Agricultural Economics Research Review
Vol. 29 (No.1) January-June 2016 pp 1-14
DOI: 10.5958/0974-0279.2016.00014.8

Patterns and Drivers of Dairy Development in India: Insights from Analysis of Household and District-level Data

Avinash Kishore*[a], Pratap S. Birthal[b], P.K. Joshi[a], Tushaar Shah[c] and Abhishek Saini[d]

[a]International Food Policy Research Institute, South Asia Office, NASC Complex, Pusa, New Delhi-110 012
[b]National Institute of Agricultural Economics and Policy Research, Pusa, New Delhi-110 012
[c]International Water Management Institute, 'Jal Tarang', Near Smruti Apartment, Anand-388 001, Gujarat
[d]Independent Consultant, New Delhi

Abstract

Traditionally, Indian farmers kept bovines, especially cattle, for draught purposes in agriculture and transportation with milk as an adjunct. However, with increasing farm mechanization and rising demand for milk, the bovine functions have shifted more towards dairying. While bovine population has been increasing, the chronic scarcity of feed and fodder reinforces the need for optimization of bovine population for sustainable growth of dairying. In this paper, using district-level data from 1997 to 2007, we show that this transformation from draught to dairying is underway in some parts of the country, and further using household-level data, we find that smallholders have contributed disproportionately more to this transformation. This transformation or intensification of dairying is demand-driven with urbanization having a strong positive influence on dairy development. On the supply-side, factors like farm mechanization, improved access to groundwater irrigation and crop diversification away from cereals, are associated with a shift in the bovine economy from draught to dairying.

Key words: Dairy development, smallholders, urbanization, mechanization, crop diversification

JEL Classification: Q12, O18, P25

Introduction

India holds more than a quarter of world's bovine population, and with a production of more than 133 million tons in 2012-13 it is the largest producer of milk in the world (GoI, 2014). Between 1981-82 and 2011-12[1], milk production increased more than four-fold, making it the largest agricultural commodity in quantity as well as value terms (Birthal and Negi, 2012). Milk now accounts for over a quarter (26.4% in 2011-12) of the total value of agricultural output[2] and two-thirds of the total value of livestock production. Every second rural household in India owns at least one dairy animal, either cattle or buffalo, and the ownership rate exceeds 70 per cent among the households owning more than 0.5 hectare of land (GoI, 2006).

In spite of sustained growth in milk production, the demand for milk is outpacing its supply. Gandhi and Zhou (2010) have projected the demand for milk to grow faster than its annual production. The increasing demand-supply gap may lead to sharp rise in the prices of milk. Mishra and Roy (2011) have shown that rising price of milk has been the most important contributor to food price inflation in India since 1998. It may threaten the nutritional status of people as milk is the main source of animal protein for Indian households. Note that, milk accounts for nearly three-fourths of the household expenditure on livestock

* Author for correspondence
Email: avinash.kishore@gmail.com

products (Mishra and Roy, 2011). Milk and milk products have the highest income elasticity of demand amongst food commodity groups, and therefore, the demand is likely to increase rapidly as the economy grows and incomes rise (Joshi and Kumar, 2012).

India has the world's largest bovine population, but the chronic scarcity of feed and fodder—their prices have doubled since 2004-05[3]—and shrinking area and deteriorating quality of grazing lands entail that the milk output increases without further increase in the number of cows and buffaloes. Instead, the total bovine population should decline while the number and yield of in-milk animals should increase. It means that India's dairy production system needs to become more efficient.

In this paper, we study trends and patterns in dairy development in India and try to identify key drivers of these patterns using district-level data from three quinquennial rounds of Livestock Census, supplemented by an analysis of the household-level data from a large-scale survey on Land and Livestock Holdings conducted by the National Sample Survey Organization (GoI, 2006). The next section describes data and assumptions made to examine and interpret the emerging trends in India's bovine economy. The third section focuses on the changes in equity in ownership of bovines across landholding classes. The fourth section brings out the regional differences in dairy development in India. Then, we discuss the estimation strategy to identify drivers of dairy development. Results are presented in section 6 and concluding remarks are made in the last section.

Data and Key Assumptions

The Livestock Censuses of India conducted in 1997, 2002-03 and 2007 and the survey on 'Livestock Ownership across Operational Land Holding Classes in India', conducted by NSSO in 2003, are the two main sources of data used in this paper. The Livestock Census provides district-level data on livestock demography. For dairy animals, it includes data on total number of non-descript cows (NDC), crossbred cows (CB) and buffaloes by sex (male-female), age-group (< 1 year, 1-2.5 years), usage (work, breeding, work and breeding, neither used for breeding nor work) and lactation status (in-milk, dry, not-calved, others). The NSSO survey has data on ownership of number of different types of bovines owned by households allowing us to explore equity in bovine ownership. Throughout the paper, we restrict our analysis to rural areas that account for more than 95 per cent of the total bovine population in India.

Ideally, one would like to have data on yield and production of milk by different types of dairy animals to analyze the changes in dairy economy. However, this type of data are not available at district-level. We, therefore, rely mainly on demographic variables available in the Livestock Censuses and survey reports of the National Sample Survey Organization for our analysis. India's bovine economy is likely to become increasingly focused on milk production as it develops and intensifies into a specialized activity while the draught function will become less important (Birthal and Parthasarathy Rao, 2004). We believe that this specialization will be achieved, among other things, by increasing the share of in-milk bovines in the bovine herd[4]. If this is true, then we can use the ratio of in-milk bovines to the total bovine population—called herd efficiency ratio (HER) in this paper—as an indicator of dairy development. Other things being equal, a region (or a farmer) with higher percentage of in-milk bovines in its herd (i.e. higher HER), we claim, has a more intensive and more efficient dairying than the one with lower HER. We assume that a more efficient dairying system will have higher proportion of crossbred cows and buffaloes in it. It will have a higher ratio of females and more in-milk females in the female stock. Starting from these assumptions about relationship between bovine population structure and levels of dairy development (or dairy production efficiency), we use HER to characterize the levels of dairy development.

Dairying in India: A Smallholders' Enterprise

From 1981 to 2011, milk production in India has grown at more than 4 per cent compounded annually, surpassing growth rates in the global dairy output and India's own food grain production (Birthal and Negi, 2012). Even more striking, smallholder farmers are driving this growth. From 1981 to 2003, farm households cultivating less than or equal to one hectare of land (termed as marginal farm households) in total farm households increased from 41 per cent to 48 per cent and their share in in-milk animals soared from 31 per cent to 52 per cent (Table 1). There was a time

Table 1. Ownership of in-milk bovines by operational landholding size class in 2002-03

Category of farmers	Per cent operating households	Per cent cattle	Per cent buffalo	Per cent in-milk crossbreds	Per cent in-milk buffaloes	Per cent in-milk non-descript cows	Herd Efficiency Ratio (HER)
Marginal[9] (< 1 ha)	69.60	52.90	50.01	59.68	55.09	49.63	0.203
Small (1-2 ha)	16.30	21.30	20.88	18.03	18.54	20.56	0.159
Medium (2-4 ha)	9.10	14.75	15.37	12.44	14.00	15.22	0.167
Large (> 4 ha)	5.10	11.05	13.78	10.37	12.68	14.45	0.163
Near-landless(< 0.04 ha)	15.40	8.58	11.96	17.10	10.60	12.90	0.229

Source: Estimated by authors from GoI (2006).

when the rural poor tended dry bovines of the rich farmers on common and fallow lands, until they calved again; this meant that, at any point in time, the poor held a large share of unproductive bovines, while the rich had bulk of the milking cows and buffaloes (Binswanger and Rosenzweig, 1986). This practice is much less common now. Presently, not only do the marginal farmers own a disproportionate share of milking bovines, they also own 60 per cent of India's crossbred cows (Tables 2 and 3).

We explore the relationship between herd efficiency ratio and land ownership using unit-level data from Land and Livestock Holding Survey conducted in 2003 with data from a representative sample of more than 26,000 rural households who owned bovines (Table 4). In the regression model we also control for the time-invariant district-level characteristics (district dummies are not shown in the table). We find that households who do not own any agricultural land, have higher HER (by 0.054 points) than the households who do. Among the land-owning households, HER is higher for households with larger land sizes. Similarly, households with relatively elder and more educated heads and more irrigated land have higher HER. Among different social (or caste) groups, tribal households have the lowest HER, followed by scheduled castes, other backward castes and non-backward caste households in that order.

Table 2. Growth in marginal holdings and their share of in-milk bovine stock, 1971-72 to 2002-03

Year	Per cent share of marginal holdings in total in-milk bovines	Households with marginal holdings as per cent of total rural households
1971-72	20.0	32.9
1981-82	31.0	41.1
1991-92	44.0	48.3
2002-03	52.0	47.9

Source: Estimated by authors

Table 3. Herd efficiency ratio (HER) across landholding classes, 1971-72 to 2002-03

Year	Marginal farmers (<1 ha)	Small farmers (1-2 ha)	Medium farmers (2-4 ha)	Large farmers (>4.0 ha)	All farmers
1971-72	0.190	0.176	0.187	0.215	0.21
1981-82	0.164	0.134	0.159	0.160	0.16
1991-92	0.231	0.213	0.222	0.256	0.22
2002-03	0.237	0.214	0.225	0.260	0.23
2007					0.25*

Source: Estimated by authors using data from NSSO
*Livestock Census, 2007.

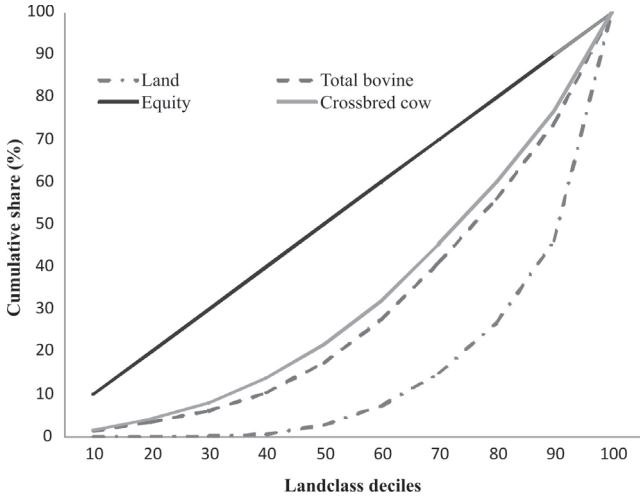

Figure 1. Inequity in ownership of land and bovines in India, 2002-03

Bovine stock is more equitably distributed than land (Figure 1). Marginal farmers, operating less than one-fifth of India's cultivable land[5], own more than half of in-milk bovines. Small farmers with land size 1-2 ha, own about one-fifth of the stock. Thus, with nearly three-quarters of in-milk stock owned by small and marginal farmers, dairying in India is predominantly and increasingly a smallholders' enterprise and its rapid growth may help in more equitable distribution of farm income and reduction in poverty (Birthal and Negi, 2012).

Inequity in bovine holdings has also declined over time. The Gini ratio—a measure of the degree of inequality taking values from 0 to1— of bovine holding in India declined from 0.43 in 1961 to 0.37 in 1971 and further to 0.28 in 1991 (Sharma *et al*., 2003). However, there has been a slight increase in inequity of in-milk bovine ownership between 1992 and 2002-03: a reversal of the trend observed over the previous three decades, and strengthening of the positive association between in-milk bovine stock ownership and size of household operational holdings during 1992 to 2002-03 (GoI, 2006). Our own estimates show that the Gini ratio of bovine holdings had gone up to 0.36 in 2002-03—almost the same level as in 1992. We do not know the exact reasons for this trend reversal. Some studies (e.g., Birthal and Taneja, 2006) suggest that decline in the area and the quality of common grazing lands and fallows is making animal husbandry more difficult or even unviable for the near-landless and marginal farmers. Increasing opportunities for such land-constrained households in the non-farm sectors could be another possible reason for their exit from bovine husbandry.

Table 4. Regression showing household level determinants of herd efficiency ratio (HER) in India

Variables	HER
If owns land (0=No; 1=Yes)	-0.0535***
	(0.00870)
Landholding size (ha)	0.00309***
	(0.00109)
Groundwater irrigated area (%)	0.000139
	(0.000222)
Surface irrigated area (%)	0.000201***
	(6.75e-05)
Education (years of schooling)	0.00875***
	(0.00122)
Age (years)	0.000638***
	(0.000204)
Scheduled castes	0.0816***
	(0.00953)
Other backward castes	0.116***
	(0.00766)
Others	0.147***
	(0.00821)
Constant	0.150***
	(0.0189)
Observations (No.)	25,959
R-squared	0.048

Notes: *** p<0.01, ** p<0.05, * p<0.1

Robust standard errors within parentheses

District dummy variables not shown in the table; *If owns land* is a dummy variable =1 if a households owns agricultural land; *holding size* measures total land owned by the household; *Groundwater irrigated area (%)* and *Surface irrigated area (%)* indicate percentage of land irrigated by groundwater and surface water, respectively; Scheduled tribes were dropped in the regression.

The landless and near-landless households, defined here as those who own less than 0.02 hectare of land, are most likely to own bovines in northern states of Jammu & Kashmir, Punjab, Uttarakhand, Haryana and Rajasthan, while they are least likely to own one in the southern states of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu (Appendix 1).

A probit analysis (Table 5) of more than 16,000 near-landless or landless rural households shows that within a state (we control for state dummies in the regression), a Sikh or Hindu household that owns some land, has a larger family size, belongs to other backward castes (OBC) or non-backward castes, has cultivation or agricultural labour as its main occupation, and is less educated is more likely to own a bovine. Most state dummies are statistically significant, suggesting that the rate of bovine ownership among near-landless and landless rural households is significantly different in most states from that in Jammu & Kashmir—the omitted state in the regression.

Table 5. Characteristics associated with higher likelihood of a landless or near landless rural household owning at least one bovine

Explanatory variables	Coefficient
Land (ha)	44.84***
	(9.916)
Household-size	0.178***
	(0.0161)
Sex (0=male; 1=female)	-0.415***
	(0.134)
Age (years)	0.101***
	(0.0175)
Age squared	-0.000965***
	(0.000178)
If married (0=No; 1=Yes)	-0.142
	(0.0932)
If secondary education or above	-0.525***
(0=No; 1=Yes)	(0.133)
If Scheduled caste	0.194
	(0.125)
If Other backward caste	0.292**
	(0.130)
If Others	0.261*
	(0.155)
If agricultural labourer	0.737***
	(0.108)
If non-agricultural labourer	-0.0745
	(0.0787)
If a cultivator	2.014***
	(0.158)
If Muslim	-0.730***
	(0.123)
If Sikh	0.417***
	(0.0996)
If Jain	-1.417**
	(0.687)
Constant	-3.769***
	(0.454)
Observations (No.)	16,366
State dummies	YES
Clustered standard errors	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1

Robust standard errors within parentheses

If* variables are all dummy variables that are assigned value of 1 if the head of the household belongs to the category. *Land* measures the total land area owned by the household; SC, OBC and Others are caste groups in India with STs (scheduled tribes) as the omitted category. Similarly, Muslim, Sikh and Jain are the religious groups with Hindus as the omitted religious group.

Recent Developments in Bovine Demography of India

In the traditional Indian farming system, cattle have been reared primarily for farm power needs. Crop and bovine production systems in India are closely intertwined with bovine playing a subsidiary role of providing draught power and manure for crop production using crop residues as feed. It is largely a self-contained system with limited market integration. This age-old system is changing, giving way to dairying as a specialized activity (Birthal and Parthasarathy Rao, 2004)—still maintained off crops, but not for it. In many parts of India, dairying accounts for a significant and growing part of farm income and farm employment, especially for marginal farmers (Shukla and Brahmankar, 1999; Siddhu and Bhullar, 2004; Singh and Verghese, 2004; Birthal and Taneja, 2006). The rise of milk-orientation of Indian bovine economy is evident from the changing herd composition. The number of bullocks, including bovines used for draught, decreased by more than 10 millions between 1992 and 2007 and the female: male ratio increased from 1:1 in 1992 to almost 2:1 in 2007. However, different regions of India are in different stages of this transition from traditional, self-contained mixed farming system toward dairying as a specialized economic activity. We report some of the key trends in bovine herd structure in India and the inter-regional variations therein in this section.

Slow Decline in Excess Cattle

India had 0.6 billion bovines in 2007—more than any other country in the world. Being a country scarce in land and fodder but facing fast growth in demand

Table 6. Bovine and land ownership, herd size and herd efficiency ratio (HER) values across households of different social categories in India in 2003

Social group	Per cent rural households that own at least one bovine	Mean land owned per household (ha)	Average number of bovines owned per household		HER value
			All households	Bovine-owning households	
Scheduled tribes	52.57	0.79	1.87	3.56	0.126
Scheduled castes	38.57	0.31	0.96	2.49	0.217
Other backward castes	49.15	0.76	1.67	3.40	0.249
Others	50.55	1.01	1.74	3.44	0.290

for milk and milk products, India needs to reduce its population of unproductive bovines and increase the productivity for efficient use of existing resources. However, India's bovine population continued to grow steadily till 1992, it stabilized in 1990s and registered a small reduction between 1997 and 2003—for the first time since 1951—only to record an increase again between 2003 and 2007.

Slow Improvement in HER

The in-milk females constituted only 22 per cent of the total bovine stock of India in 1997. Their share increased to 23 per cent in 2002-03 and to 25 per cent in 2007. The HER of 0.25 is still quite low and indicates the persistent problems of low productivity and low efficiency. The HER is relatively higher for buffaloes (0.33) and crossbred or exotic cows (0.32) and lower for non-descript cows (0.18). This is expected as the non-descript cattle are still valued more for draught power as compared to crossbred cattle and buffaloes that are reared mainly for milk production.

Across social classes, the HER seems to follow the existing social status gradient found in rural India with lowest values for scheduled tribes (STs) followed by scheduled castes (SCs), other backward castes (OBC) and other castes (Table 6). The tribal households are most likely to own a bovine and their average herd size is also the largest, but they have the lowest herd efficiency (HER) ratio, probably because of their greater dependence on cattle for farm power needs and cultural taboos on milk consumption. Geographically, eastern India and tribal districts of the country continue to have the most under-developed dairy economy with HER well below the national average of 0.25, while districts in northern states of Punjab and Haryana have a higher HER (Table 7).

More Buffaloes than Cows

In India, buffaloes are increasingly becoming the preferred dairy animals. Rapid farm mechanization especially, increasing use of tractors, power tillers and threshers, has been reducing farmers' dependence on animal power. Thriving rental markets for these

Table 7. Herd efficiency ratio (HER) by state and region of India in 2007

State	HER value
Eastern region	
Assam	0.18
Chhattisgarh	0.12
Odisha	0.12
West Bengal	0.18
Western region	
Gujarat	0.28
Rajasthan	0.30
Maharashtra	0.24
Madhya Pradesh	0.22
India	0.25
Northern region	
Punjab	0.39
Haryana	0.32
Uttar Pradesh	0.30
Southern region	
Andhra Pradesh	0.28
Karnataka	0.27
Kerala	0.3
Tamil Nadu	0.27

Table 8. Ratio of female and in-milk buffaloes to cows across selected states of India

State	Ratio of number of buffaloes to cows	
	All females	In-milk females
Haryana	4.99	4.92
Punjab	3.48	3.28
Andhra Pradesh	2.01	2.08
Gujrat	1.77	1.77
Uttar Pradesh	1.67	1.83
Rajasthan	1.18	1.28

machines allow even smallholders to use these for agricultural operations. In 2007, India had more than 0.2 billion buffaloes accounting for more than one-third (34.5%) of total bovine population[6]. If we look at female bovines only, buffaloes constituted 44.0 per cent of the adult female bovine population and 46.3 per cent of total in-milk bovines. If this trend continues, soon, India will have more in-milk buffaloes than in-milk cows. The states of Haryana, Punjab, Andhra Pradesh, Gujarat, Uttar Pradesh and Rajasthan already have more female buffaloes than female cattle by 2007 (Table 8).

The data in Table 9 show that indigenous or non-descript cows account for more than half of the total bovine population and more than 40 per cent of all female (45%) and in-milk (43%) bovines. Their population share, however, has been declining, giving way to buffaloes and crossbred cows as the bovine economy moves from draught to dairying. The share of in-milk cows in all females is close to 40 per cent for all three types of bovines, but the share of females in total itself is much lower for indigenous cows. About 44 per cent of all indigenous cattle are males while they account for only 24 per cent of crossbred cattle and buffaloes. Male animals account for a high share of indigenous population because a large number of farmers still depend on animal power for agricultural work and transportation. Nearly two-thirds (63%) of the indigenous male cattle are kept mainly for draught purposes. As machines substitute animals as motive power for agriculture, the need for animal power will decline and the share of indigenous cattle and the fraction of male animals therein will go down, resulting in a rise in the HER.

To summarize, the rapid dairy development in India seems to be confined to arid and semi-arid north-western and southern regions of the country while the eastern and tribal regions continue to trail behind. Districts with dynamic dairy economies, found in states like Punjab, Haryana, Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, are marked by decline in bullock population, increase in the population of buffaloes and crossbred cows, relatively high ratio of milking to female stock and decline in non-descript cows. In the next section, we will try to identify the key drivers of increasing orientation of bovine demography towards dairying using district-level data.

Several studies have been carried out to understand the changes in demographic structure of livestock at the national and state levels (Sharma, 2004; Birthal and Negi, 2012), but to the best of our knowledge none of these has used district-level data. State-level data could mask considerable inter-district variations in bovine demography and its drivers that may exist within a state. For example, the Kolhapur district in Maharashtra has the distinction of having highest HER in the country (0.46) while the Chandrapur district in the same state has the lowest HER of 0.13. Hence, an analysis of the bovine demography using district level

Table 9. Population shares of different types of bovines in India: 1997 to 2007

Year	Indigenous cows			Cross-breds			Buffaloes		
	Share in total bovine population (%)	Ratio of female to total animals	Ratio of in-milk to total female animals	Share in total bovine population (%)	Ratio of female to total female animals	Ratio of in-milk to total population animals	Share in total bovine animals (%)	Ratio of female to total female	Ratio of in-milk to total animals
1997	57.00	0.52	0.35	9.00	0.72	0.39	33.74	0.75	0.38
2003	53.00	0.54	0.35	10.45	0.75	0.40	36.54	0.77	0.40
2007	52.00	0.56	0.37	13.02	0.76	0.41	35.00	0.76	0.40

data is important to understand the causes of such uneven development and to target efforts and investment accordingly.

Empirical Strategy

We use the district-level data on bovine demography from three rounds of Livestock Censuses pertaining to the years 1997, 2003 and 2007 (GoI, 2003; 2005; 2010), and combine these with variables on human population, land uses and agricultural variables such as farm size, cropping pattern, fertilizer-use intensity, area under surface water and groundwater irrigation, density of tractors and power tillers, etc.[7] for the corresponding years to understand the emerging pattern in bovine demography and its drivers.

First, we estimate a pooled OLS or POLS model where we pool data from three rounds of Livestock Censuses assuming that observations across years are not correlated over time for the same district, i.e.

$$Y_{it} = \alpha + X_{it}\beta + \varepsilon_{it} \quad \ldots(1)$$

where, Y_{it} is the dependent variable, HER of district i in year t; α is the constant term; X_{it} is a set of time varying variables influencing Y in district i and ε_{it} is the error-term.

The assumption of errors being uncorrelated across years for the same district is quite a strong. We relax this in the subsequent models where we use the panel data to estimate fixed effects model (Equation 2):

$$Y_{ist} = \alpha_s + \gamma t + \theta_{st} + X_{ist}\beta + \varepsilon_{ist} \quad \ldots(2)$$

where, Y_{ist} is the herd efficiency ratio in district i in state s and year t; α_s is the state fixed effect; γ controls for national trend in the dependent variable; θ_{st} is a state-year interaction effect and ε_{ist} is a district-year specific error-term. X_{ist} is a set of time varying control variables for the district. The state fixed effects control for time-invariant characteristics of the state that may affect livestock demography and are correlated with regressors, while the state-year interactions control for annual shocks across districts in a state. A brief description of the explanatory variables is given below.

Urbanization — Other things held constant, per capita milk consumption is generally higher in urban areas and among the high income populations. Therefore, it is likely that more urbanized districts will show demand-led development of dairying economy[8].

Population Density — The literature predicts that higher population density leads to a greater intensification of agriculture (Boserup, 1965). In the case of livestock, it is argued that interaction between crop and livestock production systems is weak at low population densities; it increases with population density and finally declines giving way to specialized crop and livestock activities (McIntire *et al*., 1992 cited in Birthal and Parthasarathy Rao, 2004). Accordingly, HER is expected to be higher when dairying is practised as a commercial activity. Vaidyanathan *et al.* (1982) argue that bovine male-female ratio is density dependent in India. They posit that as human density increases, draught animal density increases only up to a threshold; thereafter, draught animals are discarded and cows are retained. Thus, both Vaidyanathan *et al*. (1982) and McIntire *et al*. (1992) suggest that milk-orientation or HER of a district should increase with increase in population density, once it crosses a threshold level. Since most districts in India have relatively high population densities, we would expect a positive correlation between HER and population density and negative correlation between bovine and work animal density and density of the (human) population.

Literacy — Literate households are more likely to adopt new technology that can enhance dairy production. We expect districts with higher rural literacy rates to have higher herd efficiency ratios and lower density of working bovines.

Mechanization — Historically, cows in India have been valued to produce draught animals and milk as adjunct (Vaidyanathan *et al*., 1982). If animals are the main source of draught power, then there should be more male cows in the herd. During the past four decades, India has adopted crossbreeding technology to enhance milk production, but crossbred males are not considered suitable for draught purposes. The use of male buffaloes for work is also limited. Farm mechanization (mostly tractors and power tillers) reduces the compulsion of rearing male cattle (mainly non-descript). Therefore, we expect districts with higher degrees of mechanization to have higher herd efficiency ratios.

Irrigation — The districts with better irrigation facility tend to be more mechanized with higher cropping intensity and crop yields, and therefore greater availability of green and dry fodder and less need for

draught animals. The per capita income is also higher in more irrigated areas (Bhattarai and Narayanamoorthy, undated). Thus, irrigation creates both supply and demand side conditions for more advanced dairying. Groundwater irrigation allows higher cropping intensity and year-round cultivation of green fodder crops and is associated with better yields compared to surface water irrigation. We expect positive coefficients for both surface and ground water irrigated areas, but the latter is likely to have a larger coefficient.

Cropping Pattern — Cereals are the main sources of dry fodder. Other things held constant, districts with a lower fraction of area cropped with cereals will have lower availability of dry fodder. It is our surmise that the pressure to get rid of low-yielding excess cattle and to intensify dairying is higher when roughage is relatively scarce. Therefore, we expect districts with lower (and declining) area under cereal crops to have more intensive dairying.

Fertilizer Use — Higher use of chemical fertilizers is a sign of more intensive agriculture and probably a more milk-oriented dairying, as it contributes towards improving availability of roughages.

Barren and Permanent Pastures — Common grazing lands (pastures) comprise an important source of fodder for the smallholders and landless farmers who have limited availability of harvested crop residues to feed cattle and buffalo (Dikshit and Birthal, 2010). It is likely that fodder is more easily available in the districts with larger fraction of their geographical area as barren lands and permanent pastures. If so, then we can expect less intensive dairying in the districts with larger area under pastures.

Road Density — Better road connectivity makes milk marketing easier, facilitating dairy development. Therefore, we expect road density in a district to be positively correlated with HER.

Results and Discussion

First, we discuss results from the pooled OLS regression (column 1 of Table 10). The model explains nearly half of the inter-district variation in herd efficiency ratio (HER). All the included variables have expected signs and except surface irrigation, road density and pasture lands, are statistically significant at 99 per cent confidence level. However, the OLS estimates could be biased and inconsistent if there are unobserved variables that may be correlated with independent variables included in the model.

We try to mitigate the problem of unobserved heterogeneity employing panel regression with state fixed effects. We also include national and state-specific time trends (see columns 2 and 3 in Table 10). Column 3 with both national and state-specific time trends is our preferred model.

We find that more urbanized districts have a greater orientation toward dairying. A one- percentage point increase in the share of urban population in a district is associated with 0.085 point higher HER. The districts with higher rural population densities also have higher HER, but the HER starts declining once the population density exceeds a threshold level, as indicated by Vaidyanathan *et al*. (1982) and McIntire *et al.* (1992). The coefficient on squared of population density is statistically significant too. Districts with higher rural literacy rate also have higher herd efficiency. Irrigation sources, both groundwater and surface water have positive coefficients, but the coefficient on surface irrigation variable is not significant. A one-percentage point increase in area under groundwater irrigation is associated with 0.05 point higher HER. Mechanization (measured here by the density of tractors and power tillers) is strongly and significantly correlated with HER. However, the effect of increase in availability of tractors and power tillers on HER starts shrinking after a threshold is reached. The vibrant rental markets ensure that the agricultural demand for machines is saturated at relatively low machine densities than it would be in the absence of markets. The districts where cropping pattern is dominated by cereals tend to have a lower HER, as is indicated by the negative and statistically significant coefficient on area under cereals crops. It seems that diversification toward non-cereal crops and dairying happens in tandem. It is also possible that fodder constraint in the less cereal-centric districts forces the farmers to be more efficient in their herd management as in peri-urban districts.

The coefficients on fertilizer use, landholding size and under barren and pasture lands that are statistically significant in the OLS model, lose their significance in the models with state fixed effects and state-specific time trends. We do not find statistically significant

Table 10. Determinants of variation in herd efficiency ratio (HER) across districts of India

Variable	(Pooled Regression) HER	(Panel with State Fixed Effects) HER	(Panel with State and Time fixed effects) HER
Per cent urban population	0.11169***	0.07583***	0.08504***
	(0.015)	(0.016)	(0.016)
Rural population density (population in '00'/sq km of geographical area)	0.02144***	0.02213***	0.01562***
	(0.003)	(0.004)	(0.004)
Squared rural population density	-0.00126***	-0.00086**	-0.00072*
	(0.000)	(0.000)	(0.000)
Per cent sown area under cereals	-0.07684***	-0.04390***	-0.04595***
	(0.008)	(0.011)	(0.010)
Groundwater irrigated area (% of NSA)	0.06953***	0.04740***	0.04551***
	(0.012)	(0.013)	(0.012)
Surface irrigated area (% of NSA)	-0.00924	-0.00350	0.01465
	(0.013)	(0.014)	(0.014)
Road density (km/sq km area)	0.00018	-0.00016	0.00009
	(0.000)	(0.000)	(0.000)
NPK (kg/ha)	0.00016***	0.00002	0.00002
	(0.000)	(0.000)	(0.000)
Average land size (ha)	0.00979***	0.00494*	0.00212
	(0.002)	(0.002)	(0.002)
Tractor density (No./ha of NSA)	1.11495***	0.33969***	0.20612*
	(0.151)	(0.090)	(0.088)
Tractor_density squared	-3.22057***	-0.70158*	-0.60596*
	(0.511)	(0.277)	(0.259)
Literacy rate (percent)	0.11888***	0.12389***	0.08303***
	(0.016)	(0.019)	(0.024)
Per cent area under barren land and pastures	0.06051*	0.02444	0.00243
	(0.029)	(0.035)	(0.036)
Year		-0.00077	-0.00044
		(0.000)	(0.001)
Constant	0.08323***	1.69336*	1.06425
	(0.015)	(0.852)	(1.748)
Observations (No.)	807	807	807
R-squared	0.51721		
State fixed effects		Yes	Yes
State-specific time trend		No	Yes

Note: *** p<0.001, ** p<0.01, * p<0.05
Standard errors within the parentheses

association between HER and road density, land-use or landholding size, probably because of limited variation in the shorter time-series.

To summarize, both supply and demand side factors seem to affect milk-orientation of a district's bovine economy. Bovine economies are more milk-oriented in more urban districts with greater population density, higher rural literacy, better access to groundwater irrigation and higher levels of farm mechanization. On the contrary, districts with cereal-centric cropping pattern tend to have fewer in-milk

animals in their bovine herd. Diversification to non-cereal crops goes with diversification or greater dairy orientation of bovine economy too.

Conclusions and Policy Implications

India's dairy economy has grown rapidly over the past four decades. We highlight two positive aspects of this recent growth. First, this growth has been achieved with an increase in the overall productivity of the bovine herd (measured here by HER) and reduction in the number of male bovines. Farmers are becoming more efficient in herd management. Animals are being reared more for dairying than for the draught power. In a land and fodder scarce country like India, this improvement in efficiency is much needed for sustainable development of dairying.

Second, an increasing share of this growing economy has been captured by the marginal and sub-marginal farmers. Though there has been a reversal in this trend in recent years, the bovine ownership continues to be more equitable than land ownership and the marginal and near-landless or landless farmers have been at forefront in the transformation of bovine economy from draught to dairying. They have the highest share of in-milk animals in their herds. If these trends persist, rapid dairy development could lead to more equitable distribution of farm income. It will also help improve the nutritional status of the poor households since ownership of diary animals has a large positive impact on consumption of milk. This happens because households tend to consume more of what they produce themselves in areas with missing or poorly developed markets like in rural India (Hoddinott *et al.*, 2014).

On the flip side, there are large inter-district variations in the levels of dairy development (as measured by HER (ranging from 0.085 to 0.43, see Table 11) and the pace of change in the dairy economy. The districts of eastern India and tribal India continue to have a very small share of in-milk animals in their bovine herd and they have lagged further behind the rest of India over the past fifteen years. These are also the districts with higher level of poverty where rapid dairy development could make a notable difference.

Our analysis shows that proximity to larger demand centres has a strong influence on dairy development.

Table 11. Inter-quartile range of district level herd efficiency ratio (HER) in 2007

Quartile	HER value in 2007
Zero (Minimum)	0.085
First	0.207
Second (Median)	0.265
Third	0.315
Fourth (Maximum)	0.463

Source: Computed by authors using data from *Livestock Census 2007*

Milk is a bulky and perishable commodity. Its marketing is difficult and production is unlikely to take off unless there is a ready access to the market (Birthal, 2008).

On the supply side, groundwater irrigation helps farmers to intensify land use and ensures year-round access to green fodder which is required to maintain an efficient herd with high proportion of in-milk animals at any point of time. Farm mechanization is another big contributor to increase in herd efficiency and development of dairy economy. It reduces the need for or dependence on draught animals and allows farmers to diversify towards dairying. Crop diversification away from cereals is also associated with increase in herd efficiency.

In India, and in many other countries of the world, bovines are a major source of household income and nutrition. The poorer households tend to have even a higher dependence on bovines for their livelihoods. As diets diversify and intake of milk and milk products increases, the production needs to keep pace with the rising demand. This can be achieved sustainably only if the productivity of dairy animals increases. Farm mechanization, crop diversification, improved access to year-round irrigation and improvement in market linkages help smallholders become more efficient milk producers. A more efficient and sustainably growing dairy economy would not only improve nutritional status of households, but also help bring a greater share of farm income to the farmers who own very small landholdings. The policy should, therefore, focus on increasing crop diversification and smallholders' access to irrigation, farm machines and markets.

End Notes

[1] Based on AHS (2006) and Table 1 in http://www.nddb.org/English/Statistics/Pages/Milk-Production.aspx: Estimates of Production and Per Capita Availability of Milk 1950-51 to 2006-07, All India

[2] Excluding contributions from forestry and fisheries.

[3] http://www.nddb.org/English/Statistics/Pages/Index-number-of-Wholesale-prices.aspx

[4] Improvement in dairy production efficiency will also involve having bovines with higher milk yield. As mentioned earlier, we do not have data on milk yield at the disaggregate level.

[5] Directorate of Economics and Statistics, 2001

[6] Indigenous and crossbred cows accounted for 55.2 per cent and 10.3 per cent of total bovines in India in 2007, respectively.

[7] See ICRISAT Meso-data at http://vdsa.icrisat.ac.in/vdsa-database.htm for district level time-series data on a number of variables related to agriculture.

[8] There might be districts that are not highly urbanized but are close to big urban centres like Bharatpur and Alwar in Rajasthan (close to Delhi), Mehsana in Gujarat (Close to Ahmedabad) and Bangalore-rural (close to Bangalore) and many others. Such districts will have high levels of dairy development too.

We do not have district level data on per capita income. Also, there is a possible problem of endogeneity in including per capita income as an explanatory variable in our regressions because higher income means higher milk demand, but more developed dairying could also lead to higher incomes.

[9] This category includes the 15.4 per cent near-landless households also.

Acknowledgement

The author thank the referee for helpful suggestions on the earlier draft of the paper.

References

Bhattarai, Madhusudan and Narayanamoorthy, A. (Undated) Impact of irrigation on agricultural growth and poverty alleviation: Macro level analyses in India. *Water Policy Research Highlight* 12. IWMI-Tata Water Policy Program, India

Binswanger, Hans P. and Rosenzweig, Mark R. (1986) Behavioural and material determinants of production relations in agriculture. *The Journal of Development Studies*, **22**(3): 503-539.

Birthal, P.S. (2008) Linking smallholder livestock producers to markets: issues and approaches**.** *Indian Journal of Agricultural Economics*, **63**(1):19-37.

Birthal, P.S. and Parthasarathy Rao, P. (2004) Intensification of livestock production in India: patterns, trends, and determinants. *Indian Journal Agricultural Economics*, **59**(3): 555-566.

Birthal, P.S. and Taneja V.K (2006) Livestock sector in India: Opportunities and challenges for smallholders. In: *Smallholder Livestock Production in India: Opportunities and Challenges,* Eds: P.S. Birthal, V.K. Taneja and W. Thorpe. National Centre for Agricultural Economics and Policy Research, New Delhi, India and International Livestock Research Institute, Nairobi, Kenya.

Birthal, P.S. and Negi, D.S. (2012) Livestock for higher, sustainable and inclusive agricultural growth. *Economic and Political Weekly*, **47** (26/27): 89-99.

Birthal P.S., Taneja, V.K. and Thorpe, W. (Eds) (2006) *Smallholder Livestock Production in India: Opportunities and challenges*. National Centre for Agricultural Economics and Policy Research, New Delhi, India and International Livestock Research Institute, Nairobi, Kenya.

Boserup, Ester (1965) *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. G. Allen & Unwin, London, UK.

Dikshit, A.K. and Birthal, P.S. (2010) India's livestock feed demand: estimates and projections. *Agricultural Economics Research Review*, **23**(1):15-28.

Gandhi, V.P. and Zhou, Z. (2010) Rising demand for livestock products in India: nature, patterns and implications. *Australasian Agribusiness Review*, **18**(1): 103-35.

GoI (Government of India) (undated) *All-India Area, Production and Yield of Foodgrains from 1950-51 to 2006-07*. Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi. Available at: http://dacnet.nic.in/eands/4.5(a)Allper cent20Indiaper cent20Area,per cent20Productionper cent20andper cent20Yieldper cent20ofper cent20Foodgrains.xls

GoI (Government of India) (2003) *16th Indian Livestock Census 1997*. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, New Delhi.

GoI (Government of India) (2005) *17th Indian Livestock Census 2003*. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, New Delhi.

GoI (Government of India) (2006) *Livestock Ownership across Operational Land Holding Classes in India 2002-03*. Report No. 493, Ministry of Statistics and Program Implementation, New Delhi.

GoI (Government of India) (2010) *18th Indian Livestock Census 2007*. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, New Delhi.

GoI (Government of India) (2014) *Annual Report 2012-13*. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, New Delhi. Available at: http://www.dahd.nic.in/dahd/WriteReadData/Annualper cent20Reportper cent202012-13per cent20EFG.pdf (accessed on 17th June 2014).

Hoddinott, J.F., Headey, D.D. and Dereje, M. (2014) *Cows, Missing Milk Markets and Nutrition in Rural Ethiopia*. International Food Policy Research Institute, Washington, D.C. Available at: http://www.ifpri.org/sites/default/files/publications/esspwp63.pdf

Joshi, P.K. and Kumar, P. (2012) Food Demand and Supply Projections for India, (Mimeo). International Food Policy Research Institute New Delhi Office.

Mishra, Prachi, and Roy, Devesh (2011) *Explaining Inflation in India: The Role of Food Prices, (*Mimeo). International Monetary Fund, Washington, D.C.

Sharma, V.P. (2004) Livestock economy of India: current status, emerging issues and long term prospects. *Indian Journal of Agricultural Economics,* **59**(3): 512-554.

Sharma V.P., Delgado C.L., Staal, S. and Singh, R.V. (2003) *Structural Changes in the Dairy Sector and Equity Issues in Livestock Industrialization Project: Phase II - Policy, Technical, and Environmental Determinants and Implications of the Scaling-Up of Milk Production in India*. Foof and Agriculture Organization of United Nations, Rome. Available at: http://www.fao.org/wairdocs/lead/x6170e/x6170e30.htm#TopOfPage

Shukla, R.K. and Brahmankar, S.D. (1999) *Impact Evaluation of Operation Flood on Rural Dairy Sector.* National Council of Applied Economic Research, New Delhi.

Singh R.P. and Verghese K.A. (2004) *Diversification of Economic Activities and Farm Household Income in Rajasthan*. Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan.

Sidhu, R.S. and Bhullar, A.S. (2004) Changing structure of the farm economy in Punjab: impact of livestock on income and employment. *Indian Journal of Agricultural Economics*, **59**(3): 578-587.

Vaidyanathan, A., Nair, K.N., Harris, Marvin, Abruzzi, William S., Adams, Richard N., Batra, S.M., Chibnik, Michael, Crotty, R., Doherty, Victor S., Freed, Stanley A., Freed, Ruth S., Fruehling, Royal T., MacLachlan, Morgan D., Nonini, Donald M., Odend'hal, Stewart, Prasada, Rao D.L. and Robkin, Eugene (1982) Bovine sex and species ratios in India (and comments and reply). *Current Anthropology*, **23**(4): 365-383.

Received: July, 2015; Accepted: November, 2015

Appendix 1. Percentage of landless or near landless (< 0.02 ha) households across states in rural India who owned at least one bovine in 2002-03

State	Fraction of landless and near landless (<0.02 ha) households that owned a bovine	Fraction of all rural households that owned a bovine
Andhra Pradesh	0.046	0.275
Assam	0.111	0.593
Bihar	0.095	0.47
Chhattisgarh	0.049	0.618
Gujarat	0.115	0.498
Haryana	0.23	0.627
Himachal Pradesh	0.037	0.657
Jammu & Kashmir	0.148	0.771
Jharkhand	0.041	0.568
Karnataka	0.098	0.467
Kerala	0.024	0.166
Madhya Pradesh	0.09	0.606
Maharashtra	0.043	0.396
Odisha	0.053	0.489
Punjab	0.319	0.656
Rajasthan	0.142	0.643
Tamil Nadu	0.051	0.225
Uttar Pradesh	0.14	0.635
Uttarakhand	0.121	0.734
West Bengal	0.065	0.432
India	0.186	0.476

Source: Estimated by authors using LLSS data from NSSO (2006)