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Can States become Wealthier While Keeping Livestock Intensification Low? Evidence from India

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Abstract: Rising demand and urbanization have led to the global increase and intensification of livestock production. Intensive production has harmful effects on the environment, public health (due to the emergence of zoonotic diseases), and animal welfare. In order to better understand how livestock production intensifies as countries develop and incomes rise, we examine the relationship between income per capita and intensification of poultry and cattle, using the states of India as a study region. We also replicate this analysis at the district level to test whether the relationship holds at different spatial scales. We identify outlying states and districts to see if there are policies that can keep agriculture production largely extensive, even as economic growth occurs. The results support the relationship of income being positively correlated with the proportion of livestock in intensive conditions. However, there are notable outlier states which have grown wealthy while still maintaining largely extensive production, indicating that there may be some cases where economic growth can occur without intensification.

Keywords: dairy; GDP; meat consumption; net state domestic product; poultry; urbanization

1. Introduction

In what has been called the "Livestock Revolution," there has been a dramatic transformation in the animal agriculture sector in the last few decades, particularly in developing countries (Delgado et al., 1999). This transformation has occurred in four ways. First, production is more geographically concentrated in regions with access to the market and availability of cheap inputs. Secondly, the scale of production has increased, leading to more intensive farming. Thirdly, there has been a movement in production from cattle and sheep to poultry and pigs. Fourthly, when intensification eventually gives rise to industrialisation, the entrance of large firms has increased vertical integration and commercialisation (T. Robinson et al., 2011). These transformations have driven the massive increase in global meat and dairy production. Per capita meat consumption has risen from 22.9 kg in 1961 to 42.3 kg in 2020 (FAO, 2023; Our World in Data, 2023).

There are several concerns caused by intensive agriculture. Intensification can increase the risk of the emergence of zoonotic diseases (Jones et al., 2013). This is because high densities of intensified livestock, such as pigs and poultry, with genetically homogenous populations increase the rate of spread of diseases and escalate the probability of pathogens to develop adaptations that allow for transmission to humans (J. Otte & Roland-Holst, 2008). For example, a number of highly pathogenic avian influenza (HPAI) viruses have emerged, such as H5N1 in China which later spread to Thailand and other countries in Asia (Graham et al., 2008; Ito et al., 2001). Furthermore, there is often heavy use of antimicrobials to reduce disease transmission, enhance growth, and increase productivity (Van Boeckel et al., 2015). The rapid increase of antimicrobial usage can result in the development of dangerous zoonotic pathogens with antimicrobial resistance in not just animals, but also humans (Van Boeckel et al., 2019). Additionally, high densities of livestock generate large quantities of animal manure that can, if released into the environment, cause nutrient overloads in land and water (Gerber et al., 2005; Springmann et al., 2018; Steinfeld et al., 2006).

The socioeconomic effects are less certain. Intensification could reduce the price of animal proteins, increasing availability to low-income groups, though meat produced by intensively raised animals may have lower nutritional value and pose health risks (Leheska et al., 2008; Snow et al., 2010). There is also the potential displacement of smallholder livelihoods that use extensive methods (Liao & Brown, 2018; Mcleod et al., 2009). Lastly, the confinement of animals in small spaces and heavy use of hormones can cause substantial harm to animal welfare (Garner, 2004; Singer, 2003; von Keyserlingk & Hötzel, 2015).

2. Literature review

It is well-established that there is a positive relationship between GDP per capita and consumption of meat per capita (Gilbert et al., 2015; Godfray et al., 2018; Milford et al., 2019; Sans & Combris, 2015; Schroeder et al., 1996). Furthermore, as economies transition from low to middle income, there is a shift from extensive to intensive production. Intensive livestock production involves larger flock size and densities, high input costs, and greater commercial-orientation. In contrast, extensive production is smaller-scale, has lower input costs, and is primarily for home-consumption (Ilea, 2009; T. Robinson et al., 2011). During the transitioning phase, the two production methods co-exist (Van Boeckel et al., 2012).

There is currently a lack of research and consensus among experts if intensification can be prevented or slowed (Blyth & Ryba, 2023; Tan, 2021). In order to mitigate these concerns, it is important to understand how livestock production will evolve as countries develop economically. There are several reasons for why economic growth could drive intensification. Firstly, rising incomes lead to greater demand and consumption of meat, providing an economic incentive for producers to intensify and reduce costs by scaling up. Secondly, the investment required to afford the higher input costs of intensive production are more readily available in countries with a higher income per capita. Thirdly, rising incomes could increase people's preference for branded, reliable meat products that more often come from large, intensive producers rather than local smallholders. Fourthly, increased urbanization reduces the space for open pastures, making extensive production less feasible (Gilbert et al., 2015; Reichenbach et al., 2021; T. Robinson et al., 2011; Thornton, 2010).

Several other studies have modeled livestock density (the number of animals per unit area) throughout the world (Neumann et al., 2009; Prosser et al., 2011; T. P. Robinson et al., 2007, 2014; Van Boeckel et al., 2011). However, most of these studies have not separated extensively and intensively raised livestock, though there are two exceptions discussed further below (Gilbert et al., 2015; Van Boeckel et al., 2012). This is important since the impacts of livestock for society, the environment, public health, and animal welfare depend not only on the densities of livestock, but on the modes of production used to rear them.

Some studies have examined intensification across a specific region or country, but all of these have looked at spatial predictor variables such as availability of cheap feed or vegetation, topography, access to cheap markets, and climate, rather than wealth (Cheng et al., 2023; Gerber et al., 2005; Van Boeckel et al., 2012; Zhao et al., 2022).

This study aims to expand upon previous work in several ways. Studies on the relationship between wealth and livestock intensification have so far been limited to a single spatial scale—that of countries. This is the first to test whether wealth (measured as income per capita) and intensification are correlated at subnational scales, at the level of states and districts. Given the significant harms of intensification, the study further aims to identify outlier states which have managed to grow wealthy without increasing intensification, and if so, whether this achievement was caused by specific policies that can be used as a model by other jurisdictions. Finally, we test whether per capita availability of eggs, poultry meat, and milk is correlated with income. This would give greater insights on whether income growth leading to rising demand is one of the major drivers of expansion and intensification of animal agriculture in the study region.

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3. Methods

3.1. The study region

As a study region, this paper examines India. India was chosen for several reasons. Firstly, many Indian states and even districts have a population similar to large or medium sized countries. Secondly, Gilbert et al. (2015) shows that the transition from extensive to intensive production is likely to be most prominent in developing countries with a GDP per capita (PPP) of 1,000 to 10,000 USD for poultry and 1,000 to 30,000 USD for pigs. The net state domestic product per capita (PPP) of Indian states closely align with this interval, and, as of 2019, ranged from 1,800 to 19,104, making India a good country to study this transition. Specifically, this paper focuses on the dairy and poultry industries. Cattle and poultry were chosen to study the intensification of livestock in India for two reasons. Firstly, they are the largest livestock sectors, and secondly, other livestock such as sheep, goats and pigs have not still not seen intensification in India (Sahoo et al., 2015). The rising intensification of chicken could pose a particular harm to animal welfare (Alonso & Schuck-Paim, 2022; Klaura et al., 2023; Mathur, 2022).

India's dairy and poultry industries are rapidly growing. The dairy industry primarily functions on a three-tiered structure consisting of dairy cooperative societies at the village level, unions at the district level, and federations at the state level (Government of India, 2023). India is ranked first in the world in terms of total dairy production (Anbu, 2020; FAO, 2022). Approximately 46% of milk produced is consumed locally, by farmers or in their villages, while the remaining 54% is available in the market for sale in the organized and unorganized sector (Government of India, 2023).

The per capita availability of milk has increased from 107 grams per day in 1970 to 444 grams per day as of 2021-2022. This was higher than the world average of 322 grams per day in 2021 (Government of India, 2023; Singh et al., 2023). However, it differs widely throughout the country, reaching as high as 1271 grams per day in Punjab, a major milk producer, and under 100 in many Northeastern states such as Assam (77), Manipur (65), and Mizoram (55) (Government of India, 2022).

In contrast, India's poultry industry runs on two models: backyard and commercial poultry. Backyard poultry is reared in an unorganized sector where small and marginal farmers raise chickens as a form of supplemental income and nutrition. Around 5-10 chickens per household are raised in free range conditions, and productivity is low. Approximately 31% of poultry are backyard, and the rest are raised commercially. The commercial poultry sector is well-organized, and it uses broiler and layer breeds for poultry and egg production respectively. It accounts for 85% of egg production and has rapidly grown in the past few decades. India is third in the world in terms of egg production and eighth in terms of poultry meat production. India's poultry meat and egg production have grown at an annual average rate of 9.2% and 7.2%, respectively, from 2000 to 2020 (Gulati & Juneja, 2023).

Cattle and poultry are intensified in different ways. For poultry, intensification primarily comes in the form of very large flock sizes, large factories, and heavy use of feed. In contrast, the vast majority of dairy is still produced by smallholders. For cattle therefore, intensification is likely to focus on commercialisation and increasing productivity by investing in higher yield breeds and using self-cultivated forages rather than pastures (Reichenbach et al., 2021).

India's per capita consumption of broiler meat has increased from under 0.8 kg per person per year in 2000 to 2.6 kg per person per year in 2021. Still, it is substantially below the per capita consumption of other countries like China (14.0 kg), Vietnam (16.9 kg), and Brazil (40.8 kg) (Gulati & Juneja, 2023; OECD, 2023). India's per capita availability of egg production in 2021-22 was 95 eggs per annum, below the 180 eggs per capita recommended by the Indian Council of Medical Research (Government of India, 2022). As with milk availability, this differs widely among states, with Andhra Pradesh having a per capita availability of 501 eggs/annum compared to just 23 eggs/annum for Jharkhand (Government of India, 2022). This is in part due to India having the highest rate of vegetarianism (where "vegetarian" often refers to lacto-vegetarian) of any country, with large differences seen in rates of vegetarianism across different regions of India (Devi et al., 2014).

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Previous work analyzing the determinants of agricultural intensification in India found that human population density and urbanization are positively correlated with agricultural intensification and that it is largely driven by demand (Birthal & Rao, 2004).

3.2. Data and analysis

The latest available livestock census data was from the 20th Livestock Census conducted from October 1st, 2018 to September 20th, 2019 by the Department of Animal Husbandry & Dairying (Government of India, 2019a).

India had detailed census data on the number of fowl farmed under backyard (extensive) and commercial (intensive) systems for 28 states and 8 union territories. For poultry, the analysis was conducted on just fowl as they account for 98.96% of egg production, though the analysis was repeated for other types of poultry (supplemental file). Fowls were subdivided into desi (indigenous) and improved breeds.

Data for the number of cattle raised under intensive and extensive conditions was not directly available. Instead, the proportion of cattle of exotic/crossbred breed was used as a proxy for intensification. The transition to intensification and increasing productivity is generally associated with using more exotic cattle because they are more expensive to acquire and maintain than indigenous or non-descript cattle and so require higher input costs (Kuchimanchi et al., 2021; McDermott et al., 2010; Reichenbach et al., 2021). Breed as a proxy has a close relationship with the intensification of fowl, which lends further support to using breed as a proxy of intensification for cattle (supplemental file).

Data on per capita availability of animal products, production, and productivity of livestock was obtained from the Basic Animal Husbandry Statistics and was used as a proxy for consumption (Government of India, 2019b; Henneberg & You, 2016; Sans & Combris, 2015).

Net state domestic product (NSDP) per capita in USD (PPP) in the year 2018-2019 was used as a measure of income per capita for states and was obtained from the Reserve Bank of India (Reserve Bank of India, 2023). Per capita income for districts was obtained from the ICRISAT district database (ICRISAT, 2023). To correct for purchasing powering disparities and to make the results comparable with previous studies, income was converted to USD corrected for PPP (OECD, 2022). District-wise data from the 2019 livestock census was not available. Instead, 2012 census data was used for the district-wise analysis and to construct the district-level maps.

33 out of 36 states/union territories and 534 out of 640 districts were analyzed. Per capita income was not available for 3 union territories and 106 districts, so they were dropped. These states/union territories had a mean population of 40.3 million people and the districts approximately 2.2 million people, meaning that even India's districts have a population similar to small countries.

Linear regression models were used, with each state given a weight proportional to the total number of the livestock being analyzed in that state. A linear model is justified in this case given that Gilbert et al's analysis showed a linear trend between GDP per capita (PPP) and proportion of animals in intensive conditions in the income range where India's states are currently situated.

Regression models were generated to test the effect of income on the following variables: proportion of fowl in commercial conditions, proportion of cattle of exotic breed, and per capita availability of milk, eggs, and poultry meat. For models involving the proportion of intensified fowl or cattle, states were weighted by the total number of that livestock in the state. For models involving per capita availability of milk, eggs, or poultry meat, states were weighted based on their population. The relationship between percentage change in income and change in proportion of intensive livestock between 2012 and 2019 was also tested, to see if states which had a larger increase in income intensified production more. The states Andhra Pradesh and Telangana were excluded from this analysis, as the geographical boundaries differed between 2012 and 2019.

All analyses were performed using R 4.3.1 (R Core Team, 2023), the ggplot2 (Wickham, 2016), and the gtsummary (Sjoberg et al., 2021) packages.

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4. Results

Regression analysis showed a positive relationship between the log of GDP per capita (PPP) and intensification for both fowl (as measured by proportion of fowl in commercial conditions) and cattle (as measured by proportion of cattle of exotic/crossbred breed) (Figure 1). For fowl, the relationship was stronger, and income was able to predict the proportion of intensively raised chickens with an R^2 value of 0.536 for states and 0.270 for districts, compared to an R^2 value of 0.219 in states and 0.127 in districts for cattle (Table 1). All slope coefficients are highly statistically significant. Coefficients show that for every 10% increase in income, the percentage of fowl raised in intensive conditions for states increases by 4.6 percentage points and the percentage of exotic cattle increases by 1.8 percentage points. The coefficients are similar for districts; a 10% increase in income corresponds to a 3.2 percentage point increase in the percentage of intensively raised fowl and a 1.7 percentage point increase in the percentage of exotic cattle.

Table 1. Regression results.

Proportion of commercial fowl	**Beta**	**SE[1]**	**p-value**
(Intercept)	-3.4***	0.703	<0.001
Log per capita income	1.1***	0.184	<0.001
No. Obs.	33		
R^2	0.520		
Proportion of exotic cattle			
(Intercept)	-1.4*	0.554	0.019
Log per capita income	0.44**	0.151	0.006
No. Obs.	33		
R^2	0.219		
Egg per capita availability			
(Intercept)	-546*	220	0.019
Log per capita income	167**	59.7	0.009
No. Obs.	32		
R^2	0.208		
Per capita milk availability			
(Intercept)	-319	675	0.6
Log per capita income	192	183	0.3
No. Obs.	32		
R^2	0.036		
Per capita poultry meat availability			
(Intercept)	-20*	7.49	0.010
Log per capita income	6.4**	2.02	0.004
No. Obs.	33		
R^2	0.242		
District proportion of commercial fowl			
(Intercept)	-2.1***	0.202	<0.001
Log per capita income	0.77***	0.055	<0.001
No. Obs.	534		
R^2	0.270		
District proportion of exotic cattle			
(Intercept)	-1.3***	0.168	<0.001
Log per capita income	0.42***	0.048	<0.001
No. Obs.	534		
R^2	0.127		
Change in proportion of commercial fowl			

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(Intercept)	-0.12	0.062	0.068
Percentage change in income	0.16	0.125	0.2
No. Obs.	31		
R^2	0.055		
Change in proportion of exotic cattle			
(Intercept)	-0.03	0.033	0.4
Percentage change in income	0.19*	0.070	0.010
No. Obs.	31		
R^2	0.206		

[1] SE = Standard Error. Note: *p<0.05, **p<0.01, ***p<0.001.

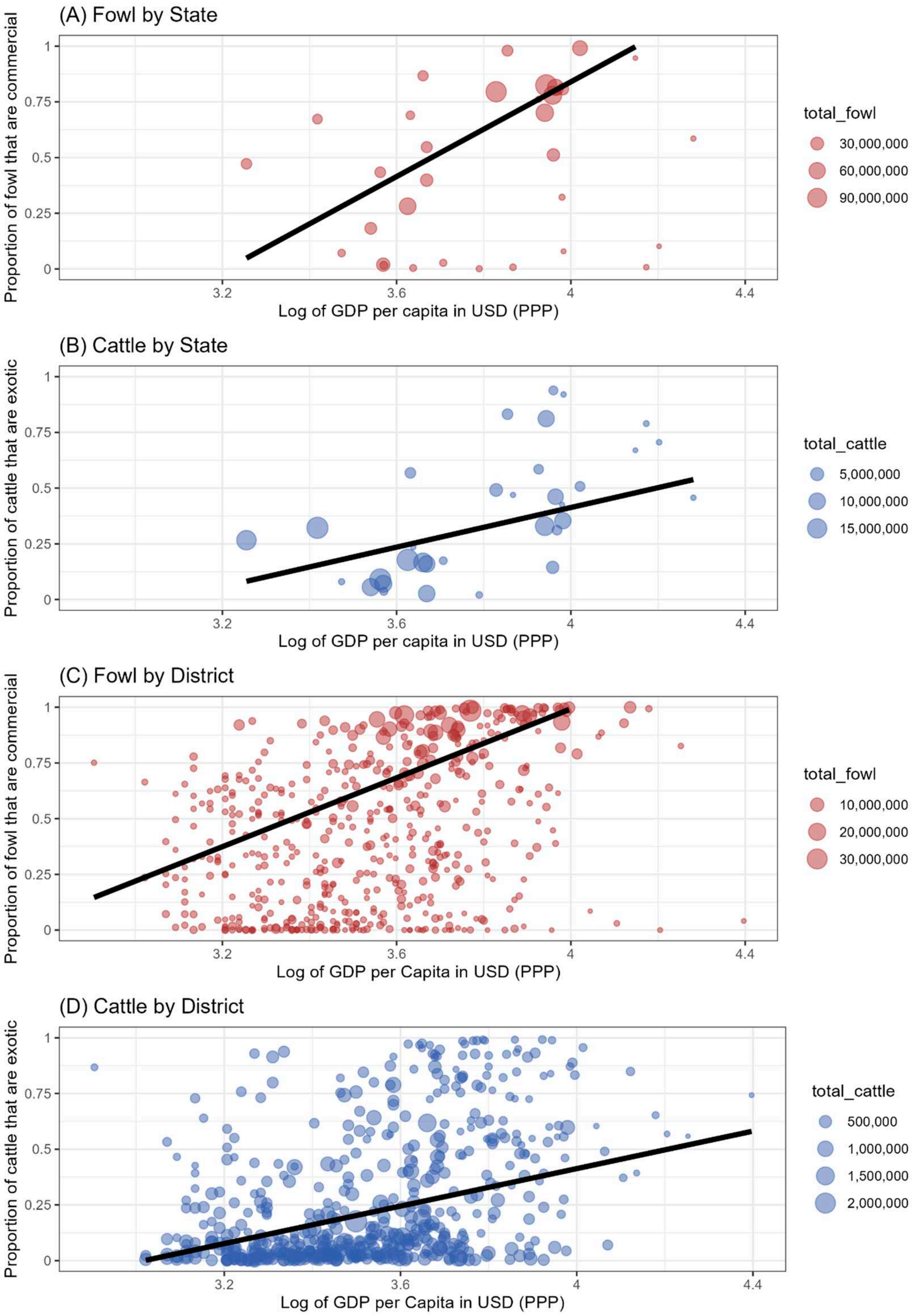

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Figure 1. Scatterplots of log of income against proportion of intensive livestock.

From 2012 to 2019, there was a positive relationship (R^2 = 0.21, p=0.01) between the percentage change in income and the change in proportion of exotic cattle. The slope coefficient showed that for every 10% increase in income, the proportion of exotic cattle increased by 0.019. In contrast, this relationship was not statistically significant for fowl.

Per capita income was correlated with egg and poultry meat per capita availability with an R^2 value of 0.208 and 0.242 respectively. For every 10% increase in income, the egg per capita availability increased by 7 eggs/year and the poultry meat per capita availability increased by 0.26 kg/year. There was no statistically significant relationship found between milk availability per capita and income per capita.

Haryana and Telangana, which have the third and fourth highest per capita income, respectively, had 99% and 78% of fowl raised commercially. In contrast, poorer states like Jharkhand and Assam with an income per capita of $2,664 and $2,844 respectively, had only 18% and 2.0% of fowl raised commercially. Maps show that densities of intensively raised fowl and cattle are particularly high in South Indian states such as Kerala, Karnataka and Tamil Nadu, some Northern regions, particularly Haryana and Punjab, and parts of Maharashtra and West Bengal (Figure 2).

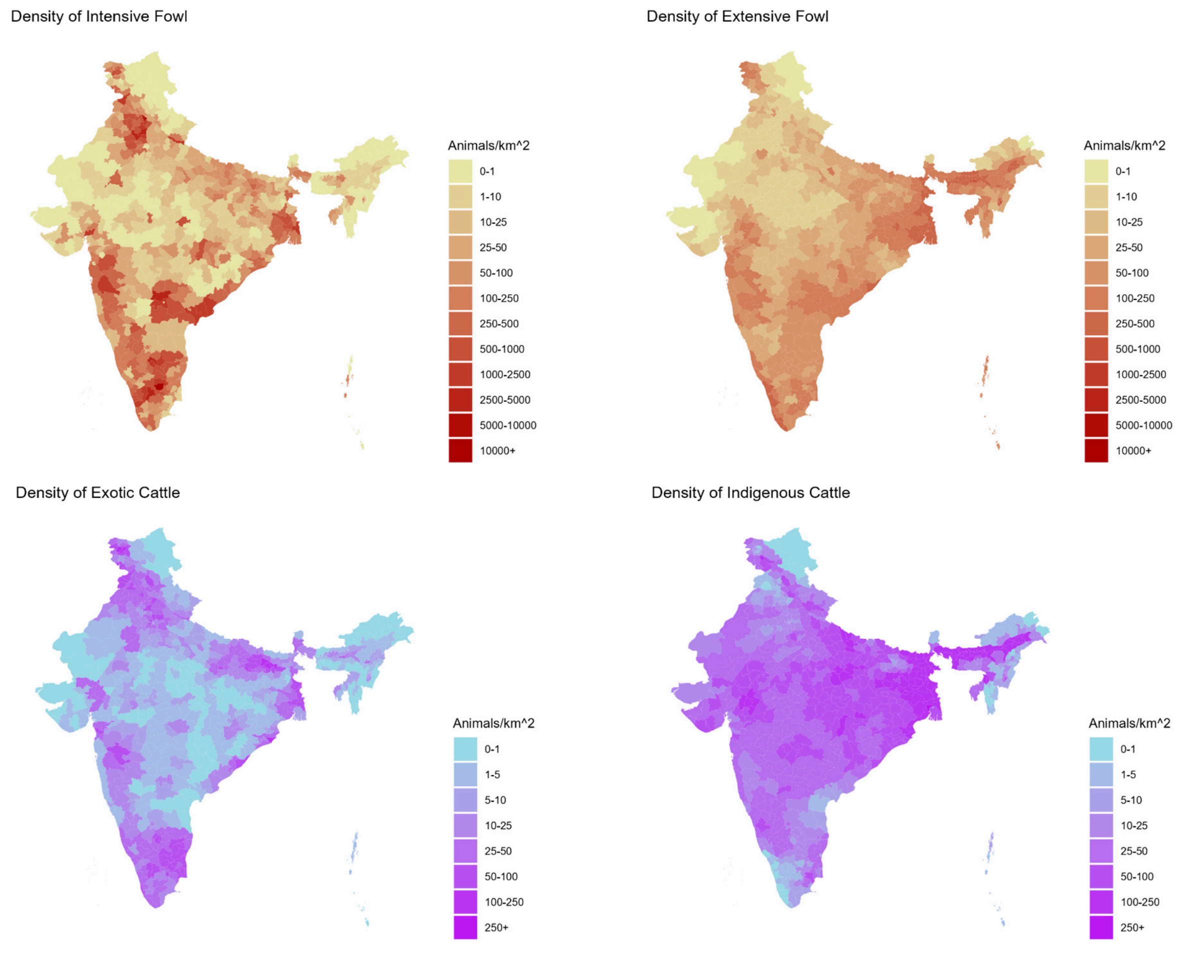

Figure 2. District maps of densities of intensive and extensive livestock.

It is notable that since the 2012 livestock census, the backyard poultry population has grown by 46%. This growth exceeds that of the commercial poultry population, which has grown by 5%. This indicates that despite India's GDP per capita (PPP) increasing from $3,919 to $5,741 from 2012 to 2019, the percentage of chickens in intensive conditions has decreased from 70% to 63%. The absolute number of commercial fowl still increased in most states, though in some states, such as Uttar

Pradesh, West Bengal, and Chattisgarh, the number of commercial fowl declined despite income increasing.

5. Discussion

5.1. General discussion

This study investigated whether the relationship between income and intensification of livestock held at a spatial level of states and districts within a country and whether there were any outliers to this trend. It was found that intensification was correlated with income at both the state and district level. The relationship was less strong for districts, perhaps because it is more likely for production and consumption to cross the boundaries of districts rather than states. Income and per capita availability of eggs and poultry meat had a positive relationship, though there was surprisingly no relationship between per capita availability of milk and income.

District maps show that the density of intensive fowl is spatially concentrated in some regions and very low in others. For instance, two neighboring districts from the same state may have very different densities of intensive fowl. This might be because the cultivation of intensive fowl is dominated by large companies, which may concentrate their activity in particular regions. Intensive production also takes less land as there is greater use of feed and large grazing grounds are not required. In contrast, extensive fowl is more uniformly distributed, and districts in the same state can be expected to have roughly similar levels of intensification. This is also reflected in the ranges of densities. For intensive fowl, densities range from 0 to 10,000+ fowl per kilometer squared. For extensive fowl, no district has a density of 0, and the highest densities only just exceed 1,000 fowl per kilometer squared.

This spatial clustering might lead to the harms of intensification also being more locally concentrated. Zones of dense production dominated by a smaller number of very large farms may displace smallholders from the market, both in these areas and in neighboring areas where production declines. Additionally, industrial systems are often delinked from the natural resources used to produce feed (Naylor et al., 2005). This disrupts nutrient cycles by simultaneously creating nutrient depletion in land that produces feed, while causing nutrient overloads which can seep out into the environment in regions of high livestock density (Gerber et al., 2005; Sanderson et al., 2010). As India and other low-income countries further develop, regional or state-wise specialisation in livestock agriculture may lead to further spatial clustering that is seen in high income countries (Neumann et al., 2009).

Income and per capita availability of egg and poultry meat were found to be correlated. This is expected given that there is a well-established relationship between GDP per capita and per capita animal products consumption and that there has been a rise in poultry meat consumption per capita as incomes in India have risen (Godfray et al., 2018; Iddamalgoda et al., 2001; Milford et al., 2019; Sans & Combris, 2015; Schroeder et al., 1996). In contrast, there was no statistically significant relationship found between milk availability per capita and income per capita. This is surprising given past research that showed that income was a large determinant of the amount of milk consumed (De Alwis et al., 2011; Kapaj, 2018). India's per capita availability of milk still shows an upward trend, correlating with the rise in income in this period. This may mean that a factor other than income, such as the change in production structures of dairy, may be contributing to rising dairy production and per capita availability. In contrast, the rise in egg and poultry meat production may be primarily demand-driven, with rising incomes encouraging greater production. These are only hypotheses, however, and may be a valuable area for future research.

The limitation in this analysis is that per capita availability is derived from estimates of annual egg, meat, and milk production and population, meaning that actual human consumption is not measured (Russo et al., 2017). Therefore, this does not account for imports and exports out of a state, food that is unsold in the market, and food wastage. There is no direct measurement of human consumption that takes these factors into consideration. However, given that many regions are at least partially self-sufficient in milk, and the small size of the processed chicken market makes

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transportation to other states challenging, it is still likely that a significant portion of a state's production is consumed within the state (Government of India, 2017, 2022).

There are several implications and new research directions. First, since the relationship between income per capita has been established at three spatial levels, at the country, state, and district level, the densities of intensive and extensive livestock within countries could be forecast using GDP and population growth projections. Such forecasts could ideally take into account the spatial concentration of production as intensification occurs. These forecasts could be used to analyze the environmental, economic and epidemiological effects that arise as a result of intensification (Cang et al., 2004; Haas et al., 2001; Pritchard, 2000). Gilbert et al. (2015) suggested conducting such an analysis at a global level—since we have now demonstrated that the relationship between wealth and intensification holds at smaller spatial scales, such an analysis could also be done on a state or district level. There have been many attempts to model out global livestock production systems, based on assumptions of how livestock are distributed. Comparisons with maps created from India's detailed census data may help assess the validity of these models and their assumptions.

Secondly, by studying states like Sikkim which have experienced economic growth without intensification, policies to slow down intensification even as countries develop can be identified. This can be of particular interest as policymakers become more concerned about the harms of intensification to human health and animal welfare (Coghlan et al., 2021; Cox & Bridgers, 2019; Fraser, 2008; von Keyserlingk & Hötzel, 2015).

The impacts of intensification to animal welfare are another open area of research. Increased intensification would likely improve productivity of livestock, increasing the yield per livestock. Exotic cattle are over twice as productive in terms of milk yield per day compared to indigenous cattle. This could reduce the number of animals that experience suffering, since fewer animals would be required to produce the same amount of meat or milk. Given that demand for animal products is rising as incomes rise in India and other developing countries, intensification might be necessary to increase production without a corresponding large increase in the number of livestock.

On the other hand, intensification could substantially worsen welfare conditions for animals, especially chickens. Additionally, increased productivity could increase revenue for firms, allowing them to further increase production such that even with productivity increases, more animals are farmed. If intensification does worsen animal welfare, it could be necessary to strengthen and enforce legislation protecting animals, such as with guidelines for humane slaughter, the provision of adequate space, and the banning of harmful practices like castration without anesthesia (Fraser, 2008).

5.2. Policy lessons for promoting extensive agriculture

What about outliers? Maps showed that the Northeastern states, such as Manipur, Assam, Arunachal Pradesh, and Sikkim, had particularly low densities of intensive livestock. Some of these states had low intensification despite having high incomes. For example, Mizoram had a per capita income of $5648 and Sikkim had the second largest income of all states - nevertheless, each of these two states had less than 1% of fowl raised commercially. In Northeast India, rearing tends to be dominated by smallholders, preventing the scale necessary for intensification to occur (A. Kumar et al., 2007).

Many outlier districts were cities, like Hyderabad and Chennai, which tend to outsource their production and had low populations of livestock relative to people. The Kodagu district in Karnataka also had low intensification of fowl and cattle while having a large livestock population, though this is likely due its tourism and coffee agroforestry based economy, and is therefore unlikely to be replicable as a policy (Sathish & Kushalappa, 2006).

The state outliers can be caused by two reasons - geography and policy. The Northeast has a very mountainous terrain and large forest cover. This can make distribution more difficult, making it less feasible to concentrate production in one area. Population densities are also low in the Northeast indicating there might not be a large enough market to encourage commercialisation. In contrast, the mountainous climate is more conducive to extensive, agro-pastoral farming systems that are commonly seen in Northeastern states.

However, for Sikkim in particular, there is a specific policy that may have caused the state's poultry to remain extensive: Sikkim is the first state in the world to go 100% organic. It has phased out synthetic fertilizers and pesticides in place of organic fertilizers (J. Kumar et al., 2018). It has also stopped the use of hormones, growth regulators, feed additives, and antibiotics that have negative health impacts, and regulated the use of inorganic feeds - these are all pervasive in commercial poultry and dairy farming in India (Government of Sikkim, 2019; Prakash et al., 2018; Sakshi Gurjar, 2022). Moreover, the government supports extensive systems of animal husbandry which provide supplemental income to farmers.

If Sikkim's organic farming policies have been one of the main causes of agriculture remaining extensive, they could plausibly be replicated in other states or countries to reduce the rate of intensification. Additionally, Sikkim's economy is agrarian and animal husbandry is a major activity with over 80% of households owning livestock (Sharma et al., 2016). This means that in order to increase production of meat as incomes and demand rise but keep intensification low, the number of poultry farmed extensively would have to grow. If poultry are spread out over the entire population, as opposed to concentrated amongst a few households or enterprises, poultry farming may not reach the scale necessary to intensify. Therefore, a possible government policy to reduce intensification might be to encourage more households to take up backyard farming. This would increase the population of poultry, as their productivity is lower compared to commercial poultry, but they would likely be in better welfare conditions compared to when they're raised commercially.

6. Conclusion

The study finds a positive relationship between income and intensification and identifies slope coefficients that can be used to model future changes in intensive livestock populations and densities. We also explore several outlier states and districts, and for the state of Sikkim, identify a particular policy that may have caused this. Further research into these outliers could develop a more concrete understanding of why they do not follow this trend.

Research extending this work to other study regions, with other predictor variables, or on other species would also provide valuable insights into the causes and effects of transformations of the livestock industry. As meat and animal products production in developing countries continues to rise, this is vital to understand the environmental, social, and health risks the future holds.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org.

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Data Availability: The data that support the findings of this study are openly available at: https://github.com/ishankhire/india-livestock-census-and-regression.

Conflict of interest: The authors have no conflicts of interest to declare.

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