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Breaking free from the trend: outlier policies promote sustainable poultry practices

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The intensification of livestock production is globally on the rise, driven by increased demand and urbanization. This presents a large potential threat to animal welfare, environmental sustainability, and public health, particularly in the developing world where the increase in intensification is most prominent. However, it remains unclear whether policymakers have tools to limit intensification even as their country or state increases in wealth. In this paper, we address the knowledge gap: is it possible for countries or states to develop economically while keeping livestock intensification low? We test whether there exist any jurisdictions that have maintained unexpectedly low levels of livestock intensification, after statistically accounting for wealth and other demographic and agricultural variables. Using India's egg and chicken meat industry as a case study due to its immense size and its intermediate stage of economic development, we successfully identify a number of states that have developed economically while maintaining low levels of chicken intensification. Subjecting these Northeastern states to a deeper examination, we find that these states have deliberately pursued policies prioritizing organic agriculture and environmentally sustainable methods of production. While there are hurdles and limitations to implementing these organic policies, the examined jurisdictions offer promise for policymakers seeking to keep levels of intensification low and maintain good animal welfare as countries develop.

KEYWORDS

gross domestic product, meat consumption, net state domestic product, poultry, urbanization

1 Introduction

In what has been called the "Livestock Revolution," there has been a dramatic transformation of the livestock industry in the last few decades. This has driven the massive increase in global meat, egg, and dairy production (Delgado et al., 1999). As economies transition from low to high income, meat consumption per capita increases and the scale of production expands (Delgado et al., 1999; Robinson et al., 2011; Milford et al., 2019). Economic growth drives intensification, particularly in the chicken industry, for several reasons. Firstly, rising incomes lead to greater demand for chicken meat and eggs,

providing an economic incentive for producers to intensify and reduce costs by scaling up (Thornton, 2010). Secondly, the investment required to afford the higher input costs of intensive production is more readily available in wealthier countries (Robinson et al., 2011). Thirdly, increased urbanization reduces the space for open pastures, making extensive production less feasible (Reichenbach et al., 2021). This drives a shift from extensive to intensive production. Extensive production here is defined as being smaller scale, having lower input costs, and being primarily for home consumption. Intensive production here is defined as having larger flock sizes, having higher input costs, being more commercially oriented, and having a heavy dependence on the use of concentrated feed (Gilbert et al., 2015). In the Indian livestock census and studies on the Indian agricultural industry, the term 'backyard' is used to refer to small-scale extensive chicken while the term 'commercial' refers to large-scale intensive chicken. The large-scale extensive commercial rearing of chickens in India in free-range conditions (for broilers) or cage-free conditions (for laying hens) is negligible. Livestock intensification causes a range of concerns, including for the welfare of farm animals (Singer, 2003; Garner, 2004; von Keyserlingk and Hötzel, 2015). This is a key consideration given that farm animal welfare is increasingly recognized as an important aspect of a sustainable food system, particularly in developing countries (von Keyserlingk and Hötzel, 2015; Cox and Bridgers, 2019; Racciatti et al., 2023; Verkuijl et al., 2024). This is illustrated by the Sustainable Development Goals and One Welfare framework (Pinillos et al., 2016; Keeling et al., 2019; Marchant-Forde and Boyle, 2020).

Intensification involves confining chickens in crowded, indoor units (Buijs et al., 2009). These units restrict their movement and prevent them from expressing natural social and non-social behaviors (Weeks and Nicol, 2006). In India, the majority of laying hens are housed in battery cages (Rokade et al., 2024). These cages prevent hens from opening their wings and moving about freely (Fraser, 2008; Schuck-Paim et al., 2021). Although broilers are not typically housed in cages in India, high stocking densities in litter systems increase the risk of contact dermatitis and can cause heat stress (Bessei, 2006). Broilers are also transported in cages where they face severe thermal stress, feed withdrawal, and are subjected to harsh environmental conditions (Chikwa et al., 2019). Broilers genetically selected to rapidly gain weight often suffer skeletal disorders and lameness (Meluzzi and Sirri, 2009). To reduce obesity and other health problems in broiler parent stock, the feed they receive is severely restricted, causing chronic hunger (Jong and Guémené, 2011). Additionally, common practices like mutilation procedures (such as beak trimming) without anesthetic can cause high-intensity pain (Nordquist et al., 2017; Mench, 2019). These conditions contribute to both acute and chronic forms of both physical and psychological suffering for farmed animals (Alonso and Schuck-Paim, 2022). Intensification may offer short-term benefits for animals such as better healthcare (Rodenburg et al., 2008; Mench and Rodenburg, 2018). However, comprehensive research studies based on the Five Freedoms framework have found that intensive systems of production significantly increase animal suffering overall (Hartcher and Jones, 2017; Alonso and Schuck-Paim, 2022; Göransson and Lundmark Hedman, 2024). While we recognize that it is possible for commercial chickens to be in free-range conditions with better welfare, in India, the cage-free egg industry and free-range broiler industry remain very limited (Mehta and Nambiar, 2007; Panda and Samal, 2016; Rokade et al., 2024). Based on these theoretical foundations, we assume for the purposes of this paper that chicken welfare is, on average, worse in intensive production systems than backyard production in India. However, we acknowledge that this remains a knowledge gap, and it would be ideal for future research to conduct systematic comparisons of chicken welfare across these two production systems in India specifically.

In most countries, the most numerous group of land-dwelling farm animals are chickens. In fact, chickens often outnumber all other categories of land-dwelling livestock combined (HYDE and FAO, 2017). As such, the rising intensification of chickens in developing nations could harm animal welfare (Alonso and Schuck-Paim, 2022; Mathur, 2022; Klaura et al., 2023). Furthermore, the chicken industry offers a clear indicator of whether a jurisdiction is pursuing intensive agriculture—the production and consumption of chicken tends to rapidly rise as wealth increases, while this effect is less pronounced for other meats (FAO, 2023). Beyond the effects on animals, livestock intensification can also impact human wellbeing. Intensification can increase the risk of the emergence of zoonotic diseases and antimicrobial resistance in pathogens, cause nutrient overloads in the environment and displace smallholders that use extensive production (Graham et al., 2008; Jones et al., 2013; Liao and Brown, 2018; Marco Springmann et al., 2018; Van Boeckel et al., 2019).

It is critical to understand whether the harms that arise from livestock intensification can be prevented. Is it possible for a country or state to develop in wealth while keeping livestock intensification low—in short, to decouple economic development from livestock intensification? Whether such decoupling is possible remains a key knowledge gap (Tan, 2021; Blyth and Ryba, 2023). Several studies have modeled livestock population density throughout the world (Robinson et al., 2007, Robinson et al., 2014; Neumann et al., 2009; Prosser et al., 2011; Van Boeckel et al., 2011). However, most of these have not separated extensively and intensively raised livestock. Other studies have examined intensification across a region or country, but all of these have looked at purely spatial predictor variables such as availability of cheap feed, access to markets, and climate, rather than wealth (Gerber et al., 2005; Van Boeckel et al., 2012; Zhao et al., 2022; Cheng et al., 2023). One study examined the relationship between wealth and livestock intensification across countries, but this study did not focus on identifying countries that have decoupled economic growth from livestock intensification (Gilbert et al., 2015).

This study aims to address the knowledge gap faced by policymakers by identifying whether there are jurisdictions that have decoupled economic growth from livestock intensification. In doing so, this study expands upon previous work in several ways. Most crucially, this study provides an analysis of a large-scale case of the relationship between economic development and livestock

intensification, with an emphasis on policy lessons. Given the significant harms of intensification, the study aims to identify outlier states which have managed to grow wealthy without intensifying, and if so, whether this achievement was caused by specific policies that can be used as a model by other jurisdictions. Furthermore, this study is the first to test whether wealth drives intensification at the subnational scale (i.e., states)—studies on the relationship between wealth and livestock intensification have so far been limited to the scale of countries (Gilbert et al., 2015).

2 Materials and methods

2.1 Theoretical approach

In this paper, we aim to address the question: "Are there jurisdictions that have decoupled economic growth from the intensification of egg and chicken meat production?". A jurisdiction may be a country or some subnational entity, such as a state. If any such jurisdictions exist, it is possible to detect them using a conceptually simple approach. First, recall that livestock intensification is strongly related to the growth of a jurisdiction's wealth (Steinfeld et al., 2006; Thornton, 2010; Robinson et al., 2011). When a sample of jurisdictions is graphed, visualizing the relationship between wealth and livestock intensification, the graph shows a clear positive relationship (Gilbert et al., 2015). However, the fit is rarely perfect—some jurisdictions will naturally depart from the average trend. If any jurisdictions have a *disproportionately* low level of livestock intensification then the jurisdiction may have pursued policies that kept livestock intensification low. Therefore, searching for outliers in the trend of wealth and livestock intensification (and any other important variables—see below) may offer a valuable source of policy guidance for other jurisdictions around the world.

The conceptual approach of searching for jurisdictions that depart from some average trend, and then interrogating those outlying jurisdictions for policy lessons, has been applied in other contexts. For example, Mor (2022) searched for countries with disproportionately low levels of Disability Adjusted Life Years lost per 100,000 population, a measure of health outcomes, to inform healthcare policies in developing countries. Likewise, Bonet et al. (2010) used this approach to identify jurisdictions with disproportionately high or low breastfeeding rates.

2.2 Study region

As a study region, we examine India in this paper. India has 28 states and 8 union territories. India offers a highly valuable source of data for two reasons. The first is India's size—many Indian states have human population sizes that would, if those states were independent countries, rank among the world's largest countries. The population in 2019 of the analyzed states and union territories ranged from 397,000 to 225 million and the mean human population was 40.4 million. The second is that India is at a very informative stage of its economic development for the policy question of livestock intensification. To illustrate, the net state product per capita (adjusted for purchasing power parity) of Indian states and territories in 2019 ranged between 1,800 and 19,000 USD (Reserve Bank of India, 2023). This is the precise range where the transition from extensive to intensive livestock production tends to be most prominent—Gilbert et al. (2015) estimate that, at the country level, this transition occurs between 1,000 to 10,000 USD for chickens and 1,000 to 30,000 USD for pigs.

India's chicken industry runs on two models: backyard and commercial. Backyard (extensive) chickens are reared in an unorganized sector where small and marginal farmers raise desi chickens, an indigenous dual-purpose chicken breed that provides eggs and meat, as a form of supplemental income and nutrition. Less than 20 chickens per household are raised in free-range conditions and productivity is low (Rajkumar et al., 2021). Approximately 35% of chickens are backyard, and the rest are raised commercially (Government of India, 2019). The commercial (intensive) chicken sector is well-organized, and it uses broiler and layer improved chicken breeds for chicken meat and egg production respectively (Mehta and Nambiar, 2007). It accounts for 85% of egg production and has rapidly grown in the past few decades. As mentioned previously, the number of large-scale commercial operations which raise free-range broilers or cage-free laying hens (extensive conditions) are negligible. Government reports and previous studies on India's egg and chicken meat industry support this distinction of commercial chickens being intensive and backyard chickens being extensive (Mehta and Nambiar, 2007; Government of India, 2019; Churchil, 2022). India is third in the world in terms of egg production and eighth in terms of chicken meat production. India's chicken meat and egg production have grown at an annual average rate of 9.2% and 7.2%, respectively, from 2000 to 2020 (Gulati and Juneja, 2023).

2.3 Statistical methods and data

To search for states that have a disproportionately low rate of chicken intensification, we first need to account for the variables that exhibit a systematic relationship with chicken intensification. The most obvious of these is wealth (Gilbert et al., 2015). However, a handful of other such variables exist. Previous work analyzing the determinants of agricultural intensification in India found that human population density and urbanization are positively correlated with agricultural intensification (Birthal and Rao, 2004). This supports studies from outside India that identified population density and urbanization as key variables (Van Boeckel et al., 2012; Milford et al., 2019). Furthermore, since the biggest cost component in chicken production is feed, previous studies have identified local feed production as a possible driver of chicken intensification (Van Boeckel et al., 2012). One variable that has been suggested by previous

authors but is *not* included by us is proximity to ports—the volume of chicken feed imported by India is negligible compared to its domestic production (Mehta and Nambiar, 2007).

As such, we generate a regression model across India's states and territories where the response variable is the percentage of chickens housed in intensive production and the predictor variables are net state product per capita (PPP adjusted, expressed as USD), human population density (people per square kilometer), urbanization (percent of human population residing in urban areas), maize production (tons), and soy production (tons). Then, we calculate each state's *residual* intensification. Residual intensification is calculated by subtracting the predicted chicken intensification level from the observed value for each state. We identified states with the lowest residuals as potential outliers that deviate significantly from the trend. We examine these states and explore the policies that may be responsible for this apparent decoupling between the predictor variables and chicken intensification.

Since the response variable is bounded to the range between 0% to 100%, we utilize a beta regression model with a logit link function. That said, the outlier states we identify using the beta regression model are the same as those identified using an ordinary least-squares regression model (not reported), indicating that the policy implications are robust to the choice of model. Likewise, the outlier states we identify are robust to the exclusion of predictor variables, except for wealth—thus, while there is some positive correlation between predictor variables (e.g. population density and urbanization), this correlation does not influence our findings. We perform the analysis using R 4.3.1 and the *betareg* package (Cribari-Neto and Zeileis, 2010; Core Team, 2024), with visualization performed using *ggplot2* (Wickham, 2016) and *gtsummary* (Sjoberg et al., 2021).

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, 2019). India had detailed census data on the number of chickens farmed under backyard (extensive) and commercial (intensive) systems for 28 states and 8 union territories. From this data, we calculate the proportion of chickens farmed under intensive conditions in each state and territory. Chickens account for 99% of egg production and therefore the analysis is reflective of the broader poultry industry as well.

We use net state domestic product (NSDP) per capita in USD (PPP) in the year 2018-2019, obtained from the Reserve Bank of India, as a measure of income per capita for states (Reserve Bank of India, 2023). To correct for purchasing powering disparities and to make the results comparable with previous studies, we convert income to USD corrected for PPP (OECD, 2022). We obtain data on maize and soy production for 2019 from the Department of Agriculture (Ministry of Agriculture and Farmers Welfare, 2019). We obtain data on human population density and urbanization from the 2019 Population Projections Report (National Commission on Population, 2019).

3 Results

3.1 Regression results

Regression analysis showed a positive relationship between the log of GDP per capita (PPP) and intensification for chickens (as measured by the proportion of chickens in commercial conditions) (Figure 1; Table 1). Gross domestic product per capita was the most influential variable in the regression model, indicating a strong linear relationship between the log of GDP per capita and intensification. Other variables were statistically significant but the effect sizes were generally smaller.

By examining the residuals, we identified nine states and union territories whose observed chicken intensification levels were well below model predictions: Sikkim, Delhi, Puducherry, Arunachal Pradesh, Andaman & Nicobar Islands, Mizoram, Goa, Tripura, and Assam (Table 2). These states and territories either had levels of intensification near zero (e.g. Sikkim 0.8%, Delhi 10.2%, Puducherry 7.9%, Arunachal Pradesh 0.1%, Mizoram 0.8%, Tripura 2.7%, Assam 2.0%) or levels of intensification that were high but much lower than model predictions (e.g. Andaman & Nicobar Islands at 32.2% compared to 72.5%; Goa at 58.5% compared to 92.7%). We subject these nine states to a detailed policy discussion below.

All statistical analysis was conducted in R version 4.4.2 (Core Team, 2024) with visualization conducted using the package ggplot2 (Wickham, 2016).

3.2 States that break free from the trend

3.2.1 Northeastern states with organic policies

Our analysis identified several states in the Northeast of India as having disproportionately low rates of chicken intensification. Specifically, Manipur, Assam, Arunachal Pradesh, and Sikkim, had low intensification despite having high incomes. For example, Mizoram had a per capita income of 7,365 USD and Sikkim had the second-largest per capita income of all states—nevertheless, each of these two states had less than 1% of chickens raised commercially.

Why do these Northeastern states have such unexpectedly low rates of chicken intensification (Table 3)? One reason might be livestock density. In Northeast India, rearing tends to be dominated by smallholders, preventing the scale necessary for intensification (Kumar et al., 2007). Geography is likely a contributing factor; the Northeast's mountainous terrain and large forest cover can make it less feasible to concentrate agricultural production in one area. The mountainous climate is more conducive to extensive, agro-pastoral farming systems that are commonly seen in Northeastern states. Population densities are also low in the Northeast, indicating that there might not be a large enough market to encourage commercialization.

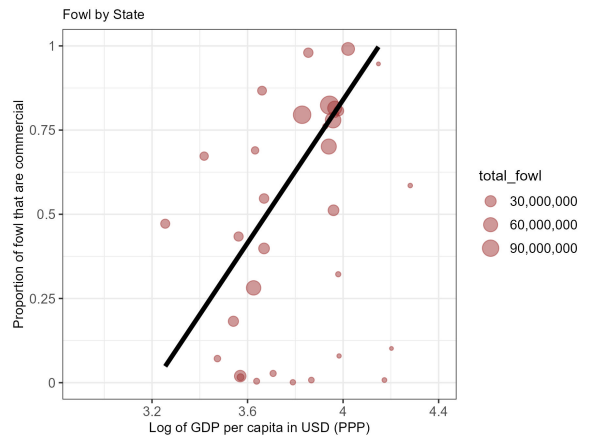

FIGURE 1
Scatterplot of log of income against proportion of intensive chicken.

However, there is another major factor that may have caused chicken to remain largely extensive in this region: the widespread adoption of organic farming policies (Bordoloi and Arunachalam, 2022). For instance, Sikkim is the first state in the world to go 100% organic. Sikkim has phased out synthetic fertilizers and pesticides in place of organic fertilizers (Kumar et al., 2018; Das, 2023). This state 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 practices all pervasive in commercial chicken and dairy farming in India (Prakash et al., 2018; Government of Sikkim, 2019; Gurjar, 2022). Similar to Sikkim, the state governments of Mizoram, Arunachal Pradesh, and Meghalaya have policies that back organic farming (Singh et al., 2021; Bordoloi, 2023). The Ministry of Agriculture and Farmer Welfare launched a central scheme in 2015–16 called Mission Organic Value Chain Development for North Eastern Region (MOVCDNER) (Ministry of Agriculture and Farmers Welfare, 2018). This aims to support the organic production value chain from procurement of seeds, certification, connecting farmers with consumers, and aiding in brand-building (Reddy, 2018). All of the states included in this scheme (Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim, and Tripura) have below 6% of their chicken farmed under intensive conditions (Government of India, 2019). One indication that organic policies have played a significant role is that Uttarakhand, which also has a mountainous geography and a low population density, has high levels of intensification.

If the Northeast's organic farming policies have been a key cause in the success of these states' chicken industry remaining extensive, these policies could plausibly be replicated in other states or countries to reduce the rate of intensification. There are three important limitations in our analysis of Indian states: first, the phenomenon of offshoring of undesirable production practices (Gill et al., 2018). That is, jurisdictions may simply shift undesirable production practices to other jurisdictions (Saussay and Zugravu-Soilita, 2023). It is possible that India's Northeastern states are simply consuming products that were farmed intensively elsewhere in India. For example, Assam and Sikkim import large amounts of chicken meat and eggs to satisfy domestic demand (Sasidhar et al., 2019; The Sentinel, 2024). Secondly, economies in the Northeast Region are agrarian and animal husbandry is a major activity with 57% of households owning livestock (Kumar et al., 2007). This means that to keep chicken farming extensive, it may be necessary for a majority of households to own livestock, and as such, the policy may not be replicable for urban regions. Thirdly, when Sikkim started transitioning to organic farming in 2013, it was already using much less chemical fertilizers compared to the national average and thus intensification was already low (Meek and Anderson, 2020).

Despite these limitations, we offer three reasons why the policy lessons identified in this paper remain promising. Firstly, some Northeastern states of India, such as Tripura, Meghalaya, Mizoram, and Nagaland, produce a surplus in meat—offshoring of meat appears limited for these states (Deb, 2022; Government of Sikkim, 2024). Furthermore, the state governments of Northeastern states have targets and policies to achieve self-sufficiency in egg production and chicken meat through organic farming (Indian Council of Food and Agriculture, 2015; Government of Assam, 2016; Singh et al., 2024). Government

TABLE 1 Descriptive statistics (left) and beta regression model predicting proportion of intensive chicken (right).

	Summary statistics				Beta regression model estimates			
	Mean	Median	Min	Max	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	–	–	–	–	-28.6	$1.39x10^{-03}$	-20631	< 0.001
log(per-capita GDP USD PPP)	3.81	3.85	3.26	4.28	3.40	$1.73x10^{-04}$	19648	< 0.001
population_density (humans/km^2)	1,169	343	18.0	13,360	$9.76x10^{-04}$	$1.39x10^{-07}$	7001	< 0.001
urbanization (%)	40	35	10	99	$-3.93x10^{-02}$	$6.03x10^{-06}$	-6523	< 0.001
maize (1000 tons)	992	345	0	4258	$8.34x10^{-05}$	$3.14x10^{-08}$	2659	< 0.001
soy (1000 tons)	340	2	0	4887	$-1.57x10^{-05}$	$2.21x10^{-08}$	-709	< 0.001
Pseudo R-squared = 0.476; log likelihood = $3.67x10^{8}$ on 7 df								

TABLE 2 Residual intensification by state*.

State	Chicken — Proportion Commercial (%)	Model Prediction (%)	Residual (%)
Sikkim	**0.8**	**93.0**	**−92.2**
Delhi	**10.2**	**100.0**	**−89.8**
Puducherry	**7.9**	**94.9**	**−87.0**
Arunachal Pradesh	**0.1**	**53.5**	**−53.4**
Andaman & Nicobar Islands	**32.2**	**72.5**	**−40.3**
Mizoram	**0.8**	**40.7**	**−39.9**
Goa	**58.5**	**92.7**	**−34.1**
Tripura	**2.7**	**36.5**	**−33.8**
Assam	**2.0**	**31.2**	**−29.2**
Kerala	51.2	73.5	−22.3
Meghalaya	1.6	21.6	−20.0
Nagaland	0.4	17.7	−17.3
West Bengal	28.2	41.4	−13.3
Himachal Pradesh	76.2	87.5	−11.3
Chandigarh	94.7	100.0	−5.3
Odisha	39.9	43.8	−4.0
Jharkhand	18.2	20.4	−2.2
Manipur	7.2	7.7	−0.6
Maharashtra	70.1	70.6	−0.5
Karnataka	81.5	81.4	0.2
Uttarakhand	79.8	79.5	0.3
Telangana	77.9	77.0	0.9
Gujarat	80.7	76.1	4.6
Tamil Nadu	82.4	73.6	8.8
Haryana	99.1	87.8	11.3
Andhra Pradesh	79.6	63.0	16.5
Chhattisgarh	54.7	34.6	20.1
Madhya Pradesh	43.4	21.6	21.8
Punjab	98.0	65.1	32.9
Bihar	47.2	10.3	36.9
Jammu & Kashmir	69.0	27.7	41.3
Uttar Pradesh	67.3	15.6	51.7
Rajasthan	86.7	34.7	52.0

Bold font denotes a state explored further in this publication
*Residual intensification is calculated by subtracting the predicted level of intensification with the observed level for each state/union territory.

support of extensive systems of animal husbandry to increase supplemental income can be used in conjunction with organic policies. For example, Sikkim has invested in high-yield indigenous breeds to increase productivity while maintaining extensive production (Sasidhar et al., 2019). Secondly, even if production is partially shifted to other states, it is unlikely to cause the complete and total collapse of the local, extensive industry. A Northeastern state might import some intensively farmed chicken, but it still produces plenty of extensively farmed chicken of its own. Thus, there is still a global reduction in the level of intensification (Gill et al., 2018).

Thirdly, policies in one jurisdiction can be a first step toward a more comprehensive shift toward sustainable production practices in developing countries (Gill et al., 2018). This step-wise approach is well-accepted in other policy contexts—for example, offshoring happens to some extent in EU animal welfare (Bayne et al., 2013), but this has not been used as justification to forego the entire project of improving the EU's animal welfare policies.

While the specific model Sikkim and Northeastern states have implemented may not be readily applicable to all jurisdictions, their policies show that it is *possible* to limit intensification as jurisdictions economically grow. The practice of 'glocalization', combining global concern for animal welfare while considering local context when designing specific policies, can enable jurisdictions to adopt the organic model (Cox, 1997; Roudometof, 2016). For example, Uttarakhand, an Indian state with a similar geography and population density as the Northeast, but a high level of intensification, can draw inspiration from the region's policies. Sikkim's Organic Mission may also provide a blueprint for Bhutan, a country neighboring Sikkim which aimed to go fully organic by 2020 but has made very little progress, to successfully transition to 100% organic farming (Babajani et al., 2023; Paull, 2023). Furthermore, in other jurisdictions, even if demand for animal products is not fully fulfilled by organic production, organic policies can mitigate intensification (Paunglad, 2022). For instance, the European Union's Farm to Fork Strategy has an objective of having at least 25% of agricultural land under organic cultivation (Moschitz et al., 2021).

3.2.2 Less informative outliers

We also identified a couple of small, urban territories with disproportionately low rates of chicken intensification. However, in these cases, the low rates of intensification are likely due to demographic factors that cannot be replicated elsewhere. To illustrate, Delhi is a densely populated urban area with a very small chicken industry and chicken population compared to its human population. This likely results in Delhi importing egg and chicken meat from neighboring states like Haryana with very high levels of intensification (Poultry World, 2008; Government of India, 2019). Puducherry is a small union territory and has a low chicken population that is insufficient to satisfy domestic demand (Sowmiya et al., 2020). In Goa, high labor costs and feed prices have curtailed the growth of commercial chicken as local producers are less price-

TABLE 3 Summary of policy lessons from states with disproportionately low intensification.

State or union territory	Explanation for low level of poultry intensification
Sikkim, Arunachal Pradesh, Assam, Tripura, and Mizoram	• Organic farming policies by the state and central government (Mission Organic Value Chain Development for North Eastern Region) to support organic farmers and discourage the use of inorganic inputs • Hilly terrain, conducive to agroforestry and subsistence farming
Delhi, Puducherry, Goa, and Andaman & Nicobar Islands	• Limited land available for commercial cultivation • Low poultry population • Uncompetitive domestic industry due to high costs

competitive relative to outside producers (Swain et al., 2008, Swain et al., 2009). This has made rearing backyard chicken more attractive. The Andaman and Nicobar Islands have very limited land available for cultivation and as such, chicken production is largely backyard with indigenous chicken breeds used in free-range rearing systems (Kundu et al., 2010). Thus, none of these states are likely to reveal broadly applicable policy lessons.

4 Discussion

This study succeeded in identifying jurisdictions that may have broken free from the trend of intensification of livestock farming as wealth increases. Using India as a study region and focusing on chicken, this study identified several states and territories that have disproportionately low rates of intensification of chicken after wealth and other demographic and agricultural variables were taken into account (Table 2). We identified India's Northeast organic policies as a promising precedent for jurisdictions seeking to keep their levels of agricultural intensification low.

There are several implications and new research directions. First, since the relationship between income per capita and livestock intensification has now been established at two spatial levels—at the country level and, given our findings, the state level—the densities of intensive and extensive livestock within countries could be forecast using fine-scale 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 animal welfare, environmental, economic, and epidemiological effects that arise as a result of intensification (Pritchard, 2000; Haas et al., 2001; Cang et al., 2004). 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 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.

Moreover, the negative effects of intensification on animal welfare, especially for chickens, are very well documented. In recent years, there has been an increase in laws and policies protecting animal welfare in developed countries, such as the Better Chicken Commitment in the EU and corporate cage-free welfare commitments (Mendez and Peacock, 2022). However, in developing countries, animal welfare has likely worsened due to increasing intensification (Frank, 2008). Asian countries have seen a particular lag in the adoption of cage-free egg farming, despite its growing prominence in developed nations (Compassion in World Farming, 2023; Sinergia Animal, 2023; Rokade et al., 2024). The lack of welfare regulations and enforcement in developing countries means that intensification is likely to happen in ways that worsen animal welfare rather than preserve it (Robins and Phillips, 2011; Meng et al., 2012; Nielsen and Zhao, 2012; Poletto and Hötzel, 2012; von Keyserlingk and Hötzel, 2015). Countries may be following an animal welfare Kuznets curve, in which as the income of countries grows, animal welfare initially worsens until nations reach a level of development beyond which animal welfare improves (Frank, 2008). This means as intensive production continues to rise in developing countries, it is necessary to strengthen and enforce legislation protecting animals, such as with guidelines for humane slaughter, the provision of adequate space, and the banning of extremely painful practices, like castration, without anesthesia (Marchant et al., 2023). There is evidence that high-income countries with greater income equality have lower meat consumption and more regulations against harmful animal welfare practices. However, this may not hold true for developing countries (Morris, 2013). By studying jurisdictions like India's Northeastern states, which have experienced economic growth without intensification, policies to slow down intensification even as countries develop economically can be identified. This can be of particular interest as policymakers become more concerned about the harms of intensification to animal welfare and human health (Fraser, 2008; von Keyserlingk and Hötzel, 2015; Cox and Bridgers, 2019; Coghlan et al., 2021).

In conclusion, research extending this work to other study regions, with other predictor variables, or on other species would allow us to find more outliers and provide further valuable insights into the causes and effects of transformations of the livestock industry. Other regionally globally important meat-producing countries with subnational jurisdictions, such as Brazil and Indonesia, may offer fruitful insights into sustainable production policies. As meat and animal products production in developing countries continues to rise, this research is vital to understand and mitigate the animal welfare crisis the developing world may be facing.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

IK: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. RR: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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