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Investigating the impact of information on the efficiency of smallholder dairy production systems in India and the lessons for livestock extension policy

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Abstract Using data from a nationally representative farm survey and applying the instrumental variable method, this study has assessed the impact of information on the efficiency of smallholder dairy farming in India. There are four key highlights of this study. One, using information in farm decisions leads to an improvement in dairy productivity by about 15%. Two, different types of information have differential impacts — information on livestock management has a more significant effect than on health, breeding, and nutrition. Three, the payoff is larger for joint use of information than to any kind of information used in isolation. Four, there is also an information source effect — public extension system has a larger effect than any other information source.

Keywords Information, efficiency, dairying, India

JEL codes Q12, Q16

In developing countries, which are dominated by resource-poor small landholders, livestock are not only a source of nutritious foods for humans, draught power, and organic manure for agriculture, they also act as a financial institution—a bank deposit with offspring as interest and self-insurance during income shocks—and as an instrument for reducing socio-economic inequality (Delgado et al. 1999; Birthal et al. 2014) and rural poverty (Heffernan 2004; Upton 2004; Birthal and Taneja 2012; Birthal and Negi 2012; Bijla 2018). Using data from a large-scale survey of farm households in India, Birthal and Negi (2012) have empirically demonstrated that compared to the income from crop farming, the income from animal farming is more equally distributed and has 1.4 times larger poverty reduction potential. Using a panel dataset on rural households, Bijla (2018) too has shown that livestock help households escape poverty and prevent them from falling into poverty.

India's livestock production system has experienced a significant demand-driven growth over the past five decades. Milk production, which had rarely exceeded 25 million tons during the 1960s and 1970s, crossed 210 million tons in 2020–21 (GoI 2022). Similarly, the production of eggs increased from 10.1 billion in 1980–81 to 114.4 billion in 2019–20. Overall, the economic contribution of livestock has grown faster than that of crops, making it an engine of agricultural growth. Its share in agricultural growth increased from 32% in the 1990s to 36% in the 2000s (Birthal and Negi 2012) and further to over 50% in the 2010s (Birthal and Mishra 2021). In 2019–20, livestock contributed 4.5% to the overall gross domestic product (GDP) and 29.7% to the agricultural GDP.

Nevertheless, the need for a sustainable growth in livestock production remains as urgent as in the past. The growing population, urbanization, and increasing per capita income have been fuelling rapid changes in food consumption patterns in favour of animal-source foods (Hamshere et al. 2014). The trends in these factors have been quite robust, and these are unlikely to subside soon, implying a faster increase in the demand for animal-source foods. By 2050, in a business-as-usual scenario, the demand for most animal-source foods is projected to be more than double that in 2009 (Hamshere et al. 2014).

India has a large population of diverse livestock species; yet, fulfilling the future demand for animal-source foods from the domestic production would be challenging. The current productivity levels of most livestock species are low. For instance, the annual milk yield of a cow in India is about 1,700 kilograms, which is just 16% that in North America and 25% that in Europe.

Further, resource-poor smallholders—or households cultivating plots of land as small as one hectare or even smaller, with an average herd size that hardly exceeds two animals—dominate India's livestock production systems (Birthal and Mishra 2021). Smallholder farmers face several constraints, including the scarcity of feed and fodder, and poor access to animal breeding and health services, credit, and markets, in improving livestock productivity.

Information can catalyse a transformation in smallholder production systems. Farmers' access to and use of information influence their decision to adopt improved technologies and practices and, consequently, farm outcomes (Mwabu 2001; Liu 2013; Bandierra and Rasul 2006; Conley and Udry 2010; Birthal et al. 2015). However, most of these studies have analysed the impact of information on returns from crop farming, and crop prices. Our understanding of the impact of information on the performance of other agricultural activities, including animal husbandry, and fisheries, is extremely limited.

On the other hand, with the increasing biotic and abiotic pressures on animal production, the demand for information is expected to increase exponentially. Furthermore, the inherent potential of ruminants' greenhouse gas (GHG) emissions, and the zoonotic nature of several animal diseases, would compel farmers to adjust their production practices to protect the environment, conserve natural resources, and ensure food safety and hygiene.

Farmers' information needs are diverse. They need information on animal breeds and breeding practices, feeds and feeding practices, disease prevention and control, animal housing, clean production practices, food safety standards, credit, insurance, markets, prices, and trade. A single agency is unlikely to cater to all sorts of information; for their information needs, therefore, farmers rely on multiple sources, including traditional and modern, public and private, formal and informal. These sources likely differ in the quality of information and the method of its delivery and, hence, in their impact on farm outcomes.

This paper assesses the impact of information on the efficiency of dairy farming in India by its type and source. The study uses data from a nationally representative survey of farm households conducted by the National Sample Survey Office (NSSO) of the Government of India. This survey contains data on the subject and sources of information along with several farm and household characteristics, which allow us to estimate the impact of different types and sources of information on farm outcomes, controlling for several covariates that can potentially influence the farm outcomes.

Nevertheless, establishing a causal relationship between the information and farm outcomes is challenging. Several observable and unobservable factors may simultaneously influence the uptake of information and the farm outcomes, leading to bias in its impact (Aker 2011; Birthal et al. 2015). This study employs the instrumental variable (IV) method to estimate the true effect of information, therefore.

To the best of our knowledge, there is hardly any empirical evidence on the impact of information on livestock productivity. Ours is perhaps the first study that analyses the relationship between the information and livestock productivity. Four key findings have emerged from this study.

Controlling for several observable and unobservable covariates, using information in farm decisions results in 15% higher milk yield.

Information has a source effect on productivity — information acquired from public sources impacts productivity greater than information sourced from social networks, mass media, private service providers, and input dealers.

The impact of information differs by its content—livestock management information is more effective than information on animal breeding, feeding, and health.

The payoff from using different sorts of information in combination is higher than from using any type of information in isolation.

Our findings have some important implications for developing countries, where governments rarely accord priority to livestock extension systems (Morton and Matthewman, 1996). In India, for instance, investment on extension accounts for hardly 2% of the total public spending on livestock sector (Birthal and Mishra 2021). Only about 25% of livestock farmers have access to information, mainly from non-governmental sources. The outreach of the public extension system is limited to 14% of information users.

Our findings indicate that a comprehensive livestock extension strategy needs to be designed to empower farmers to cope with the challenges in the process of the transformation of the livestock production systems.

Data and descriptive statistics

This study uses data from a nationally representative survey of farm households conducted by the National Sample Survey Office of the Ministry of Statistics and Programme Implementation, Government of India, for the agricultural year 2018–19 (NSSO 2021). This survey is a sequel to the surveys conducted in 2002–03 (NSSO 2005) and 2012–13 (NSSO 2014).

This survey aims to track the changes in the status of farming and farm households and the factors underlying these dynamics. The survey followed a multistage stratified random sampling procedure (see NSSO (2021) for sampling details) and collected data from 50,840 farm households spread over 5,885 villages across all the states of India. Compared to the previous farm surveys, this survey is extensive in its coverage of several characteristics of farming and farm households.

The survey provides data on the subsectors of agriculture (crops, livestock, and fisheries) and on the subject and channel of information dissemination for each subsector. It contains data on the production and value of crops, livestock, and fisheries outputs, and on farm and household variables (land and livestock holdings; irrigation coverage; income sources; access to credit; disposal of farm produce; and age, gender, education, social status (caste and religion) of household heads, and their affiliation with formal or informal farmer organizations). Yet, a key limitation is that the dataset provides production cost data not by individual farm commodity but by subsector.

Characteristics of information users and non-users

Dairying has a 20% share in the value of agricultural output. It is the largest agricultural activity. Therefore, this study focuses on examining the impact of information on dairy productivity.

The survey data shows that over 50% of the farm households in India own one or the other livestock species and 63% of them are engaged in dairying (in-milk cows and buffaloes). Farm households' informational constraints are acute: only 25% have access to information on livestock production and management. Notably, most information seekers (92%) utilize it in their decision-making. Hence, our analysis is based on the use of information and not access to it.

Farmers' access to, and use of, information is influenced by demographic characteristics (age, education, and gender of the household head or decision-maker); availability of labour (family size); socio-economic status (religion, caste, assets, and income); landholding size; irrigation status; number and type of livestock owned; input use in livestock production; and access to credit, market and support services (Ali 2012; Alvarez and Nuthall 2006; Babu et al. 2011; Carter and Batte 1993; Okwu and Dauda 2011; Solano et al. 2003).

Table 1 compares the key characteristics of non-users and users of information. Regarding demographic characteristics, the heads of information-using households are older and have a slightly higher level of schooling. The number of households reporting formal training in agriculture and allied activities and affiliation with farmer organizations is extremely small, but their proportion is higher among information users.

The information-using households have smaller families but a more diversified income portfolio (non-farm business activities, wages, salaries, and remittances). Interestingly, there is no gender bias in accessing and using information—the proportion of

Table 1. Means and standard deviations of characteristics of users and non-users of information

	Non–users		Users		Difference in means and proportions (t–statistics)
Milk yield (litre/in–milk animal/annum)	1716.835	(1498.28)	2467.963	(1873.30)	–26.7***
Household characteristics					
Family size (No.)	5.51	(2.58)	5.07	(2.45)	9.8***
Age of the household heads (years)	51.94	(13.21)	52.56	(13.04)	–2.65**
Female–headed household (%)	7.07	(0.26)	6.82	(0.25)	0.6
Education level (% household heads)		–		–	
Illiterate	34.79	(0.48)	31.71	(0.47)	3.65***
Below primary	8.96	(0.29)	10.62	(0.31)	–3.2**
Primary	14.65	(0.35)	16.10	(0.37)	–2.3**
Middle	16.03	(0.37)	15.64	(0.36)	0.6
Secondary	12.88	(0.33)	14.76	(0.35)	–3.15**
Higher secondary	7.01	(0.26)	6.29	(0.24)	1.6*
Graduate and above	5.68	(0.23)	4.88	(0.22)	2**
Caste (% households)		–		–	
Scheduled caste	11.31	(0.32)	7.68	(0.27)	6.75***
Scheduled tribe	13.56	(0.34)	11.05	(0.31)	4.25***
Other backward caste	45.68	(0.50)	52.19	(0.50)	–7.4***
Upper or other caste	29.45	(0.46)	29.08	(0.45)	0.45
Net assets (Rs/person)	1699.05	(19173.66)	3468.42	(48848.71)	–1769.375***
Formal training in agriculture (% households)	1.81	(0.13)	3.23	(0.18)	–5.55***
Non–farm business income (% households)	7.84	(0.27)	8.97	(0.29)	–2.35**
Wages, salary and remittance (% households)	46.89	(0.50)	53.07	(0.50)	–7***
Farm characteristics					
Landholding size (ha/household)	1.04	(1.41)	1.05	(1.76)	–0.5
Area irrigated (%)	63.14	(0.44)	52.87	(0.47)	12.9***
Herd size (No. of in–milk animals/household)	1.54	(1.15)	1.92	(2.50)	–13.9***
Proportion of buffaloes in herd	22.04	(0.71)	25.63	(0.80)	–2.8**
Breeding charges (Rs/animal)	123.64	(1,088.06)	306.18	(3,475.02)	–5.35***
Feed cost (Rs/animal)	3507.37	(3,873.81)	5021.27	(5,584.56)	–19.8***
Veterinary charges (Rs/animal)	90.91	(465.97)	250.67	(659.06)	–17.5***
Membership of farmer organizations (% households)	0.34	(0.06)	2.42	(0.18)	–11.3***

Note Standard deviations are in parentheses. *** and ** denote significance at the 1% and 5% levels, respectively.

female-headed households is almost identical in both categories.

The social status of households can differentiate them in their access to, and use of, information and its outcomes (Batte and Arnholt 2003; Ali 2012; Birthal et al. 2015). Caste is an important social identity in rural India, and households at the bottom of the caste hierarchy (Scheduled Castes and Scheduled Tribes) have lower access to information (Birthal et al. 2015). A look at the distribution of non-users and users of information by caste confirms this—the proportion of lower-caste households among information-using households is low (Table 2 in the Appendix).

In terms of farm characteristics, information non-users and users have an identical landholding size on average, but users' access to irrigation is lower. On the other hand, information users have a larger herd size (in-milk cows and buffaloes). Notably, the availability of information facilitates households to expend more on feeds, animal health, and breeding.

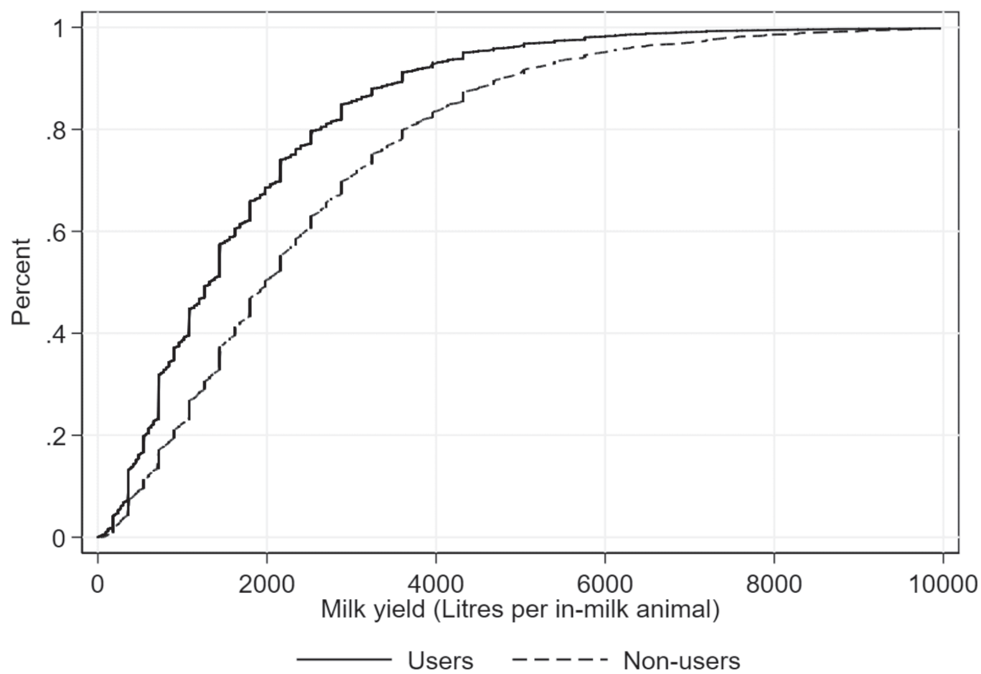

Figure 1. Cumulative distribution functions of milk yield for non-users and users of information

Information users realize almost 1.5 times the milk yield as non-users (Table 1). The difference in the cumulative distribution functions of milk yield for information non users and users is significant (Figure 1), and it is confirmed by the Kolmogorov-Smirnov test (K-S =0.21, p=0.0).

Heterogeneity in information and its sources

Livestock farmers' information needs are diverse, ranging from information on breeds and breeding practices, feed and nutrition, diseases and their management, animal hygiene and shed management, food safety standards, markets, prices, and trade. Farmers acquire such information from several sources, including public and private, formal and informal, traditional and modern. The public information system comprises government institutions, including veterinary hospitals, dispensaries, artificial insemination centres, research institutions, Krishi Vigyan Kendras (agriculture science centres), agricultural universities /colleges, dairy cooperatives, and government extension agents, and farmer producer organizations.

Following Anderson and Feder (2007) and Aker (2011), the rest of the information channels is aggregated into private information channels, mass media, input dealers, and progressive farmers. Private information sources are private clinics, nongovernmental organizations, and private commercial agents (including contract farming sponsors and companies) and commodity traders and processors. Mass media comprises telephones, mobile phones, radio, print, and the internet and other electronic media.

Farmers' information needs are diverse, and they seek these from multiple sources; hence, information sources are not mutually exclusive. The information on a subject can be accessed from various sources, or a single source can provide all sorts of information, and farmers seek information from multiple sources. About 73% seek only one type of information, and 60% of them acquire it from two or more sources; the rest acquire more than one type of information and mostly from more than one source (Table 1 in the Appendix).

A two-way frequency distribution of farmers by subject and information source shows that private service providers appear to be the dominant source of information (Table 2). Overall, 39% of dairy farmers have acquired information from private sources. The outreach of other information sources, including the public extension system, is almost equal, catering to the information needs of around 15% of the farmers.

Information on animal health is the most sought after; and over 50% of farmers acquire it from private

Table 2 Frequency distribution of information by its subject and source

	Breeding	Feeding	Health	Management	All
Progressive farmers	19.83	26.99	43.85	9.33	100
	16.48	23.38	14.92	21.12	17.43
	[440]	[599]	[973]	[207]	[2219]
Input dealers	21.15	20.97	45.56	12.32	100
	13.37	13.82	11.79	21.22	13.26
	[357]	[354]	[769]	[208]	[1688]
Mass media	22.60	18.87	50.73	7.80	100
	17.90	15.57	16.45	16.84	16.61
	[478]	[399]	[1073]	[165]	[2115]
Government	21.22	20.49	51.62	6.66	100
	14.19	14.29	14.14	12.14	14.03
	[379]	[366]	[922]	[119]	[1786]
Private	20.63	17.14	56.53	5.71	100
	38.05	32.94	42.69	28.67	38.68
	[1016]	[844]	[2784]	[281]	[4925]
All	20.97	20.12	51.21	7.70	100
	100	100	100	100	100
	[2670]	[2562]	[6521]	[980]	[12733]

Note

The figures in the upper row against an information source are the percentage of households seeking different kinds of information from that source.

The figures in the lower row are the percentage of households seeking information from different sources.

The square brackets contain the number of households seeking information from a particular source.

sources. Private sources are important also for information on animal breeding (38%) and feed and nutrition (33%). Mass media and social networks (farmer-to-farmer exchange) are used by around 17% of the farmers. The outreach of the public extension system is limited to only 14% of the farmers, irrespective of the subject of the information.

The possibility that the content and source of information affect the productivity cannot be ruled out. The kernel density functions of milk yield by type of information (Panel A) and also by source of information (Panel B) differ (Figure 2), providing preliminary evidence of their differentiated impact on dairy productivity.

Empirical strategy

To assess the impact of information on productivity, we begin with estimating the following linear specification:

$$Y_i = \alpha + \beta D_i + \gamma X_i + \eta_i \qquad (1)$$

where,

Y_i denotes milk yield realized by the ith farm household;

X_i is a vector of demographic, farm, and institutional characteristics;

D_i is a categorical variable, taking the value of 1 if the household uses information in decision-making, and 0 otherwise; and

η_i is an independent and normally distributed error term.

If X_i includes all the variables that influence the use of information, and it is simultaneously uncorrelated with the error term (η_i), then an ordinary least squares (OLS) estimate of β in Equation 1 is consistent, that is, it provides the true effect of information on Y_i.

However, it is possible that X_i does not include the variables that influence the use of information, such as farmers' inherent abilities, skills, risk preferences,

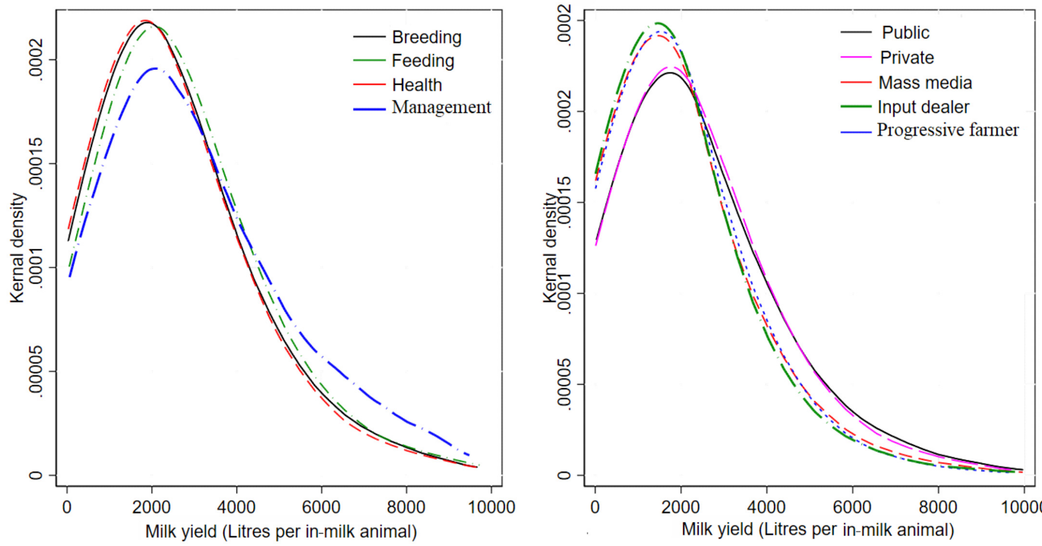

Figure 2. Kernel density functions of milk yield by type and source of information

and social ties. Such unobserved factors cannot be controlled for and may lead to omitted variable bias.

To deal with such potential biases, we employ the instrumental variable (IV) approach. An ideal instrument is correlated with the use of information (I_i has a direct effect on D_i) but not with the outcome (I_i does not have a direct effect on Y_i). Being correlated with the use of information and uncorrelated with the outcome, the instrument effectively randomizes households across treatments and achieves equal distribution of both the characteristics and the pre-treatment outcomes. Additionally, the IV method addresses both overt and unobserved biases in estimating the average treatment effect.

To construct an instrumental variable, we exploit the role of local social networks in information transmission (Evenson and Mwabu 2001; Bandierra and Rasul 2006; Conley and Udry 2010; Liu 2013). The rationale is that if a larger proportion of the farmers in the network are informed, the likelihood of a particular farmer being informed would be greater (the first condition of IV is likely to be satisfied). In addition, the proportion of informed farmers in the network should not directly affect the productivity on a particular farm (the second condition of IV is satisfied).

The literature does not provide a uniform definition for “social network”, so here we consider it to be composed of the individuals whose mean outcome and characteristics influence an individual’s outcome and characteristics (Bandiera and Rasul 2006; Conley and Udry 2010). The reference groups for a farmer in rural India need not be geographically most proximate but of the same caste, religion, or ethnic group (Fontaine and Yamada 2011). Hence, we define a social network for each farmer based on geographical proximity (residing in the same village) and social identity (belonging to the same caste). Table A2 shows farm households’ use of information from different sources by their caste group.

With these conditions in mind, we define our instrument as the proportion of informed farmers in a network; to determine whether a farmer uses information, we specify the equation

$$D_i = \delta + \theta I_i + u_i \qquad (2)$$

Combining Equations 1 and 2

$$Y_i = \vartheta + \tau I_i + \gamma X_i + \eta_i \qquad (3)$$

where,

$\vartheta = \alpha + \beta\delta$, and

$\tau = \beta\theta$.

Hence, the estimate $\hat{\beta}$ can be obtained as $\hat{\tau}/\theta$. The instrumental variable estimator is an unbiased and consistent estimator of β in large samples.

The farm survey randomly selects households in a village. The actual proportion of households using the information within a social group in a village may not equal the proportion estimated from the sample, i.e. I_i

$= I_i^* + \omega i$. This can lead to the attenuation bias in θ, due to which the analysis may provide the lower bound of θ. However, the estimated treatment effect is unbiased as long as ω_i is uncorrelated with D_i and η_i.

Equation 1 includes a dummy variable for any information, that is, whether a farmer has used any sort of information. However, farmers' information needs are diverse, as are the sources dispensing these, and it is likely that the type of information type its source may impact productivity differentially. To capture the heterogeneity in their impacts, Equation 1 is augmented by including information on breeding, feeding, health, and management or the sources of information (public, private, mass media, progressive farmer and input dealer), and their corresponding instrumental variables, as in Equation 3.

$$Y_i = \vartheta + \tau_B I_{Bi}^k + \tau_F I_{Fi}^k + \tau_H I_{Hi}^k + \tau_M I_{Mi}^k + \gamma X_i + \eta_i \quad (4)$$

Where, I_{Bi}^k, $I_{Fi,}^k$ I_{Hi}^k and I_{Mi}^k represent the instruments for the information on breeding, feeding, health, and management.

Similarly, we include information sources:

$$Y_i = \vartheta + \tau_G I_{Gi}^s + \tau_{MM} I_{MMi}^s + \tau_{PF} I_{PFi}^s + \tau_I I_{Ii}^s + \tau_P I_{Pi}^s + \gamma X_i + \eta_i \quad (5)$$

Where, I_{Gi}^s, I_{MMi}^s, I_{PFi}^s, I_{Ii}^s, and I_{Pi}^s represent the instruments for the public, mass media, progressive farmer, and input dealer, and private information sources.

To account for the heteroscedasticity and autocorrelation, we estimate linear regressions using robust (heteroskedastic-consistent) and cluster-robust variance estimates.

Impact of information on productivity

Validity tests for instrumental variables

Table 3 presents the validity tests for instrumental variables. First, we look at the results of the under-identification tests. The p-values are highly significant, rejecting the null hypotheses that the instruments are irrelevant and the model is under-identified. Further, we look at the Hansen J-statistic that tests the null hypothesis that the instruments are valid and uncorrelated with the error term. The higher p-values provide strong evidence that the instruments are valid.

We also test for the failure of the relevance condition and weak instruments. Both the Cragg-Donald Wald F-statistic (preferred in the case of no heterogeneity) and Kleibergen-Paap Wald rk F-statistic (preferred in the case of heterogeneity) are more than the Stock-Yogo critical value, rejecting the null hypothesis that instruments are weak. These test statistics enable us to conclude that the application of the IV method is necessary in our case and the proposed IVs are valid.

Impact of different types of information

First, look at the OLS estimates corresponding to Equation 1 (Table 4). Dairy productivity is positively and significantly influenced by the age and education of household heads. The effect, however, differs across

Table 3 Instrumental variable tests

	Eq. (3) [1]	Eq. (4) [2]	Eq. (5) [3]
Under-identification test (F test of excluded instruments)	33911.48	71.20	3239.36
H0: instruments are jointly irrelevant in the first stage	0.0000	0.0000	0.0000
Under-identification test (Kleibergen-Paap rk LM Statistic)	5975.22	224.70	3303.96
H0: model is under-identified, instruments are not good	0.0000	0.0000	0.0000
Over-identification test (Hansen J-statistic)	0.8789	0.8056	0.8465
H0: exclusion restrictions of instruments are valid	0.8752	0.6533	0.6256
Weak identification test (Cragg-Donald Wald F-statistic)	12000	4991.80	12000
Weak identification test (Kleibergen-Paap Wald F-statistic)	34000	36.92	765.62
H0: weakly identified system (Stock-Yogo critical value 10 %)	16.38	10.27	10.83

Note

The tests in Columns 1, 2, and 3 are based on the estimation of, respectively, Equations 3, 4, and 5.

The results of the full models for Equations 3, 4, and 5 are presented in, respectively, Column 2 of Table 5, Column 3 of Table 5, and Column 3 of Table 6.

Table 4 Estimates of OLS regression

Dependent variable: Ln milk yield	Any type of information [1]		Differentiated by type of information [2]	
Household characteristics				
Family size	0.0536***	(0.0131)	0.0548***	(0.0131)
Age	0.0305	(0.0218)	0.0283	(0.0218)
Gender	0.0025	(0.0227)	0.0006	(0.0227)
Education level				
Below primary	0.0301	(0.0207)	0.028	(0.0207)
Primary	0.0334	(0.0177)	0.0333	(0.0176)
Middle	0.0266	(0.0178)	0.026	(0.0178)
Secondary	0.1123***	(0.0177)	0.1071***	(0.0176)
Higher secondary	0.0966***	(0.0223)	0.0976***	(0.0223)
Graduate and above	0.1525***	(0.0248)	0.1531***	(0.0247)
Caste				
Scheduled caste	-0.1833***	(0.0223)	-0.1867***	(0.0222)
Scheduled tribe	-0.0588**	(0.0194)	-0.0580**	(0.0194)
Other backward caste	0.0413**	(0.0131)	0.0410**	(0.0131)
Net assets	-0.0127***	(0.0018)	-0.0128***	(0.0018)
Formal training in agriculture	0.0285	(0.0421)	0.0223	(0.0420)
Non-farm business income	-0.0481*	(0.0207)	-0.0490*	(0.0207)
Wages, salary, and remittance	-0.0971***	(0.0122)	-0.0975***	(0.0122)
Farm characteristics				
Landholding size	-0.0276***	(0.0039)	-0.0255***	(0.0039)
Area irrigated	0.0940***	(0.0143)	0.0965***	(0.0143)
Herd size	0.0101	(0.0148)	-0.0006	(0.0148)
Proportion of buffaloes in herd	0.0043	(0.0083)	0.0058	(0.0082)
Breeding charges	0.0404***	(0.0035)	0.0389***	(0.0035)
Feed cost	0.4668***	(0.0127)	0.4640***	(0.0127)
Veterinary charges	0.0248***	(0.0025)	0.0241***	(0.0024)
Member of farmer organizations	-0.0535	(0.0671)	-0.1055	(0.0654)
Information type				
Any information	0.1386***	(0.0144)		
Breeding			0.1028***	(0.0220)
Feeding			0.1704***	(0.0225)
Health			0.0820***	(0.0159)
Management			0.2618***	(0.0413)
Constant	3.1461***	(0.1397)	3.1804***	(0.1395)

Note District dummies are included in the regressions. Figures in parentheses are village-clustered standard errors. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

social groups—it is lower for the lower-caste households than for the upper-caste households. It is also negatively associated with land size, assets, and access to non-farm income sources. The effect of herd size, however, is insignificant.

Further, as expected, productivity is positively and significantly associated with expenditure on animal breeding, feeding, and health. These findings indicate that small farmers with limited assets and non-farm income expend more on productivity-enhancing inputs to compensate for the scale effect on farm income.

Information has a significantly positive impact on the efficiency of dairy farming. It raises milk yield by 14%. The impact, however, differs by the content or subject

Table 5 Estimates of IV regressions

Dependent variable: Ln milk yield	Any type of information [1]		Differentiated by type of information [2]	
Household characteristics				
Family size	0.0543***	(0.0131)	0.0559***	(0.0131)
Age	0.0297	(0.0218)	0.0266	(0.0217)
Gender	0.0028	(0.0227)	0.0005	(0.0226)
Education level				
Below primary	0.0297	(0.0206)	0.0266	(0.0206)
Primary	0.033	(0.0176)	0.0325	(0.0176)
Middle	0.0264	(0.0178)	0.0253	(0.0178)
Secondary	0.1119***	(0.0176)	0.1053***	(0.0176)
Higher secondary	0.0966***	(0.0223)	0.0973***	(0.0223)
Graduate and above	0.1525***	(0.0247)	0.1528***	(0.0246)
Caste				
Scheduled caste	–0.1833***	(0.0222)	–0.1868***	(0.0221)
Scheduled tribe	–0.0585**	(0.0194)	–0.0575**	(0.0193)
Other backward caste	0.0408**	(0.0131)	0.0402**	(0.0130)
Net assets	–0.0128***	(0.0018)	–0.0130***	(0.0018)
Formal training in agriculture	0.0277	(0.0420)	0.0201	(0.0419)
Non”farm business income	–0.0481*	(0.0206)	–0.0490*	(0.0207)
Wages, salary, and remittance	–0.0977***	(0.0122)	–0.0983***	(0.0121)
Farm characteristics				
Landholding size	–0.0271***	(0.0039)	–0.0245***	(0.0039)
Area irrigated	0.0948***	(0.0143)	0.0979***	(0.0142)
Herd size	0.0083	(0.0147)	–0.0049	(0.0149)
Proportion of buffaloes in herd	0.0046	(0.0082)	0.0066	(0.0082)
Breeding charges	0.0403***	(0.0035)	0.0383***	(0.0035)
Feed cost	0.4659***	(0.0127)	0.4621***	(0.0127)
Veterinary charges	0.0244***	(0.0024)	0.0234***	(0.0024)
Member of farmer organizations	–0.0574	(0.0669)	–0.1221	(0.0645)
Information type	–	–	–	–
Any information	0.1521***	(0.0150)		
Breeding			0.1332***	(0.0242)
Feeding			0.1719***	(0.0249)
Health			0.0951***	(0.0170)
Management			0.3315***	(0.0434)
Constant	3.1546***	(0.1394)	3.1978***	(0.1391)

Note District dummies are included in the regressions.
Figures in parentheses are village-clustered standard errors.
***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

of information—the information on management raises productivity the most (26%), followed by the information on feed and nutrition (17%), animal breeding (10%), and health (8%).

The OLS estimates, however, could be biased. The bias corrected estimates from IV regressions are presented in Table 5. Controlling for the influence of several observable and unobservable factors, the impact of information now increases marginally to 15%. This is true for all sorts of information, especially the information on management and breeding. The estimated productivity effect of the management and breeding information is now higher. These results imply that correction for selection and omitted variable bias was important in our study.

A glance at Table 1 in the Appendix shows that most farm households (73%) use the information on a single subject and only 5% on more than one information (three or more). This motivates us to probe whether a combination of information is more effective at raising productivity than any information used in isolation.

To know this, we estimate IV regressions for sub-samples of households using (1) only one type of information, (2) two types of information, and (3) three or more types of information. Notably, the impact of using three or more types of information is more than four times larger than the isolated use of any type of information (Table 3 in the Appendix).

These findings indicate a pecking order in the effect of different types of information. It is linked to the complexity of the problem and the technical expertise required for its remedy. In general, the more specialized or complex the information, the less is the impact on

Table 6 OLS and IV regressions for source effect

Dependent variable: Ln Milk yield	OLS regression [1]		IV regression [2]	
Household characteristics				
Family size	0.0528***	(0.0131)	0.0538***	(0.0131)
Age	0.0285	(0.0218)	0.0276	(0.0217)
Gender	–0.0035	(0.0227)	–0.0026	(0.0227)
Education level				
Below primary	0.0347	(0.0207)	0.0342	(0.0206)
Primary	0.0344	(0.0176)	0.0343	(0.0176)
Middle	0.0264	(0.0179)	0.0264	(0.0178)
Secondary	0.1098***	(0.0177)	0.1098***	(0.0176)
Higher secondary	0.0945***	(0.0223)	0.0954***	(0.0223)
Graduate and above	0.1492***	(0.0247)	0.1498***	(0.0247)
Caste				
Scheduled caste	–0.1902***	(0.0223)	–0.1894***	(0.0223)
Scheduled tribe	–0.0620**	(0.0195)	–0.0618**	(0.0194)
Other backward caste	0.0416**	(0.0131)	0.0410**	(0.0130)
Net assets	–0.0113***	(0.0018)	–0.0115***	(0.0018)
Formal training in agriculture	0.0128	(0.0426)	0.0101	(0.0425)
Non”farm business income	–0.0479*	(0.0207)	–0.0487*	(0.0206)
Wages, salary, and remittance	–0.0943***	(0.0122)	–0.0950***	(0.0122)
Farm characteristics				
Landholding size	–0.0290***	(0.0039)	–0.0294***	(0.0039)
Area irrigated	0.1016***	(0.0144)	0.1001***	(0.0144)
Herd size	0.0123	(0.0147)	0.0109	(0.0147)
Proportion of buffaloes in herd	0.0048	(0.0081)	0.005	(0.0081)
Breeding charges	0.0404***	(0.0035)	0.0403***	(0.0035)
Feed cost	0.4710***	(0.0128)	0.4696***	(0.0128)
Veterinary charges	0.0268***	(0.0024)	0.0264***	(0.0024)
Member of farmer organizations	–0.037	(0.0678)	–0.0426	(0.0678)
Information source				
Government	0.1207***	(0.0171)	0.1355***	(0.0175)
Mass media	–0.0173	(0.0158)	–0.0327	(0.0173)
Progressive farmer	0.0091	(0.0129)	0.021	(0.0139)
Input dealer	–0.1128***	(0.0137)	–0.1041***	(0.0148)
Private	0.0654***	(0.0146)	0.0769***	(0.0155)
Constant	3.1390***	(0.1398)	3.1447***	(0.1394)

District dummies are included in the regressions. Figures in parentheses are village-clustered standard errors. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively.

productivity. Disease diagnosis and management and animal breeding require significant knowledge and technical skills. On the other hand, the information on feed and feeding practices, financing, markets, and post production management does not involve much technical expertise and skills.

Impact of information sources

The literature indicates differential impact of different information sources on farm outcomes (Birol et al. 2015; Glaeser et al. 2002; Putnam 2001; Feder and Slade, 1986; Foster and Rosenzweig, 1995; Singh et al. 2003; Bhagat et al. 2004). Nonetheless, most studies have analysed the impact of a single information node at a time, while farmers depend on multiple sources for their information needs.

Table 6 provides the IV estimates of the impact of information sources on dairy productivity. The results indicate significant differences in the impact of information sources. The information sourced from the public extension system has the highest positive impact (13.6%), almost twice that of the private information sources. Mass media and social networks do not impact productivity significantly. The impact of information sourced from the input dealers is negative and significant.

The heterogeneity in the impact of information sources could be attributed to the differences in the quality of information and the human resources and methods deployed to deliver the information. The public extension system is more effective in improving productivity because it engages highly trained human resources capable of diagnosing the remedies and providing effective solutions. Note that an overwhelming majority of veterinarians (over 95%) in India are employed in the public sector, leaving little trained human resources for the private sector.

Studies have shown a positive and significant impact of information from social networks and mass media on the returns from crop farming (Feder and Slade 1986; Foster and Rosenzweig 1995; Birol et al. 2015). Our findings, however, show no significant effect of these sources on dairy productivity. This can be expected. Animals have a complex biological system, understanding of which is essential for the diagnosis of an ailment or disorder. Only a qualified veterinarian can, upon physical examination of the animal, diagnose the ailment and suggest remedial measures. Further, social networks and mass media often acquire information from public extension system; hence, the probability of loss of information and miscommunication in dissemination is high.

Conclusion and implications

Utilizing data from a nationally representative farm survey and applying the instrumental variable method, this study assesses the impact of information on the efficiency of dairy farming in India. A few important conclusions emerge.

Using the information in farming decisions can enhance the production potential of dairy animals by around 15%. Farmers' information needs are diverse; hence, the impact on dairy productivity differs by information type—the information on livestock management has a larger effect than the information on feeding, breeding, and health.

The payoff of using different types of information in combination is larger than of using any one type of information in isolation. The impact of information is differentiated also by the source dispensing it—information from public sources has a significantly larger impact than from private sources, social networks, mass media, and input dealers.

In the past few decades, there has been increasing recognition of livestock's contribution toward sustaining agricultural growth, reducing income inequality, poverty and malnutrition, and empowering rural women. Yet, the livestock sector is under-appreciated and inappropriately funded when public resources are allocated. The livestock sector shares approximately 10% of the total public spending on agriculture and allied activities (Birthal and Mishra 2021). The delivery of livestock services, including extension services, is grossly lacking, despite the country having an extensive veterinary infrastructure (hospitals, polyclinics, and dispensaries) engaging over 80,000 trained veterinarians. The findings of this study reveal that the government extension or service delivery system reaches only 14% of livestock farmers. A few important implications emerge.

Animals have a complex biological system; hence social networks, mass media, and input dealers need not be relied upon for disseminating complex information, especially related to animal health and breeding.

Should the government create a new institution to deliver livestock extension services or utilize the existing infrastructure and human resources? The impact of the public extension system is high, and the public sector employs most veterinarians, but its reach to livestock farmers is limited. The service functions of veterinarians need to be reconsidered, therefore, and their expertise used to provide livestock extension services.

The network of dairy cooperatives that links dairy farmers to markets is strong: 193,195 village dairy cooperatives procured 17.5 million tons of milk (9% of the total production) from 17.2 million farmers in 2020–21 (NDDB 2021). Private dairy processors procured as much. India needs to strengthen this network and use it to disseminate information, especially on livestock management, feed and feeding practices, animal hygiene, food safety, and waste management.

The livestock population is large and diverse, as are the production systems. Therefore, certain livestock services need to be privatized and the capacities of private livestock service providers built through regular interaction with the public extension system.

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Appendix

Table 1 Frequency distribution of households by number of information and information sources used

No. of Information	Number of information sources: One	Two	Three	Four	Five	Total
One type	1225	957	665	168	24	3039
Two types	118	382	274	121	33	928
Three types	4	54	79	37	26	200
Four types	0	0	6	3	5	14
All	1347	1393	1024	329	88	4181

Note Different kinds of information include information on breeding, feeding, health, and management. The different sources of information include government, private, progressive farmer, mass media, and input dealer.

Table 2 Sources of information by caste of information users

Source \ Category	Scheduled Caste	Scheduled Tribe	Other Backward Caste	Upper or Other Caste	Total
Progressive farmer	9.28	9.54	48.33	32.85	100
	14.60	10.69	11.73	12.25	12.01
	[211]	[217]	[1099]	[747]	[2274]
Input dealer	8.22	9.13	46.94	35.72	100
	14.95	11.82	13.17	15.40	13.88
	[216]	[240]	[1234]	[939]	[2629]
Mass media	7.30	10.99	50.43	31.29	100
	26.57	28.47	28.32	26.99	27.77
	[384]	[578]	[2653]	[1646]	[5261]
Government	7.30	11.10	48.56	33.04	100
	22.77	24.63	23.34	24.40	23.78
	[329]	[500]	[2187]	[1488]	[4504]
Private	7.14	11.58	51.38	29.90	100
	21.11	24.38	23.44	20.96	22.56
	[305]	[495]	[2196]	[1278]	[4274]
All	7.63	10.72	49.46	32.19	100
	100	100	100	100	100
	[1445]	[2030]	[9369]	[6098]	[18942]

Note The upper rows contain the row percentage, the lower rows contain column percentage, and frequencies are shown in square brackets.

Table 3 IV regressions for number of information used

Dependent variable: Ln milk yield	One type of information [1]		Two types of information [2]		Three or more types of information[3]	
Household characteristics						
Family size	0.0586***	(0.0136)	0.0624***	–0.0145	0.0552***	(0.0149)
Age	0.026	(0.0225)	0.0223	–0.0241	0.0296	(0.0250)
Gender	0.0005	(0.0239)	0.005	–0.0245	0.0036	(0.0260)
Education level						
Below primary	0.0279	(0.0216)	0.0111	–0.0228	–0.0013	(0.0240)
Primary	0.0255	(0.0183)	0.0214	–0.0197	0.0251	(0.0206)
Middle	0.0247	(0.0184)	0.0126	–0.0197	0.0158	(0.0205)
Secondary	0.1028***	(0.0184)	0.0926***	–0.0196	0.0886***	(0.0205)
Higher Secondary	0.0987***	(0.0230)	0.0776**	–0.0245	0.0807**	(0.0251)
Graduate and above	0.1521***	(0.0255)	0.1531***	–0.0273	0.1421***	(0.0281)
Caste						
Scheduled caste	–0.1947***	(0.0228)	–0.2151***	–0.0241	–0.2164***	(0.0241)
Scheduled tribe	–0.0652**	(0.0200)	–0.0604**	–0.0212	–0.0697**	(0.0217)
Other backward caste	0.0435**	(0.0136)	0.0339*	–0.0145	0.0372*	(0.0149)
Net assets	–0.0121***	(0.0019)	–0.0120***	–0.0021	–0.0128***	(0.0021)
Formal training in agriculture	0.0389	(0.0464)	0.0431	–0.0493	0.0813	(0.0522)
Non-farm business income	–0.0368	(0.0215)	–0.0486*	–0.0234	–0.0431	(0.0243)
Wages, salary, and remittance	–0.1040***	(0.0127)	–0.0882***	–0.0135	–0.0838***	(0.0139)
Farm characteristics						
Landholding size	–0.0263***	(0.0042)	–0.0202***	–0.0046	–0.0177***	(0.0050)
Area irrigated	0.0956***	(0.0148)	0.0783***	–0.0157	0.0704***	(0.0161)
Herd size	0.0016	(0.0159)	–0.0164	–0.017	–0.0219	(0.0179)
Proportion of buffaloes in herd	0.0098	(0.0087)	0.0191*	–0.0088	0.0230*	(0.0094)
Breeding charges	0.0395***	(0.0038)	0.0430***	–0.0038	0.0475***	(0.0041)
Feed cost	0.4612***	(0.0131)	0.4544***	–0.0137	0.4551***	(0.0139)
Veterinary charges	0.0251***	(0.0026)	0.0235***	–0.0029	0.0268***	(0.0031)
Member of farmer organizations	–0.1694	(0.1018)	–0.1114	–0.0955	–0.0113	(0.1146)
Information						
Any information	0.0974***	(0.0165)	0.2769***	–0.0246	0.4572***	(0.0505)
Constant	3.2321***	(0.1442)	3.3106***	–0.1526	3.3257***	(0.1527)

Notes District dummies are included. The figures in parentheses are village-clustered standard errors. ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively