop. From this dataset, we also extract information on temperature, rainfall, slope, and altitude, besides the crop suitability indices for each tehsil that serve as controls in our econometric analysis.

3. Measures of Diversification and Market Access

Diversification

There are several methods of assessing the level of diversity or diversification in agriculture. These include indices like richness index, Herfindahl index and Simpson index, and also the proportionate shares of crops. We estimate the Simpson index of diversification:

$$\text{Diversity index}_{i} = \left(1 - \sum_{i=1}^{C} P_i^2\right) \times 100 \qquad (1)$$

where P_i is the proportion of the total cropped area under crop *i*. Simpson index is bounded between 0 and 1; 0 implies complete specialization, and 1, complete diversification. The index, however, provides information only on the extent of diversity in a cropping system, and not on the direction of diversification within the system. Hence, we also utilize the proportion of the total cropped area allocated to a specific crop or group of similar crops as an alternative measure of diversification. The crop groups include cereals (rice, wheat, millets, maize, and sorghum), pulses (chickpea, pigeon-pea and other minor pulses), oilseeds and fibers (rapeseed and mustard, groundnut, other oilseeds, and cotton), sugarcane, vegetables, and plantations (fruits, tea, and coffee).

Market Access

The main challenge in constructing a reliable measure of market access is to identify correctly the indicators that can capture both the demand (e.g., purchasing power and population) and the supply (e.g., access to roads, travel time to market) sides of trade. From an extensive review of the empirical literature, Chamberlin and Jayne (2013) identify a number of indicators of market access, including distance to nearest wholesale or retail market, town and service center, travel time, transportation costs, mode of transportation, presence of road in a location, quality of road (all-weather, metaled or un-metaled) and road density. Chamberlin and Jayne (2013) also notice that studies often use a single indicator of market access; and in this context Wood (2007) observes that “indicators are typically selected on an ad hoc basis, with indicator choice varying widely across studies and rarely discussed in terms of specific marketing channels, explicit transactions costs, or price formation processes.”

Along with the physical distance indicators the market size, measured in terms of urban population or income, is also an important indicator of market access (Emran and Shilpi 2012). Market access influences crop diversification or specialization via demands for diverse agricultural commodities. Both the physical distance and the market size combine as complementary measures of market access.

According to Von Thunen’s (1986) theory of agricultural specialization, the inertia generated by a major economic center influences agricultural land-use around that center in a specific manner, that is, a pattern of rings of specialization develops around the center. The ring closest to the center tends to specialize in highly perishable commodities such as vegetables and milk that are high in demand in urban centers. As the distance from an urban center increases subsequent rings specialize in the production of less perishable commodities, for example, cereals and pulses.

The Von Thunen model considers the distance to a single urban center as a measure of market access. However, there could be multiple cities and towns in a producing region, and each urban center based on its economic mass may influence agricultural land-use in its neighborhood. Thus, there is a possibility of overlapping the rings of specialization.

We rely on the gravity equation in the international trade literature to construct a measure of market access, that in its simplest form estimates trade between two regions to be directly proportional to the economic mass of the regions, and inversely related to the bilateral distance between them. In its more theoretically grounded formulation, the idea of bilateral resistance (proxied by distance) is replaced by multilateral resistance, wherein the distance of a location to the nearest market although is important, its distance to all other market centers also matters. Since we consider distance to multiple urban centers simultaneously, in effect we proxy for the multilateral resistance. Intuitively, a larger urban center (in income terms) would have a larger influence on the economic activities of trading partners. Further, for a given economic mass of an urban center, as the distance between a producing region and the urban center increases the cost of transportation also increases, attenuating the effect of urbanization on economic activities of the region.

Thus, our measure of market access is:

$$\text{Market Access}_i = \frac{1}{K}\sum_{k=1}^{K}\frac{m_{ik}}{d_{ik}^2} \qquad (2)$$

where, m_{ik} denotes the size of urban center *i*, measured by its gross domestic product. $d_{ik}$is the linear distance between tehsil and k^{th} urban center and *K* is the total number of urban centers. We calculate the Euclidean distance between GPS coordinates of a tehsil and geo-coded urban centers, and it is repeated for each tehsil as many times as the number of urban centers, i.e., 494 times. To assess the degree of market access, we take the inverse of the squared distance and calculate the weighted average of all 494 inverse-squared distances with the gross domestic product of an urban center as weight. This is akin to the idea of remoteness in empirical trade literature, which is defined as the average of the distance to different locations, each weighted by their GDP. The squared distance gives more weight to urban centers located at shorter distances. This measure of market access is positively related to the economic mass of an urban center and is inverse to the distance between the urban center and producing region, i.e. the tehsil.

Figure 1 shows the density plots of the Simpson index of diversity. There is considerable variation in diversification index across tehsils. In terms of area shares, cereals account for a larger share of the total cropped area, followed by oilseeds (including fibers) and pulses (Table 1). Expectedly, cereals exhibit the lowest spatial variation in their area shares, while cash crops, including vegetables, plantations, and sugarcane, have a relatively larger spatial spread.

Table 2 presents the correlation matrix of diversification index, crop area shares and index of market access. The area share of cereals is negatively correlated with the diversification index, as well as area shares of other crops. This indicates that cereals compete for agricultural land with non-cereal food crops and also non-food crops. Overall, the cereal-based cropping system seems to be less diversified. On the other hand, diversification index has a positive correlation with area shares of pulses, oilseeds (including fibers), vegetables and plantation crops.

Figures 2 and 3 respectively show the geo-coded locations of major urban centers across India and the spatial variation in the index of market access. Except in the states along the foothills of the Himalayas and the eastern seaboard, urbanization is fairly widespread in the country. The darker shades in figure 3 denote greater market access. On the juxtaposition of figure 2 with figure 3, which is shown in figure 3b, we clearly notice a positive association between urbanization and market access.

Figure 4 shows estimates of GDP derived from the night time light satellite imagery data, and also the incidence of diversification-inhibiting cereal-centric price policy defined as the proportion of the combined output of rice and wheat procured at pre-announced minimum support prices. Importantly, the regions that have comparatively higher GDP are also the ones where policy distortions are relatively more. In terms of either the market access based on the distance to major cities or the GDP based on nighttime light data or the level of procurement of cereals, the north-western region stands out prominently.

4. Empirical Strategy

Mathematically, the relationship between crop diversification and market access can be written as:

$$Y_{ij} = \alpha_j + \delta \text{Market Access}_{ij} + X_{ij}\beta + \varepsilon_{ij} \qquad (3)$$

where, Y_{ij} represents crop diversification, as an index or the proportion of the total cropped area under a crop in tehsil i of state j. We include state fixed effects to control for unobserved differences in infrastructures, institutions, policies and governance structures across states. X is a vector that includes electricity, irrigation, and machines (mechanization), telephones, banks, schools, and hospitals. While, the electricity, irrigation, and financial institutions can directly influence the cropping pattern and agricultural productivity at a location; the schools and hospitals reflect social infrastructure, and the farmers at a location with greater exposure to social infrastructure are expected to be more informed and motivated to diversify their production portfolios (Birthal, Negi, and Roy 2017).

Another important set of controls relates to the natural endowments that not only influence agricultural land-use but also determine the location of a market or urban center. For instance, an urban center might have emerged historically in a region because the natural endowments of the region favored the production of diverse crops. The omission of natural endowments, thus, can bias estimates of market access. We use crop-specific suitability indices from the FAO-GAEZ to construct an average agricultural suitability index for each of the tehsils. We also control for topography and climatic conditions by including rainfall, temperature, slope, and altitude of tehsils.

Further, we also estimate the relationship between market access and crop diversification by farm size and modify equation (3) as:

$$Y_{lij} = \alpha_j + \sum_l \gamma^l \text{Land Class}_{ij}^l + \sum_l \delta^l \text{ Land Class}_{ij}^l \times \text{Market Access}_{ij} + X_{ij}\beta + \varepsilon_{ij} \qquad (4)$$

where, Y_{lij} is the measure of diversification for a Land Class^l l in tehsil i of state j. A land class is defined as a binary indicator, equaling one for land class l, and zero otherwise. In the Agricultural Census, the land classes are defined as marginal (less than or equal to one ha), small (1-2ha), medium (2-4 ha) and large (more than 4 ha). With marginal land class as the base, γ^l provides for the difference in the extent of diversification on a farm class relative to the marginal land class. Further, we interact market access with each of the land class and the coefficient δ^l capture the effect of market access on crop diversification on a particular land class.

The relationship between market access and diversification can be influenced by policies such as the procurement of rice and wheat at pre-determined prices that distort the price signals. To capture the role of such a policy, in equation (3) we incorporate interaction between market access and proportion of rice and wheat in state j:

$$Y_{ij} = \alpha_j + \delta \text{Market Access}_{ij} + \delta^p \text{Procurement}_j \times \text{Market Access}_{ij} + X_{ij}\beta + \varepsilon_{ij} \qquad (5)$$

As the size of procurement is state-specific, it is absorbed in the state fixed effects. The marginal effect of market access on crop diversification, then, can be estimated as:

$$\frac{\partial Y_{ij}}{\partial \text{Market Access}_{ij}} = \delta + \delta^{p}\text{Procurement}_{j} \qquad (6)$$

The relationship between market access and crop diversification is now conditional on the state-level procurement of rice and wheat. Since we take combined procurement of rice and wheat, it can be treated as exogenous to land-use decisions at the granularity of the tehsil-level.

The coefficient of interest in equation (6) is δ. It, however, may not capture the true effect of market access on crop diversification because of the omitted variables that could be endogenous with diversification. If the error term, ε, in equation (3) is composed of the omitted variables, v, and the random error, ϵ, i.e., $\varepsilon_i = v_i + \epsilon_i$, then we require an instrument for market access that can overcome the problem of endogeneity and possible bias due to measurement error.

Consider Z as a vector of exogenous variables, i.e., $Z \subseteq X$, then an ideal conventional instrument must satisfy the following conditions:

(i) Relevance condition: The instrument should be correlated with market access, i.e., $\text{Cov}(Z_i, \text{Market Access}_i) \neq 0$.

(ii) Exclusion restriction: The instrument should influence the outcome variable only through the market access, and it should not be correlated with the omitted variables, i.e., $\text{Cov}(Z_i, v_i) = 0$.

Finding an instrumental variable that satisfies these two conditions is rather difficult. Topographical features such as altitude and slope could serve as instruments as these are possibly exogenous to a household's decision problem, but these may not satisfy exclusion restriction because of their possible correlation with omitted variables.

We, therefore, implement Lewbel's two-step estimator where identification is achieved without exclusion restriction (Lewbel 2012). Several studies, for example, Emran and Shilpi (2012), Gao and Smyth (2015), Mishra and Smyth (2015), Lin, Weldemicael and Wang (2017) and Emran and Hou (2013), have relied on this strategy. In Lewbel's approach, the exclusion restriction is replaced with two additional restrictions.

Consider the following equation (7) for the potentially endogenous market access in the analysis:

$$\text{Market Access}_{ij} = \tau_j + \phi \mathrm{Z}_{ij} + \omega_{ij} \qquad (7)$$

For identification, the Lewbel two-step estimator relies on the following conditions:

(i) $\mathrm{Cov}(Z_i, \varepsilon_i \omega_i) = 0;\mathrm{i.e.},$ the variables in vector Z should be uncorrelated with the product of error terms in equation (3) and equation (7).

(ii) $\mathrm{Cov}(Z_i, \omega_i^2) \neq 0$; i.e., the variables in vector Z must be correlated with the squared residuals of equation (7). For this to be satisfied, $E(\omega_i^2)$ should not be a constant, hence there should be heteroskedasticity in the error terms in equation (7).

Lewbel (2012) shows that on satisfying these conditions, it is possible to construct an instrument as the product of de-meaned exogenous variables in vector Z and estimated errors from equation (7). Let $\hat{Z}_i$ be a vector of constructed instruments, then $\tilde{Z}_i = (Z_i - \bar{Z}_i)\widehat{\omega}_i$; where $\widehat{\omega}_i$are the estimated residuals from equation (7). The first stage equation then can be specified as:

$$\text{Market Access}_{ij} = \rho_j + \sigma\tilde{Z}_{ij} + \xi_{ij} \qquad (8)$$

As in the case of conventional instrumental variable strategy, Lewbel's approach also requires a set of controls to be exogenous. For this, an essential requirement is the presence of heteroskedasticity in the residuals of equation (7). We formally test for heteroskedasticity using Breusch-Pagan and White's general test (White 1980). We implement Lewbel's strategy as a two-step efficient generalized method of moments (GMM) estimator that provides efficiency gains over traditional IV/2SLS estimator. For an exactly identified model, the efficient GMM and the traditional IV/2SLS estimators are the same. These are also the same on the assumptions of conditional homoskedasticity and independence.

In our estimation, we have included a rich set of controls for the agro-climatic conditions derived from the FAO-GAEZ dataset. With extensive controls, it is unlikely that residual common agro-climatic factors may drive the pattern of heteroscedasticity in market size. Alternatively, to expect that variation in the second moment of the market size due to agricultural suitability is correlated with the patterns of specialization and commercialization at each location is not plausible. The variation in market size in such a situation, as Emran and Shilpi (2012) suggest, could be taken as a quasi-random assignment of the treatment to the relevant location.

5. Market Access, Price Policy, and Diversification

Market Access and Diversification

We begin by looking into the linear estimates of equation (3) in Table 3. The coefficient of market access is positive and statistically significant, indicating greater diversification in agriculture at locations better connected with markets. However, the effect of market access is heterogeneous across individual crops or crop groups. The effect is positive and statistically significant for vegetables and oilseeds (including fibers); negative and significant for plantations (fruits, tea, and coffee), and statistically insignificant for food grain crops, i.e., cereals and pulses.

Both the diversification index and the area shares are bound between 0 and 1, hence there is a possibility that these could be clustered at their lower or upper bound or both, hence a linear specification of equation (3) may yield biased estimates. Therefore, we estimate a Tobit version of equation (3) that adjusts for potential bias in the estimates. The results are presented in Table 4, and the estimates are similar to those obtained from the fixed effects specification. This implies that the linear specification of equation (3) is not a major concern in our estimates.

The estimated effects of market access on crop diversification reported in Tables 3 and 4 are indicative, but may not be interpreted as causal because of the endogeneity of market access. The results of Lewbel's two-step GMM estimator with higher moment instruments are presented in Table 5. White's χ^2 statistic rejects the null of the homoscedastic error term ω_{ij} in equation (7); i.e. our specification satisfies condition (ii) of Lewbel's approach. These results reinforce our earlier findings. Even after instrumenting, the effect of market access on crop diversification remains positive and statistically significant. For crops or crop groups, the estimates are like those from the linear and Tobit specifications of equation (3).

Our findings are consistent with the Von Thunen's theory of agricultural specialization. The locations better connected with urban/demand centers are more diversified towards cash crops, viz. vegetables and oilseeds (including fibers) and less towards cereals and sugarcane. This is expected. Vegetables are highly perishable and need quick transportation to markets or urban centers. For oilseeds and cotton, the processing facilities are mostly located around the urban centers.

Further, to see whether there is a non-linear relationship between market access and crop diversification we introduce a squared term of the index of market access in equation (3). The coefficient on its squared term, in the OLS as well as Lewbel IV-GMM estimator, is statistically significant (Table 6a), suggesting that diversification tends to increase with improvements in market access but at a decreasing rate (Figure 5a). We formally test for this non-linear relationship using Lind and Mehlum (2010) U-test, and it rejects the null hypothesis of a linear relationship between market access and crop diversification.

Further, we look for the non-linearity between market access and crop area shares. The linear as well as quadratic terms of market access are statistically significant for all the crops but are heterogenous in their direction (Table 6b). For vegetables and oilseeds (including fibers), their coefficients are positive and significant; but these are negative in the case of cereals, sugarcane, and plantation crops.

Figure 5(b) summarizes the relationships observed from Table 6b. What is observed is that with market access the production portfolio diversifies away from cereals towards cash crops but after a threshold the shift towards cash crops moderates. This can be expected, as cereals are essential for household consumption, and diversion of the area from cereals beyond a threshold has potential implications for household food security, particularly for the poor households whose production and consumption decisions are generally inseparable. Besides, differential resource constraints can also explain these patterns; for example, capital could a binding constraint to diversification on small farmers, while on large farms the higher labor and supervision costs could be a severe constraint. Emran and Shilpi (2012) also report a similar non-linear relationship between market access and diversification in the case of Nepal.

A unique feature of India's agrarian system is that it is dominated by small landholdings; over 68% of the farm households possess landholdings of less than or equal to one hectare, and they are commonly engaged in cereal-centric subsistence production. Notwithstanding resource constraints, for small farmers diversification in favor of comparatively remunerative crops such as vegetables and plantations could be an important means of raising their incomes (Birthal, Roy, and Negi 2015). Small farm households tend to have a larger endowment of labor relative to land; hence they can have an advantage over large farmers in the cultivation of labor-intensive high-value crops. Nevertheless, market access is an important barrier to diversification on small farms because of the higher cost of trade associated with a small marketed surplus.

Table 7 presents estimates of equation (4). With diversification index as regressand, the regression coefficients on land classes are positive and statistically significant, which clearly show a higher level of diversification on small, medium and large farms relative to marginal farms. Further, the extent of diversification is also found to increase with farm size. Cereals, pulses, vegetables, and oilseeds (including fibers) occupy proportionately less area on larger farms, but not sugarcane and plantation crops.

Expectedly, marginal farmers allocate a larger proportion of their land to cereals, pulses, and vegetables. Cereals account for a greater share of land for achieving the basic household food security, while vegetables are labor-intensive and generate a higher and continuous stream of income that matches closely with their resource endowments (less land and capital, more labor) and the need for the high-frequency cash flow. Sugarcane and plantation crops although more remunerative, their higher initial capital requirements and longer gestation periods favor their cultivation on large farms with a comparatively pliable capital constraint.

The effect of market access on diversification is, thus, heterogeneous across farms. With market access, marginal farmers tend to diversify their production portfolio more towards vegetables, while large farmers specialize in pulses and sugarcane. There is no significant influence of market access on crop portfolios of other farm classes. These findings presuppose that with market constraints relaxed, land (re)allocation decisions would vary across farm classes possibly due to the factors other than market access. These other factors hem in a wide range, where the ingredients such as social identity also matter, as some crops in India have traditionally been grown by some castes (e.g., vegetables by the Kurmis and Sainis). Birthal et al. (2013) observe a significantly higher probability of cultivation of vegetables among the households belonging to socially backward classes.

Effects of Government Interventions

Since the beginning of the Green Revolution in the mid-1960s, in the quest of improving food security, the government of India has followed a cereal-centric price policy. To provide farmers an adequate remuneration for their produce, the government has been fixing floor prices, i.e., minimum support prices (MSP) for several non-perishable commodities with an assurance of procurement if their open market prices at harvest fall below the government-set pre-announced support prices. Although applicable to 24 crops, the policy of minimum support price is effective only for rice and wheat that are procured in large quantities for the public distribution system and buffer stocking. Generally, the government procures 25-30% of the total output of rice and wheat, but this proportion varies widely across states (Figure 5). Our hypothesis is that the support prices backed by procurement make the playing field unleveled and act as a natural impediment to non-cereal crop adoption and intensification that would show up in low diversification away from cereals.

To test this hypothesis, we estimate equation (5) including an interaction between market access and procurement (as a proportion of total production of rice and wheat). As our policy variable is at the state level, the procurement variable is collinear with state fixed effects in equation (5) and drops out from the regression. The estimates of equation (5) are presented in Table 8(a). The coefficients of market access are comparable to those obtained earlier, in terms of their direction as well as the level of significance. However, with the policy variable added, the marginal effect of market access becomes smaller, implying an attenuating effect of the cereal-centric price policy on the role of market access in crop diversification. With diversification index being regressand the coefficient of market access is positive and statistically significant, but it turns out negative on interacting with procurement. In general, area shares of most crops, except vegetables, are negatively impacted by cereal-centric price policy.

We go a step further and regress the area shares of rice and wheat separately on the index of market access and its interaction with their respective level of procurement (as a proportion of their production). For rice as well as wheat, the coefficient of market access is negative, but it is positive on its interaction with procurement (Table 8(b)). This means that with a pre-promised price and open-ended procurement, diversifying agriculture away from rice and wheat is a challenge even amidst better market access. These crops also face lower production risks compared to cash crops. Figures 7(a) and (b) are generated from regressions where market access has been interacted with the procurement of cereals at MSP. Figure 7(a) shows the estimated marginal effect of market access on crop diversification index at an increasing level of procurement of cereals or in other words the government intervention in the food grain market. In the absence of government intervention in food grain markets, the improvements in market access lead to greater diversification in agriculture, but the increasing government intervention in food grain markets attenuates this relationship. Figure 7(b) shows the marginal effect of market access at increasing levels of procurement on acreage allocations to different crops. It clearly indicates that if the procurement of cereals abates, then with better market access the cropping pattern will undergo a shift away from cereals to cash crops like oilseeds, fibers, and vegetables.

On the whole, these findings compel us to conclude that policy-induced distortions in food grain markets lessen the positive influence of market access on crop diversification. Conditional on a level playing field, the agricultural land-use decisions are guided by the distance to markets, transportation and storage costs and market demand as implied in the Von Thunen theory of agricultural specialization.

Robustness Checks

Literature provides several indicators of market access, but most often their selection is ad hoc, leading to the problem of the appropriateness of econometric specification, erroneous conclusions and imprudent implications for policy actions (Chamberlin and Jayne 2013). With this in view, we test the sensitivity of our results to a traditional measure of market access, i.e., travel time to market or urban center. Information on travel time was extracted from the FAO-GAEZ dataset and is based on road distance from major urban centers.

Figure 8 plots index of market access against travel time. There is a strong negative relationship between the two measures of market access. This implies that our constructed measure of market access is strongly associated with lower travel time, and is consistent with the commonly used measures of market access. However, the advantage of our measure of market access is that it is theoretically founded, based on both the supply and the demand sides of trade.

Further, we estimate equation (3) replacing the index of market access with the travel time, and the results are presented in Table 9. Travel time does not seem to be significantly associated with diversification index. Its effects on area shares of crops or crop groups are like those obtained with our nuanced measure of market access. The higher travel time discourages the cultivation of bulky crops like vegetables and sugarcane because of the higher transportation costs.

Discussion

Diversification is an effective way of enhancing agricultural growth and reducing rural poverty in developing countries. Minot, Joshi, and Birthal (2006) and Birthal et al. (2013) show diversification as the second largest and sustainable source of agricultural growth after the technological change. Birthal, Roy and Negi (2015) for India, and Michler and Josephson (2017) for Ethiopia find diversification contributing to poverty reduction, and its impact is larger for smallholder farmers. Evidence also exists on its contribution to the resilience of agriculture to climatic shocks (Birthal and Hazrana 2019). These studies look at diversification from the perspective of income generation (Joshi, Birthal and Minot 2006; Birthal et al. 2013; Birthal, Roy and Negi 2015) and risk reduction (Michler and Josephson 2017; Birthal and Hazrana 2019). Either way, diversification has been found to contribute to enhancing agricultural growth and poverty reduction.

Market access is essential to harness the pro-poor growth potential of agricultural diversification. Farm households often face difficulties in accessing remunerative markets due to their remoteness, high transportation costs, asymmetry in information and lack of business skills essential to benefit from participation in markets. Several studies assess the effect of market access on several indicators of agricultural development like technology adoption, farm performance, diversification, and poverty. Emran and Hou (2013) show that in China the improved access to markets, domestic as well as international, could reduce poverty by 4-6%, the impact being bigger in case of domestic market access. Similar evidence has been reported by Diao, Magalhaes, and Silver (2019) who find that households' proximity to larger cities is associated with a lower probability of being poor. Even in developed countries like the United States, higher market access has been found to be associated with a lower incidence of rural poverty (Partridge and Rickman 2008). Some studies (Minten 1999; Muto and Yamano 2009; Shamdasani 2016) conclude that by reducing transportation costs and travel time the road infrastructure helps improve farm performance and farmers' participation in markets.

Some studies also examine farmers' choice of crops in response to changes in market access. Bittinger (2010) shows that Ethiopian farmers do respond to market access by altering their production portfolios; they diversify away from cereals, pulses, vegetables, and fruits to cash crops such as oilseeds, spices, and teff. From a study in Honduras, Buckmaster et al. (2014) show that there is a threshold distance to markets beyond which the production of fruits and vegetables does not occur as the income gains from production are outweighed by transportation costs.

Some studies specifically investigate the relationship between crop diversification and market access in the Indian context. Joshi et al. (2004) find a positive association between crop diversification and market access, measured by road density and urbanization. Rao, Birthal and Joshi (2006) also find that the districts better connected with roads and ones that are closer to urban centers are comparatively more diversified into vegetables and dairying, but not into fruits and plantation crops. Likewise, Shamdasani (2016) also shows that rural roads create incentives for farmers to allocate more land to high-value crops and to use improved technologies and farm inputs.

Note that, most studies use distance to urban centers, road connectivity or urbanization as a measure of market access. Emran and Shilpi (2012) develop a comprehensive measure of market access that integrates distance to an urban center and market size into a single measure and examine its association with crop diversification and area share of cash and non-cash crops in Nepal.

Our results are quite consistent with those reported by Emran and Shilpi (2012). As for Nepal, the diversification-market access curve seems to be concave, i.e., an increase in the extent of diversification with market access, but after a threshold, the relationship becomes weak possibly due to barriers other than the market access. We find such a relationship for vegetables and oilseeds, but not for cereals, pulses, and sugarcane and plantation crops. The scope of our paper is broader. It unpacks the effect of market access on individual crops or group of similar crops and by farm class. Moreover, it shows how government interventions in the foodgrain market can retard the pace of market-led diversification.

After a subjective threshold, in expanding their scale of production the small farmers are likely to face an increasing capital constraint, while labor and supervision cost could be binding factors for large farmers. Moreover, our findings by farm size show that compared to others, small farmers allocate a larger share of their land to vegetables that are labor-intensive and generate higher returns on a regular basis as these characteristics match with their resource endowments and cash flow requirements.

Finally, our findings show that cereal-centric policies cause distortions in the cropping pattern and deprive farmers of the benefits of diversification into relatively more remunerative cash crops. Such policies act as a disincentive to private investment in markets and associated infrastructure critical to diversification. Leaving aside the disincentive effect, such a price policy benefits more to farmers in the irrigated regions specializing in rice and wheat. There is also an argument that since the benefits of administered minimum support prices are directly proportional to marketed surplus, farmers with larger surpluses benefit more from the cereal-centric policies (Joshi, Birthal, and Minot 2006).

6. Conclusions and Policy Implications

This paper has assessed diversification and commercialization in Indian agriculture that are of great importance for sustainable development of agriculture and agriculture-based livelihoods, especially of smallholder farmers. Further, it looks into the effect of government interventions in food grain markets on the relationship between market access and product diversification.

We use novel data on local GDP and gravity model type measures to construct a measure of market access for a production location. We link this with granular tehsil level data on cropping patterns and gridded data on agroecological suitability and analyze both the dimensions of structural change, i.e., the pattern of product diversification and extent of market access that agricultural economists accept as commercialization of agriculture.

Traditionally, the distance to the nearest urban center has been taken as a measure of the market for agricultural producers. Combining it with the size of the local market, we construct a much broader measure of market access that reflects both the demand and the supply sides of trade. In empirical estimation, we also address possible endogeneity of market access using heteroscedasticity in error terms for identification and also test for non-linearity in the relationship between market access and crop diversification.

Our findings show a statistically significant effect of market access on crop diversification, away from principal cereal crops i.e. rice and wheat. The evidence clearly indicates this movement to be significantly determined by the relevant market size. The results imply that for farmers to move out of subsistence agriculture dominated by the production of cereals, access to richer urban centers is required, and a level playing field will motivate farmers to diversify more towards high-value crops.

On one side, market access has improved in India, its effects on fostering diversification have been clawed back by policies that end up favoring cereals relative to alternative crops. The role of policies although very commonly discussed has not been quantified and assessed in relation to market access, something that this paper does. For the first time, this paper quantitatively estimates the role of government intervention in foodgrain markets on the process of crop diversification, and our results clearly show that policy distortions attenuate the effects of market access on diversification.

Two important policy implications emerge from our findings. One, there is a need to improve the connectivity of remote rural locations with richer urban demand centers by investing more in public infrastructures such as road and communication networks. The improvement in public infrastructure would attract private investment in food processing, cold storages and refrigerated transport and value chains that are critical for fostering diversification into high-value food commodities that are often perishable. Two, India though has achieved self-sufficiency in cereals, yet excessive policy emphasis remains on cereal production. Our findings clearly suggest a need for agricultural policy, including the price policy, which is not distortionary of the cropping patterns and promotes efficiency and sustainability of agricultural production systems.

Diversification may be pitched against several poverty alleviation and social protection programs that require large public resources and often suffer from targeting errors. Our findings indicate that diversification is far more inclusive and is possibly a more sustainable means of increasing farmers' incomes and reducing poverty.

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Figures

Figure 1. Distribution of Simpson index of diversification

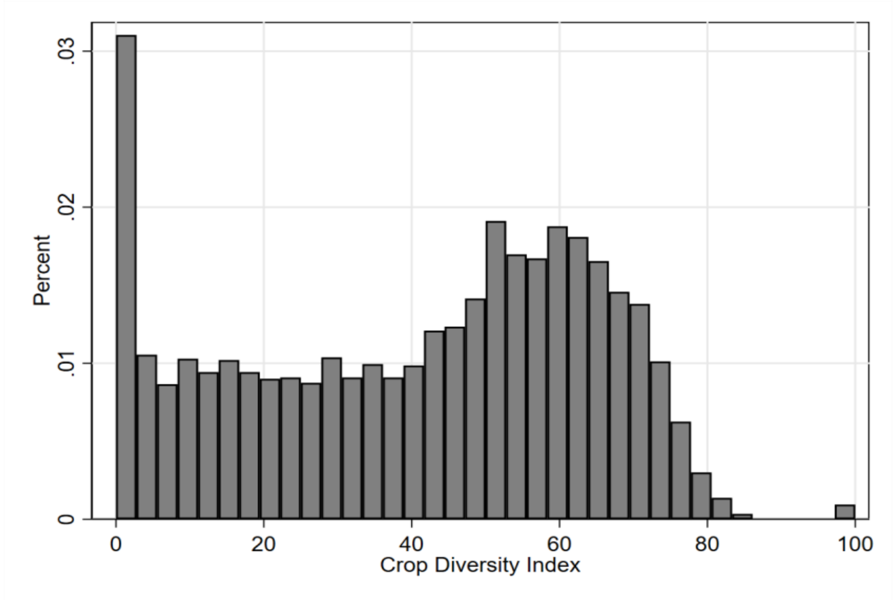


Figure 2. Location of urban centers of population at least 100 thousand

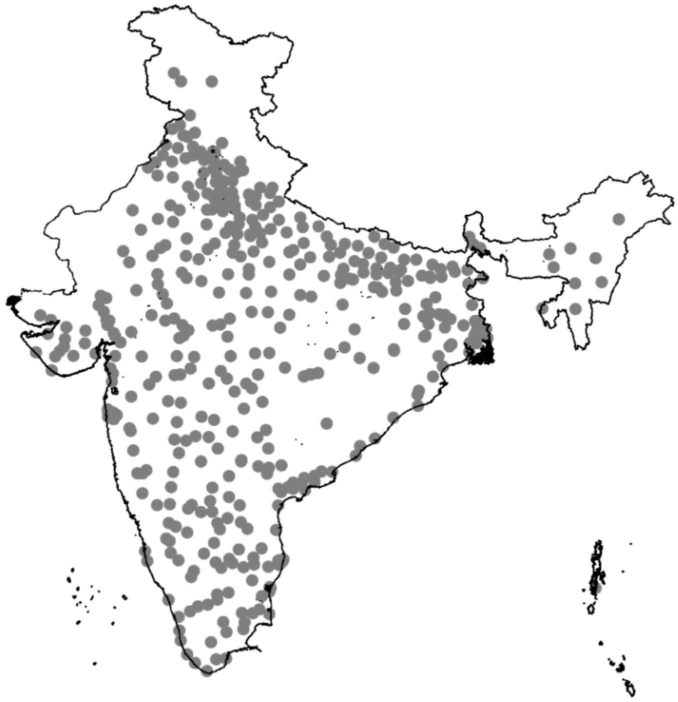
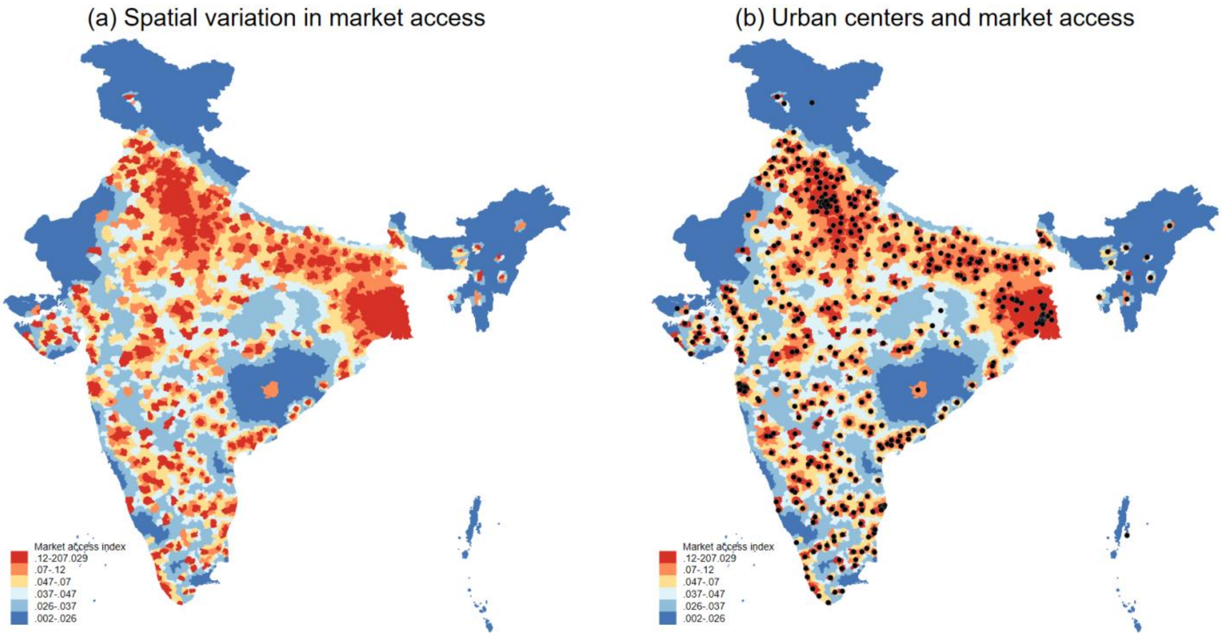
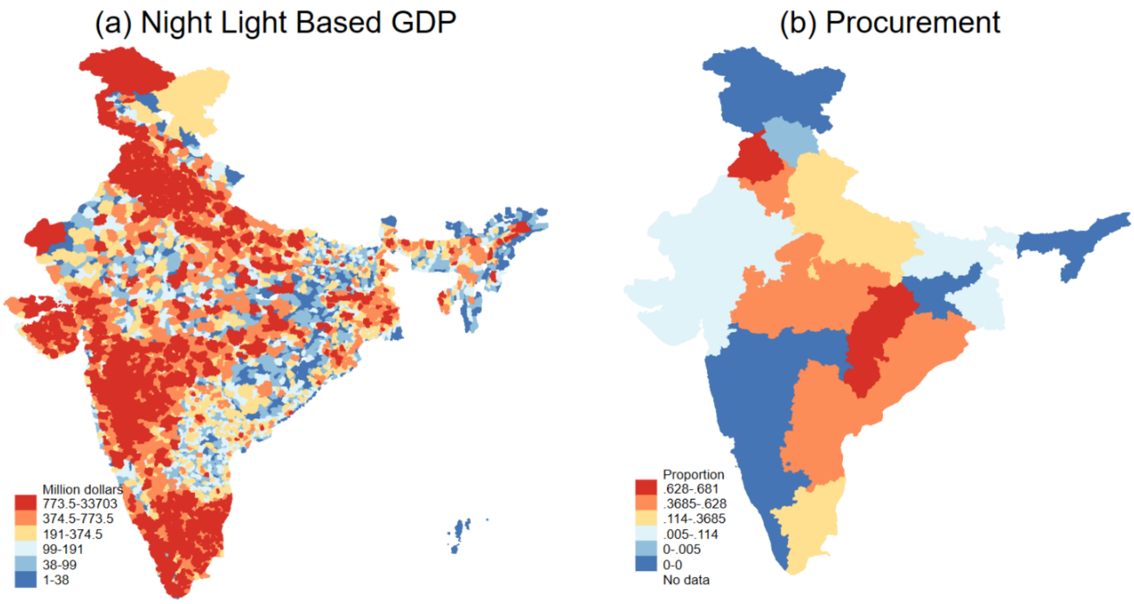


Figure 3. Market access based on the distance to major urban centers



Note: Panel (a) shows the spatial variation in the tehsil level market access index. Panel (b) shows the location of urban centers overlayed over the market access index.

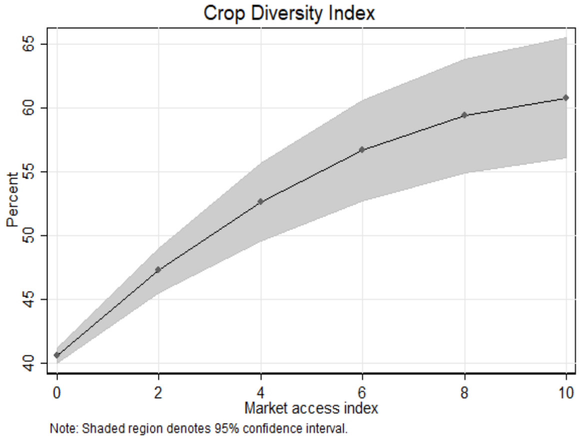
Figure 4. Map of night time light-based GDP, and government procurement of cereals



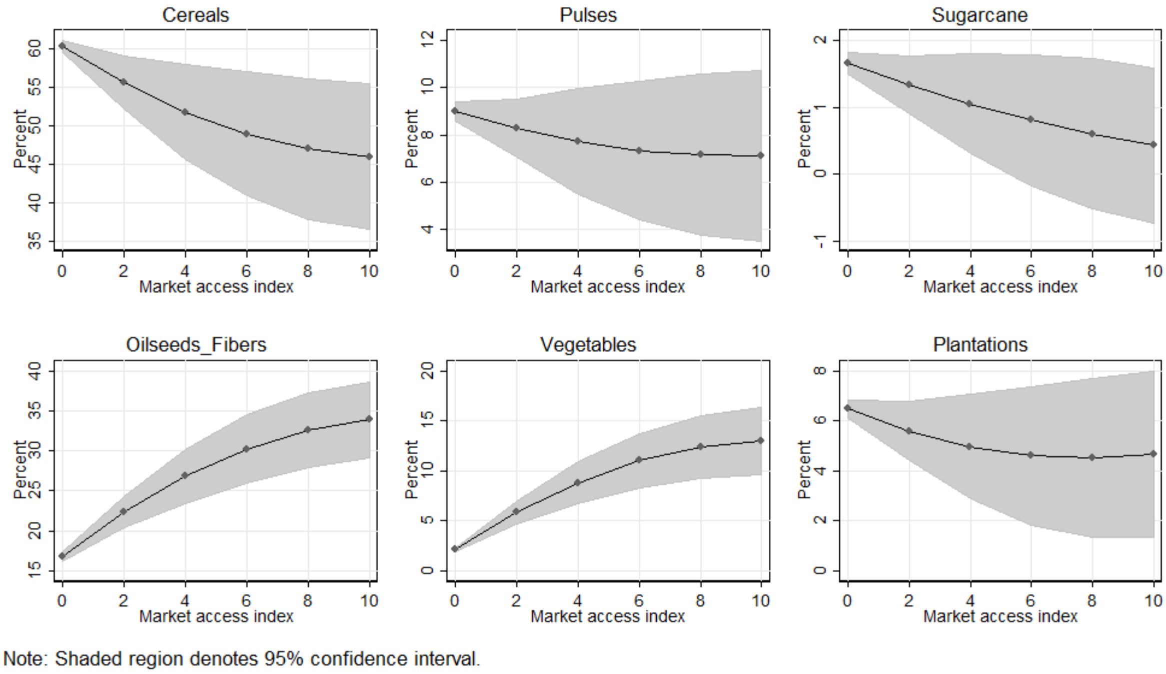
Note: Panel (a) shows the spatial variation in tehsil level night light-based GDP estimates in million dollars. Panel (b) shows the state-level proportion of rice and wheat procured by the government out of the total produced.

Figure 5. Relationship between market access and crop diversification

(a)



(b)



Note: Panel (a) plots the crop diversification index as a function of market access. Panel (b) plot the percent area allocated to a crop as a function of market access.

Figure 6. Proportion of output of rice and wheat procured by states out of total produced

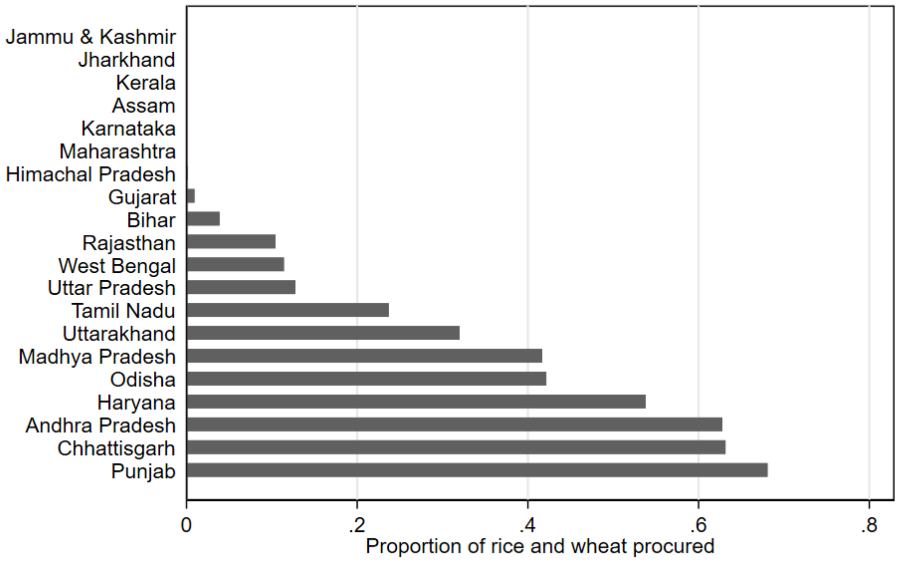
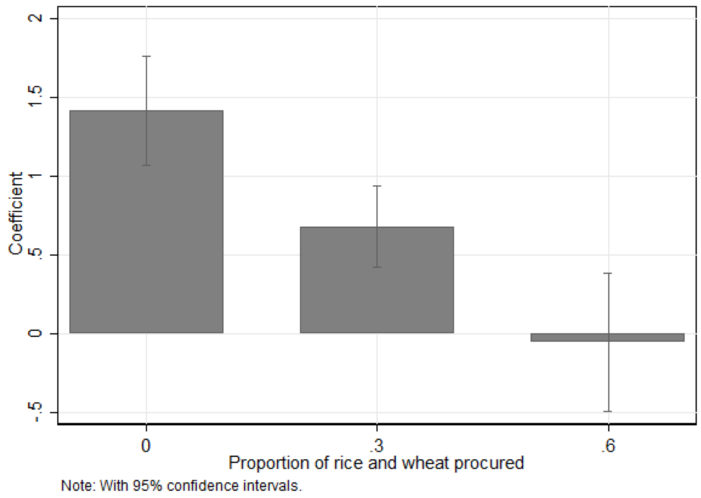
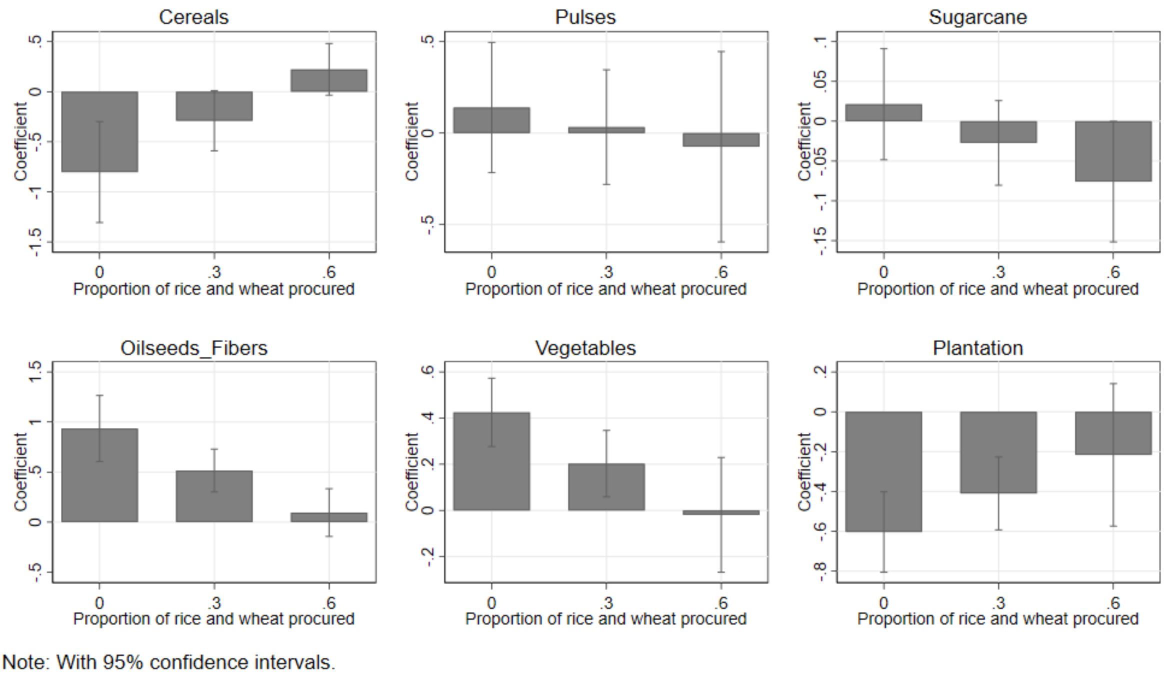


Figure 7. Effect of procurement policy on the relationship between market access and crop diversification

(a) Crop diversification index

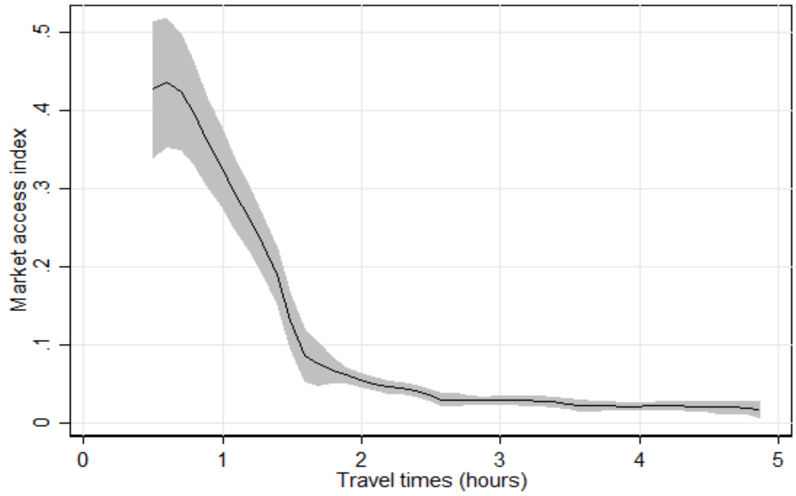


(b) Area allocation to crops



Note: The figures plot the marginal effects predicted from equation (5) where the index of market access is interacted with the state-level proportion of rice and wheat procured by the government out of the total produced.

Figure 8. Association between the index of market access and travel time



Note: Shaded region denotes the 95% confidence interval.

Tables

Table 1. Summary statistics

Variables	Source	Mean	SD	CV	Min	Max	N
Dependent variables							
Percent area under cereals	Agricultural census 2011	60.01	31.06	0.52	0.00	100.00	4188
Percent area under pulses	Agricultural census 2011	9.48	14.61	1.54	0.00	100.00	4188
Percent area under sugarcane	Agricultural census 2011	2.33	7.53	3.23	0.00	97.52	4188
Percent area under oilseeds-fibres	Agricultural census 2011	18.10	24.08	1.33	0.00	100.00	4188
Percent area under vegetables	Agricultural census 2011	2.77	7.48	2.70	0.00	81.32	4188
Percent area under plantation crops	Agricultural census 2011	7.32	14.07	1.92	0.00	100.00	4188
Crop diversity index	Agricultural census 2011	40.55	23.73	0.59	0.00	100.00	4199
Market access index	Agricultural census 2011	0.22	2.99	13.45	0.00	207.03	5469
Control variables							
Percent area under irrigation	Census 2011	43.26	30.52	0.71	0.00	126.39	4218
Percent villages with electricity	Census 2011	71.14	36.36	0.51	0.00	100.00	4224
Number of schools per person	Census 2011	2.23	1.18	0.53	0.28	20.16	4224
Number of hospitals per person	Census 2011	0.38	0.38	1.00	0.00	11.19	4224
Percent villages with a post office	Census 2011	26.64	23.49	0.88	0.00	100.00	4224
Percent villages with a railway station	Census 2011	4.54	8.12	1.79	0.00	100.00	4224
Percent villages with tractors	Census 2011	59.98	36.48	0.61	0.00	100.00	4224
Percent villages with telephone line	Census 2011	70.35	31.95	0.45	0.00	100.00	4224
Percent villages with a bank	Census 2011	19.14	15.89	0.83	0.00	100.00	4224
Percent villages with a road	Census 2011	83.09	21.39	0.26	0.00	100.00	4224
Percent villages with a local agricultural market	Census 2011	22.39	23.02	1.03	0.00	100.00	4224
Altitude (meters)	FAO-GAEZ	361.95	542.11	1.50	0.00	5058.16	5451
Slope index	FAO-GAEZ	3.54	1.56	0.44	0.00	9.00	5469
Temperature °C	FAO-GAEZ	25.54	2.96	0.12	-4.45	29.28	5280
Rainfall (mm)	FAO-GAEZ	1282.02	590.41	0.46	167.32	4398.20	5280
Agricultural suitability index	FAO-GAEZ	34.81	14.77	0.42	-0.01	71.77	5469

Note: The variables are summarized over all the available observations for each variable.

Table 2. Correlation matrix

	Cereals	Pulses	Sugarcane	Oilseeds-Fibers	Vegetables	Plantations crops	Crop diversity	Market access
Cereals	1							
Pulses	-0.404***	1						
Sugarcane	-0.147***	-0.073***	1					
Oilseeds-fibres	-0.715***	0.002	-0.080***	1				
Vegetables	-0.172***	-0.058***	0.010	-0.092***	1			
Plantation	-0.394***	-0.080***	-0.003	-0.045***	0.061***	1		
Crop diversity	-0.743***	0.346***	0.185***	0.420***	0.194***	0.360***	1	
Market access	-0.017	-0.007	0.010	0.004	0.067***	-0.002	0.032**	1

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3. Market access, crop diversity and cropping patterns: linear fixed effects model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Index of diversification	Cereals	Pulses	Sugar crops	Oilseed-fibres	Vegetables	Plantation crops
Market Access	**1.080****	**-0.754**	**0.179**	**0.013**	**0.471***	**0.359****	**-0.269***
	(0.444)	**(0.461)**	**(0.288)**	**(0.095)**	**(0.260)**	**(0.161)**	**(0.154)**
Irrigation	-0.091***	0.299***	-0.121***	0.047***	-0.186***	0.005	-0.044*
	(0.031)	(0.040)	(0.025)	(0.011)	(0.043)	(0.008)	(0.026)
Electricity	0.064***	-0.084***	0.020	0.007	0.046**	0.004	0.007
	(0.021)	(0.024)	(0.012)	(0.008)	(0.018)	(0.007)	(0.015)
Schools	-1.222**	-0.650	-0.223	-1.046***	0.519	0.675	0.725
	(0.581)	(0.997)	(0.357)	(0.286)	(0.657)	(0.540)	(0.560)
Hospitals	-1.499	3.471**	-0.205	0.301	-3.845**	-0.032	0.310
	(1.199)	(1.765)	(0.573)	(0.476)	(1.730)	(0.447)	(0.980)
Post office	-0.040	-0.073	0.011	-0.010	0.081	-0.018***	0.009
	(0.040)	(0.045)	(0.022)	(0.010)	(0.057)	(0.006)	(0.029)
Railway Station	-0.012	-0.034	-0.007	-0.044***	0.061	0.000	0.024
	(0.053)	(0.062)	(0.027)	(0.015)	(0.049)	(0.013)	(0.036)
Tractors	0.009	-0.007	-0.013	0.009	0.001	0.005	0.005
	(0.018)	(0.023)	(0.015)	(0.006)	(0.023)	(0.006)	(0.013)
Telephone	0.058***	-0.065*	0.007	0.001	0.010	0.015*	0.033
	(0.021)	(0.038)	(0.017)	(0.009)	(0.050)	(0.008)	(0.020)
Banks	-0.026	-0.042	0.019	0.022	-0.072**	0.017	0.057*
	(0.037)	(0.042)	(0.030)	(0.015)	(0.036)	(0.012)	(0.032)
Roads	0.034	0.003	-0.030*	0.012	0.007	0.005	0.002
	(0.029)	(0.036)	(0.018)	(0.010)	(0.030)	(0.014)	(0.022)
Agricultural markets	0.040	0.037	-0.004	0.013	-0.017	-0.002	-0.027
	(0.025)	(0.027)	(0.013)	(0.009)	(0.022)	(0.006)	(0.017)
Altitude (m)	0.001	-0.009	0.010*	0.002	0.014	0.004**	-0.022***
	(0.006)	(0.009)	(0.006)	(0.003)	(0.009)	(0.002)	(0.006)
Slope Index	1.615***	-1.539**	-1.143***	0.380	0.058	-0.042	2.286***
	(0.549)	(0.730)	(0.441)	(0.263)	(0.622)	(0.193)	(0.515)
Temperature (c)	-0.857	-0.558	2.212**	0.331	2.336	0.005	-4.325***
	(1.166)	(1.580)	(1.070)	(0.584)	(1.665)	(0.308)	(1.064)
Rainfall (mm)	-0.005**	0.006**	-0.003*	0.003**	-0.012***	0.001	0.005*
	(0.002)	(0.003)	(0.001)	(0.001)	(0.003)	(0.001)	(0.003)
Agricultural suitability	-0.084**	0.268***	-0.183***	0.004	-0.002	-0.001	-0.085**
	(0.042)	(0.062)	(0.035)	(0.016)	(0.047)	(0.015)	(0.034)
N	4138	4127	4127	4127	4127	4127	4127
R2	0.410	0.470	0.181	0.138	0.371	0.118	0.255

Note: All regressions include state fixed effects. Figures in parenthesis are standard errors robust to intra-district correlation of residuals. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Market access, crop diversity and cropping patterns: Tobit model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Index of diversification	Cereals	Pulses	Sugar crops	Oilseed-fibres	Vegetables	Plantation crops
Market Access	**1.078****	**-0.720**	**0.091**	**-0.014**	**0.518***	**0.371****	**-0.319***
	(0.446)	**(0.461)**	**(0.367)**	**(0.205)**	**(0.283)**	**(0.177)**	**(0.170)**
Irrigation	-0.091***	0.302***	-0.134***	0.099***	-0.215***	0.004	-0.053*
	(0.031)	(0.041)	(0.028)	(0.020)	(0.047)	(0.010)	(0.030)
Electricity	0.067***	-0.088***	0.027*	0.008	0.053**	0.010	-0.000
	(0.021)	(0.026)	(0.015)	(0.015)	(0.022)	(0.010)	(0.019)
Schools	-1.203**	-0.662	-0.290	-1.912***	0.647	0.656	0.621
	(0.582)	(0.997)	(0.408)	(0.642)	(0.737)	(0.568)	(0.615)
Hospitals	-1.531	3.556**	-0.346	-0.489	-4.417**	0.035	0.358
	(1.221)	(1.807)	(0.659)	(1.324)	(2.054)	(0.491)	(1.010)
Post office	-0.042	-0.072	0.010	-0.035	0.083	-0.020**	0.015
	(0.040)	(0.046)	(0.025)	(0.025)	(0.060)	(0.009)	(0.034)
Railway Station	-0.017	-0.021	-0.005	-0.092***	0.029	0.015	0.045
	(0.057)	(0.067)	(0.034)	(0.033)	(0.058)	(0.019)	(0.045)
Tractors	0.005	-0.004	-0.021	0.014	0.005	0.005	0.006
	(0.019)	(0.024)	(0.017)	(0.011)	(0.026)	(0.008)	(0.015)
Telephone	0.055**	-0.061	-0.001	0.023	0.013	0.023*	0.058**
	(0.022)	(0.039)	(0.020)	(0.020)	(0.055)	(0.013)	(0.028)
Banks	-0.032	-0.036	0.003	0.039	-0.095**	0.025	0.064*
	(0.038)	(0.044)	(0.036)	(0.028)	(0.040)	(0.015)	(0.037)
Roads	0.042	-0.005	-0.024	0.023	0.011	0.003	0.003
	(0.031)	(0.039)	(0.021)	(0.019)	(0.036)	(0.017)	(0.029)
Agricultural markets	0.044*	0.034	0.000	0.019	-0.004	-0.009	-0.036
	(0.026)	(0.029)	(0.016)	(0.023)	(0.026)	(0.010)	(0.025)
Altitude (m)	0.003	-0.010	0.014**	0.003	0.016	0.005**	-0.027***
	(0.007)	(0.009)	(0.007)	(0.006)	(0.010)	(0.002)	(0.007)
Slope Index	1.602***	-1.569**	-1.162**	1.029**	0.091	0.138	2.702***
	(0.558)	(0.741)	(0.508)	(0.499)	(0.692)	(0.244)	(0.613)
Temperature (c)	-0.592	-0.848	2.965**	0.529	2.971	0.188	-5.072***
	(1.200)	(1.620)	(1.242)	(1.040)	(1.808)	(0.403)	(1.231)
Rainfall (mm)	-0.004**	0.006**	-0.003**	0.003*	-0.012***	0.000	0.005
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.001)	(0.003)
Agricultural suitability	-0.086**	0.269***	-0.184***	0.011	0.008	0.004	-0.093**
	(0.042)	(0.063)	(0.037)	(0.029)	(0.050)	(0.018)	(0.038)
N	4138	4127	4127	4127	4127	4127	4127

Notes: All regressions include state fixed effects. Figures in parenthesis are standard errors robust to intra-district correlation of residuals. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5. Market access and crop diversification: Lewbel two-step estimator

	(1) Index of diversification	(2) Cereals	(3) Pulses	(4) Sugar crops	(5) Oilseed-fibres	(6) Vegetables	(7) Plantation crops
Market Access	**1.061*** **	**-0.523*** **	**0.151**	**-0.092*** **	**0.734*** **	**0.256*** **	**-0.095**
	(0.210)	**(0.152)**	**(0.176)**	**(0.025)**	**(0.125)**	**(0.056)**	**(0.114)**
Irrigation	-0.122***	0.347***	-0.077***	0.025***	-0.186***	-0.007*	-0.002
	(0.015)	(0.018)	(0.010)	(0.004)	(0.014)	(0.004)	(0.010)
Electricity	0.066***	-0.099***	0.015*	0.002	0.054***	-0.000	-0.010
	(0.015)	(0.017)	(0.008)	(0.004)	(0.012)	(0.005)	(0.008)
Schools	-1.171***	0.885	-0.692***	-0.578***	0.557	-0.211	1.141***
	(0.376)	(0.587)	(0.265)	(0.117)	(0.366)	(0.213)	(0.352)
Hospitals	-1.849**	4.193***	-0.266	-0.033	-5.439***	-0.357	-0.191
	(0.875)	(1.131)	(0.385)	(0.177)	(0.918)	(0.361)	(0.673)
Post office	-0.036**	-0.082***	0.015	-0.010***	0.092***	-0.011**	-0.006
	(0.018)	(0.022)	(0.013)	(0.004)	(0.020)	(0.005)	(0.013)
Railway station	-0.010	-0.029	0.005	-0.033***	0.034	-0.014	0.051*
	(0.043)	(0.050)	(0.026)	(0.010)	(0.043)	(0.013)	(0.028)
Tractors	0.007	-0.009	-0.007	0.003	0.025	0.003	-0.011
	(0.015)	(0.018)	(0.011)	(0.004)	(0.016)	(0.006)	(0.010)
Telephone	0.053***	-0.054**	0.014	-0.005	-0.013	0.017***	0.042***
	(0.018)	(0.023)	(0.012)	(0.006)	(0.019)	(0.006)	(0.010)
Banks	-0.015	-0.066*	0.010	0.010	-0.074**	0.006	0.018
	(0.029)	(0.034)	(0.021)	(0.008)	(0.029)	(0.009)	(0.020)
Roads	0.009	0.037	-0.028**	0.010*	-0.004	-0.011	-0.024**
	(0.023)	(0.026)	(0.013)	(0.006)	(0.017)	(0.010)	(0.012)
Agricultural Markets	0.038**	0.040**	0.001	0.003	-0.034**	-0.006	0.011
	(0.015)	(0.017)	(0.010)	(0.004)	(0.014)	(0.006)	(0.009)
N	4138	4127	4127	4127	4127	4127	4127
R2	0.396	0.446	0.121	0.111	0.340	0.075	0.159
Breusch-Pagan test $\chi^2(1)$	14982.49	14982.49	14982.49	14982.49	14982.49	14982.49	14982.49
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
White's test of heteroskedasticity χ^2 (422)	98.27	98.27	98.27	98.27	98.27	98.27	98.27
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Breusch-Pagan test $\chi^2(1)$	2.09	137.67	921.88	3335.51	1185.88	1717.81	1910.76

Notes: All regressions include state fixed effects. The omitted exogenous variables used as instruments in the Lewbel estimator are altitude, slope index, temperature, rainfall, and crop suitability index. Figures in parenthesis are robust standard errors. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6(a). Non-linear effects of market access on crop diversification

	(1) Linear fixed effects	(2) Lewbel two-step estimator
Dependent variable: Index of crop diversification		
Market access	2.853**	3.077***
	(1.191)	(0.943)
Market access (squared)	-0.117*	-0.136***
	(0.064)	(0.052)
N	4138	4138
R^2	0.407	0.046
Lind and Mehlum (2010)	1.85**	2.25**
U test for nonlinearity	[0.033]	[0.012]

Notes: All regressions include state fixed effects and control variables summarized in tables 1. Figures in parenthesis are standard errors robust to intra-district correlation of residuals. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6(b). Non-linear effects of market access on cropping patterns: Lewbel two-step estimator

	(1) Cereals	(2) Pulses	(3) Sugar crops	(4) Oilseeds-fibres	(5) Vegetables	(6) Plantation crops
Market access	-4.764***	0.650	-0.798***	3.359***	1.952***	-0.762*
	(1.331)	(0.504)	(0.192)	(0.595)	(0.434)	(0.408)
Market access (squared)	0.243***	-0.032	0.037***	-0.164***	-0.087***	0.045*
	(0.074)	(0.025)	(0.011)	(0.036)	(0.023)	(0.024)
N	4127	4127	4127	4127	4127	4127
R2	0.377	0.121	0.070	0.277	0.051	0.140
Lind and Mehlum (2010)	3.04***	1.86**	3.41***	3.67***	4.49***	2.12**
U test for non-linearity	[0.001]	[0.031]	[0.000]	[0.000]	[0.000]	[0.017]

Notes: All regressions include state fixed effects and control variables summarized in tables 1. Figures in parenthesis are robust standard errors. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Market access, crop diversification by landholding sizes: Lewbel two-step estimator

	(1) Index of diversification	(2) Cereals	(3) Pulses	(4) Sugar crops	(5) Oilseeds-fibres	(6) Vegetables	(7) Plantation crops
Small	0.011***	-1.830***	-0.142	0.999***	0.436*	-0.191*	0.535***
	(0.003)	(0.258)	(0.126)	(0.172)	(0.239)	(0.101)	(0.152)
Medium	0.018***	-1.794***	-0.666***	0.990***	-0.261	-0.398***	0.674***
	(0.004)	(0.290)	(0.192)	(0.217)	(0.333)	(0.143)	(0.205)
Large	0.041***	-2.945***	-1.445***	0.421	-1.124**	-0.994***	0.501
	(0.007)	(0.465)	(0.261)	(0.266)	(0.451)	(0.255)	(0.333)
Marginal*Market access	0.009**	-0.667	-0.074	-0.185	0.258	0.227*	-0.275
	(0.004)	(0.469)	(0.384)	(0.288)	(0.328)	(0.128)	(0.344)
Small*Market access	-0.002	0.110	0.188	0.161	0.030	-0.085	0.066
	(0.002)	(0.250)	(0.201)	(0.154)	(0.124)	(0.112)	(0.182)
Medium*Market access	-0.006**	0.052	0.191	0.241	0.100	-0.107	-0.303
	(0.003)	(0.276)	(0.182)	(0.151)	(0.362)	(0.166)	(0.196)
Large*Market access	-0.008**	0.172	0.312*	0.283*	-0.275	-0.089	0.345
	(0.003)	(0.293)	(0.175)	(0.159)	(0.369)	(0.127)	(0.640)
N	16413	16166	16166	16166	16166	16166	16166
R^2	0.294	0.415	0.136	0.104	0.324	0.079	0.252

Notes: All regressions include state fixed effects and control variables summarized in tables 1. The base omitted category is marginal farmers. Figures in parenthesis are standard errors robust to intra-district correlation of residuals. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 8. Market access, procurement and diversification: Lewbel two-step estimator

(a)

	(1) Index of diversification	(2) Cereals	(3) Pulses	(4) Sugar crops	(5) Oilseeds-fibres	(6) Vegetables	(7) Plantation crops
Market access	1.654***	-1.351**	0.176	0.112	0.973***	0.476**	-0.385*
	(0.534)	(0.627)	(0.400)	(0.154)	(0.309)	(0.192)	(0.209)
Procurement*Market access	-2.480***	2.415**	-0.009	-0.436	-2.054***	-0.479	0.563
	(0.923)	(1.159)	(0.950)	(0.278)	(0.714)	(0.364)	(0.428)
N	4138	4127	4127	4127	4127	4127	4127
R^2	0.409	0.470	0.180	0.137	0.371	0.119	0.254

Notes: All regressions include state fixed effects and control variables summarized in tables 1. Figures in parenthesis are standard errors robust to intra-district correlation of residuals. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

(b)

	(1) Rice	(2) Wheat
Market access	-1.334**	-0.070
	(0.555)	(0.153)
Rice procurement*Market access	2.266***	
	(0.748)	
Wheat procurement*Market access		0.237
		(0.272)
N	4115	4110
R^2	0.117	0.019

Notes: All regressions include state fixed effects and control variables summarized in tables 1. Figures in parenthesis are standard errors robust to intra-district correlation of residuals. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9. Travel time and crop diversification: linear fixed effects model

(a) Linear

	(1) Index of diversification	(2) Cereals	(3) Pulses	(4) Sugar crops	(5) Oilseeds-fibres	(6) Vegetables	(7) Plantation crops
Travel time (hours)	-0.565	2.416	1.384**	-1.176***	-1.667	-1.026**	0.069
	(1.248)	(1.502)	(0.633)	(0.393)	(1.234)	(0.429)	(0.772)
N	4138	4127	4127	4127	4127	4127	4127
R^2	0.406	0.460	0.160	0.140	0.372	0.120	0.249

Notes: All regressions include state fixed effects and control variables summarized in tables 1. Figures in parenthesis are standard errors robust to intra-district correlation of residuals. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

(b) Non-linear

	(1) Index of diversification	(2) Cereals	(3) Pulses	(4) Sugar crops	(5) Oilseeds-fibres	(6) Vegetables	(7) Plantation crops
Travel time (hours)	1.520	0.725	0.604	-1.768*	-0.637	-2.574**	3.650**
	(2.262)	(2.725)	(1.586)	(0.921)	(2.217)	(1.090)	(1.491)
Travel time (squared)	-0.498	0.404	0.186	0.141	-0.246	0.370*	-0.855**
	(0.574)	(0.598)	(0.358)	(0.146)	(0.407)	(0.223)	(0.380)
N	4138	4127	4127	4127	4127	4127	4127
R^2	0.406	0.460	0.160	0.140	0.372	0.121	0.251

Notes: All regressions include state fixed effects and control variables summarized in tables 1. Figures in parenthesis are robust standard errors. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.