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INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Int. J. Food System Dynamics 12 (4), 2021, 341-357

DOI: http://dx.doi.org/10.18461/ijfsd.v12i4.95

Regulations, Value Chains and Food Standards in Developing Countries: Panel Data Evidence from India

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Received January 2021, accepted August 2021, available online September 2021

ABSTRACT

Rapid growth in dairy consumption and food scandals in India in the 2000s increased awareness of food safety issues among consumers and policymakers. This led to the introduction of new standards. However, there is little information about how they affected farm-level activities and whether value chains played any role. Our paper addresses these questions using a two-round panel survey of dairy farms in Punjab and Andhra Pradesh. We find significant improvements in adoption of farm-level hygienic practices, especially in Punjab. Value chain innovations do not play a significant role in stimulating safety and quality improvements among dairy smallholders in India.

***Keywords**: dairy sector; food safety; standards; value chains; India*

1 Introduction

Domestic public and private food safety standards are emerging in developing countries, with broad implications for smallholder farmers and supply chain development. While many recent studies have analyzed the effects of international food standards on farmers and supply chains in developing countries, little attention has been paid to domestic standards within developing countries.

India is therefore an interesting and relevant case for studying the emergence of food standards and their effects on value chains. India's Operation Flood program, launched in 1970, transformed the country into one of the largest producers of milk in the world. Today, dairy provides jobs for more than 70 million households. In recent years, incomes in India have been growing rapidly, creating strong growth in demand for milk products. Rapid urbanization and the spread of modern retail have contributed to a push for high quality and safety standards (Minten and Reardon, 2008; Reardon and Timmer, 2014).

A series of food scandals in India in the early 2000s increased national awareness of safety concerns in the production, processing and marketing of food. This led to the introduction of the Food Safety and Standards Act (FSSA) in 2006, and the establishment of the Food Safety and Standards Authority of India (FSSAI) in 2008. It was expected that the combination of new FSSA regulations and increased demand for higher quality standards would transform India's dairy sector; new liability imposed on milk processors and traders, in combination with the new microbiological requirements for milk and milk products, would create incentives for supply chain reorganization and the emergence of complementary private standards; and stronger vertical links with milk producers would be created to better control milk production and quality.

There is very little evidence on this subject and it remains unclear whether new public regulations in the Indian dairy sector triggered any changes in the relationships between dairy companies/traders and their suppliers and, as such, affected farm-level activities. We fill this gap by using unique farm-level survey data from before (2008 and 2010) and after (2015 and 2016) the implementation of the FSSA regulations in two different but important milk producing regions of India (Punjab and Andhra Pradesh). This paper pursues a twofold objective: (1) to document farm-level changes in food safety practices in the Indian dairy sector; and (2) to find out whether value chains influence changes in farm-level practices.

2 Food standards and dairy value chains

The FSSA was heavily contested and it took several years before the regulations were published in the Indian government gazette (2011) and another year for them to officially go into force (2012). To oversee the implementation of the FSSA, the FSSAI was established in 2008. However, India is a large country and state-level Food and Drug Administrations (FDAs) often act as the real enforcement bodies. Importantly, the new law tried to impose self-regulation by processing companies and traders by specifying which actors in the supply chain bear responsibility when food safety regulations are not complied with (Article 27 of FSSA, 2006) (Shukla et al., 2014). With respect to milk and dairy, milk traders were deemed liable for any adulterants (e.g. water, oil, skimmed milk powder, soda) added to the milk, even if the adulteration[1] was done by their suppliers—unless they could specifically identify the culprit (Squicciarini and Vandeplas, 2013). The same is true for compliance with microbiological standards. However, a recent audit of the FSSA showed that the policy has been implemented poorly (CAG, 2017). Anticipation of proper implementation of the legislation—in conjunction with increasing pressure from consumers—may spur the emergence of private food standards in the Indian dairy industry. However, it is unclear how far these changes have spread along the value chain and to what extent these efforts have affected farm-level activities.

Empirical studies on dairy value chains in other developing and emerging countries have shown that increases in demand and the introduction of public regulations may trigger institutional innovations in value chains where dairy processors and traders help their farmers satisfy the new standards and increasing demand for more quality products (e.g. Dries and Swinnen, 2004; Charlier and Valceschini, 2010; Geng et al., 2013). Value chains can stimulate or allow improvements in farm-level standards and practices that increase milk quality and the safety of dairy products through training, investment support, and provision of inputs and information (Bellemare, 2012; Bolwig et al., 2009; Jones and Gibbon, 2011; Kumar et al., 2016; Maertens and Swinnen, 2009; Minten et al., 2009; Dries et al., 2009).

[1] These regulations in principle also extend to informal traders including street hawkers and itinerant vendors. Opponents of the FSSA have argued that poor street vendors are unable to comply with the food standards that have been imposed.

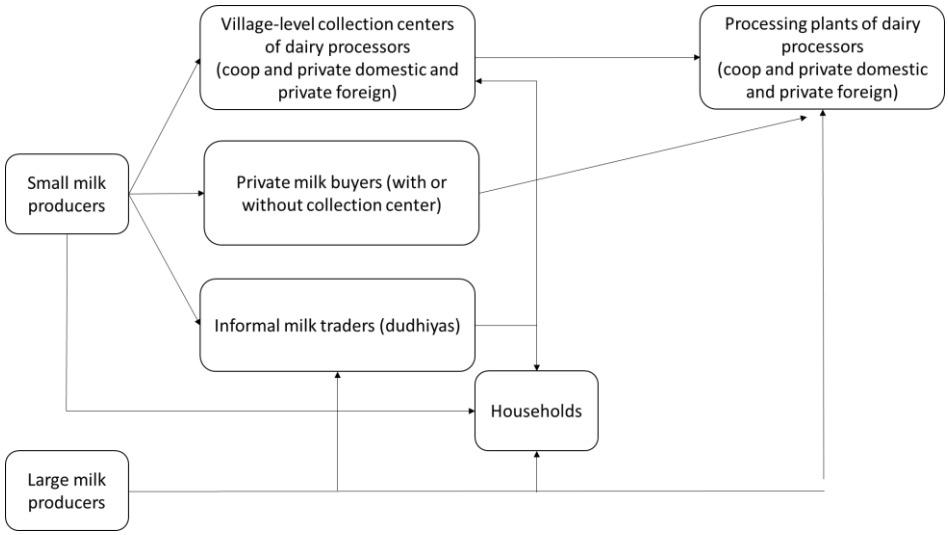

Figure 1. Milk procurement structure in Punjab and Andhra Pradesh
Source: Janssen and Swinnen, 2017

Figure 1 illustrates the structure of the dairy supply chains in Punjab and Andhra Pradesh (AP). Informal milk markets include direct sales to households or to informal milk traders. Formal markets include cooperatives and private dairy companies. In Punjab, private dairy companies are represented by both domestic and multinational companies (Nestlé), while in AP there are only domestic private dairy companies. Tables 1 and 2 document the importance of the various channels and the changes over time. The organization of the value chain in both Punjab and AP allows for close contact between milk buyers and dairy farmers and this could serve as a vehicle for information to be distributed at a relatively low cost (Janssen and Swinnen, 2017). At the farm level, milk safety and quality can be enhanced by improving basic hygienic and food safety practices such as washing hands, utensils, and the udders and teats of dairy animals (DA) before and during milking (Kumar et al., 2011). Given India's climatic conditions, timely cooling of the milk, storage and preservation practices are essential to guarantee safe milk.

Table 1.
Main channels of milk sales in Punjab for all dairy farmers in sample

	In 2008 % of dairy farmers in sample (N=710)	In 2015 % of dairy farmers in sample (N=676)
A. Cooperative	22.1%	18.5%
B. Private companies	38.9%	26.9%
Including: domestic companies	14.2%	12.6%
foreign (Nestlé)	24.7%	14.4%
C. Informal channels	13.5%	25.7%
Including: households	2.3%	10.2%
informal milk traders	11.3%	15.5%
D. No Sales	25.5%	29.1%

Source: Survey data

Table 2.
Main channels of milk sales in Andhra Pradesh for all dairy farmers in sample

	In 2010 % of dairy farmers in sample (N=729)	In 2016 % of dairy farmers in sample (N=505)
A. Cooperative	31.8%	29.5%
B. Private domestic firm	17.0%	22.6%
C. Informal channels	29.2%	32.1%
Including: households	7.0%	8.3%
informal milk traders	22.2%	23.8%
D. No Sales	21.9%	15.8%

Source: Survey data

3 Data

Our study uses data from a two-round household survey conducted in two important but quite different states of India: Punjab and AP. The first round of the Punjab data was collected in the summer of 2008 and the follow-up round seven years later in 2015 during the same period. The first round of the AP data was collected between April and June 2010 and the follow-up round six years later in 2016 during the same period. Thus, in both states the first round covers the period before most of the FSSA regulations were implemented, while the second round covers the period after the new policies were put in place.

In both survey rounds, the same questionnaire was administered. We collected detailed information on milk production practices, particularly on the adoption and implementation of different types of food standards related to milk hygiene and storage practices at the farm level. The data also include information on general household characteristics, including other income generating activities and expenditures, productive assets, and living standards. The final sample used for this analysis is a balanced panel data set containing 870 households for Punjab and 928 households for AP. [2]

4 Changes in farm-level practices affecting the safety and quality of dairy products

We focus on two indicators that capture the implementation of food safety standards at the farm level. They are hygienic practices (before, during and after milking) and storage practices after milking.

4.1 Hygienic practices at the farm

To capture the changes in hygienic practices in a single indicator, we calculated an index of hygienic practices (or "hygiene index"), which is measured as the average of the compliance levels for various sanitary practices summarized in Table A1 in the appendix 2 (panel A) for Punjab and Table A2 in the appendix 2 (panel A) for AP.[3]

Figure 2 illustrates the improvement in hygienic practices across all households by the rightward shift of the distribution of the hygiene index from 2008 to 2015 in Punjab. The rightward shift of the distribution of the hygiene index in AP is less pronounced (Figure 3).

[2] A more detailed description of the data collection is provided in the Appendix 1.

[3] In Table A1 panel A, answer categories are ranked from least hygienic to most hygienic practice (best practice). In all cases, 0 means no compliance. Some indicators (e.g. mode of washing) allow for intermediate categories which signal partial compliance with best practices. To obtain the degree of compliance for each practice, we divide the rank of the answer category by the total number of answer options minus 1. This gives us a number between 0 and 1 for each hygienic practice. We assign equal weights to each practice and therefore obtain the index by taking the average of the compliance levels for the individual indicators.

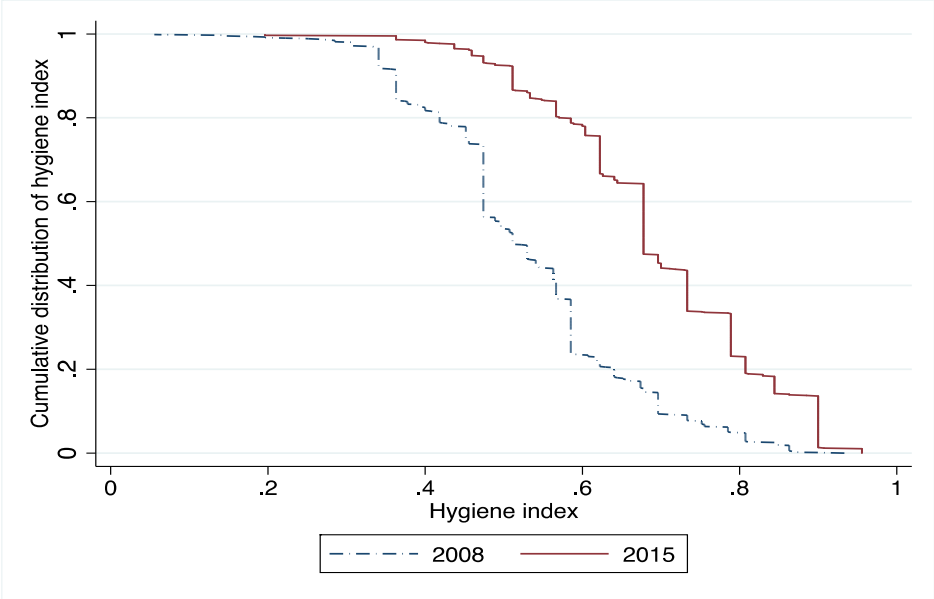

Figure 2. Distribution of hygiene index in 2008 and 2015 in Punjab
Source: Survey data

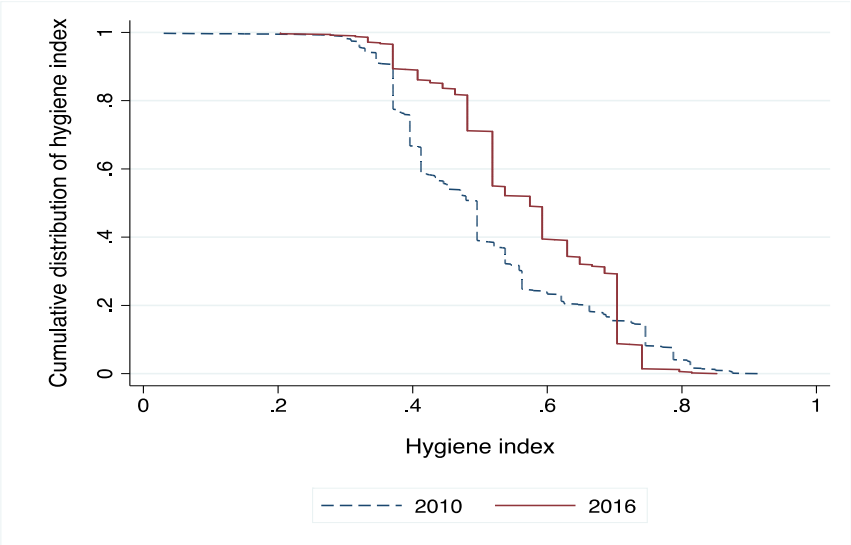

Figure 3. Distribution of hygiene index in 2010 and 2016 in Andhra Pradesh
Source: Survey data

In fact, the hygiene index improvement of 0.06 in AP is considerably less than the 0.17 increase in Punjab. While the average index of both states was close in 2010 (0.51 and 0.53) it had widened significantly by 2016 at 0.57 compared to 0.70.

4.2 Storage practices at the farm

Minimizing the time between milking and cooling the milk is one of the critical quality bottlenecks. Interestingly, the survey data suggest that there has not been a significant improvement in these practices between the first and second surveys in both Punjab and AP.

In Punjab, the methods of milk preservation before sale did not change much between 2008 and 2015 (see Table A1 panel B). Notably, only 5.1% in 2008 and 7.9% in 2015 cooled the milk before selling. However, most households market their milk almost immediately after milking—the average milk storage time on the farm was only 19 minutes in both 2008 and 2015.

Buyers thus receive raw milk soon after milking, which gives them the opportunity to cool (or boil) the milk and contain the growth of microorganisms.

In AP, storage practices worsened between 2010 and 2016. In 2016, milk was preserved (inside or outside the house) for an average of 28.4 minutes before sale, which is much longer than the 17.6 minutes in 2010 (see Table A2 in the appendix 2, panel B). In addition, more households stored the milk outside their house in 2016 (11.3%), which is generally less clean and less cool, increasing the risk of spoilage and contamination of the milk.

5 Dairy value chains and safety and quality standards: Econometric analysis

To understand the potential causal relationship between participation in various marketing channels and an index of hygienic practices, we turn to econometric analysis. The great majority of studies on value chain participation rely on cross-sectional data, which poses a number of methodological issues. Our unique panel data set allows us to address some of these caveats by estimating a fixed effects (FE) model[4] and thereby eliminating bias stemming from time-invariant unobserved heterogeneity. The core equation is specified as:

$$y_{i,t} = \alpha_i + \beta C_{i,t} + \gamma HS_{i,t} + \theta X_{i,t} + Y_t + \varepsilon_{i,t} \quad (1)$$

where $y_{i,t}$ is the hygiene index for household i at time t, α_i is the individual household intercept, $C_{i,t}$ is a set of marketing channel dummies, $HS_{i,t}$ is a vector of variables related to farm size and income, $X_{i,t}$ is a vector of other socioeconomic household characteristics, Y_t is a year dummy (taking the value of one for 2015 for Punjab sample and 2016 for AP sample regressions) and finally $\varepsilon_{i,t}$ is the error term. The summary statistics of the main variables used can be found in Table 5.

First, the vector of dummies, which capture marketing channels, are added to assess the primary objective of this chapter: the impact of specific value chains on the implementation of hygienic practices at farm level. $HS_{i,t}$ includes herd size, amount of land owned and an asset index, which can all reflect the capacity of the households and extent of the implementation of hygienic practices. We expect farmers who expanded their herd sizes to be more likely to have adopted improved hygienic practices, although the opposite is also plausible. In the absence of sufficient labor, an increase in herd size might lead to less time or effort exerted to implement hygienic practices. Physical capital in the form of land owned (in acres) and an index capturing non-land asset ownership may reflect the capacity of households to invest in the implementation of improved hygienic practices.

Furthermore, we include a control vector with time-variant household variables $X_{i,t}$ that may influence adherence to hygienic practices such as age, gender and education of the household head as well as household size. Compliance with food safety measures at farm level is found to be labor intensive (Kumar et al., 2011). Therefore, we also control for the number of household members over 55 as well as the number of female adults. Anecdotal evidence suggests that elderly and female members of the households are traditionally assigned to take care of the animals (Janssen and Swinnen, 2019). Additionally, we include a dummy indicating whether the household head changed between the two rounds of survey to pick up potential changes in management of dairy activities. A year dummy Y_t was included to capture all temporal variation between the two rounds of survey, such as weather shocks and price variations. To deal with serial correlation and heteroscedasticity, we use robust standard errors and cluster them at the household level.

[4] Regarding *reverse causality*, we follow the argumentation widely used in the value chain literature (Bellemare, 2012; Bellemare and Novak, 2017; Sutradhar et al., 2019) that it is more likely that a household's choice of marketing channel is driven by the prospect of future benefits that could be derived from participation in a certain marketing channel. Another potential source of endogeneity is the possibility of the *non-random selection* of farmers by the processors. One should consider processors' choices regarding their decisions to source the milk from the household, or else there is a danger of omitted variables problem that would bias the estimates. However, most of the literature argues that even if processing firms discriminate against certain types of farmers they are most likely to do so on the basis of observables rather than unobservable factors; our vector of observable factors will most likely hold more information (both observable and unobservable) than processors can have access to (Bellemare, 2012; Bellemare and Novak, 2017; Sutradhar et al., 2019). It is also unlikely that the variable of interest—participation in a certain marketing channel—suffers from a systematic *measurement error* that would bias our estimation in the FE specification. To our observation, households are well aware of the marketing channels they sell to and have little incentive to misreport.

5.1 Results and discussion

Estimation results for our preferred specification (FE) of equation (1) for both regions are presented in Table 6. Econometric analysis confirms our descriptives and reveals no clear patterns in the relationship between marketing channels and farm-level hygienic practices. For Punjab, the econometric analysis shows that selling to Nestlé is associated with a 9% increase in the average household's index of hygienic practices (i.e., 0.055/0.61, given that the average hygiene index in the Punjab sample is equal to 0.61). However, as there was a 40% increase in hygiene index across the entire sample from 2008 to 2015, captured by the year dummy, this differentiation is rather small. The temporal effect captured by the year dummy is significant and positive for both states, although in AP the effect is smaller than in Punjab, with only an 11% increase in the average household's hygiene index across the entire sample. Interestingly, in AP, selling to informal milk traders is associated with an 11.6% increase in the average household's hygiene index (i.e., 0.063/0.54, given the average hygiene index in AP is equal to 0.54). One explanation is selling to informal markets could be associated with more liability and higher reputation costs compared to selling to numerous private firms and cooperatives where milk is collected into one big batch.

We also run additional OLS regressions[5] to test for "convergence". We run two separate regressions to disentangle two different mechanisms. In the first one, we look at the households that remained with the same buyer. Buyers might have had more time to work with households that remained with them for an extended period. In the second regression, we add a set of dummies to identify households that switched to specific value chains. Switching to another marketing channel might require changes in hygienic practices. To test for convergence amongst households in adhering to better hygienic practices, we include the hygiene index of 2008 for Punjab and 2010 for AP. At the village level, we control for both village population and distance to the nearest city, as they reflect demand for milk and access to information and inputs, such as detergent. Finally, we control for district-level effects stemming from local differences in income, policy measures and market access, by including a set of district dummies. To deal with heteroscedasticity, we use robust standard errors and cluster them at the village level.

The results are presented in Tables A5 (appendix 2) and A6 (appendix 2) for both Punjab and AP in separate columns. Hygienic improvements do not seem to be associated with specific value chains. There are some minor results which do not indicate a clear pattern. In Punjab, households that continued selling informally to other households improved the most, while those that switched to selling informally improved the least. In AP, those households that stayed with the informal milk traders improved more than other households.

The regression analysis also confirms the convergence in hygienic practices for both Punjab and AP. Households with better hygienic practices in 2008 for Punjab and 2010 for AP improved less than those with lower hygiene index scores. Interestingly, in Punjab, households with older heads improved the most among both those that stayed with and those that switched value chains. One explanation is that age of the household head is a proxy for experience. Therefore, older farmers might find it easier to implement better hygienic practices. In AP, bigger households improved more than the rest among those that stayed with the same value chains. This could be due to more family labor that is available to implement more and/or better hygienic practices before, during and after milking.

In summary, despite considerable improvement in the adoption of hygienic practices in Punjab, and to a lesser extent in AP, it is not associated with specific value chains. There is little difference in the way different value chains interact with farmers. Dairy companies and traders focus mostly on investing in collection centers close to the farmers to minimize time between milking and cooling. Tables A1 and A2 also show that very little information on clean milk production was provided by milk buyers (only 2.5% of farmers in Punjab in 2015 and 1.2% of farmers in AP in 2016 received information). Safety and quality inspections were also still equally limited: only 2% of households in Punjab and 0.4% in AP reported on-farm inspections by milk buyers or government institutions.

One reason for the lack of value chain involvement in promoting improved hygienic practices could be that the Food Safety Act has been poorly implemented (CAG, 2017). As a result, dairy processors may not have found the investment in training, inspections, or promoting complementary standards worthwhile. Furthermore, as farmers are free to switch between milk buyers at any time, these investments are not guaranteed to benefit the milk processor in the long run.

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[5] The econometric specification is as follows: $\Delta y_i = \alpha + \beta C_i + \delta CV_i + \gamma HS_i + \theta X_i + V_i + \varepsilon_i$ (2)
where Δy_i is the change in hygiene index for household i between the two surveys, C_i is a set of marketing channel dummies, CV_i is a convergence variable, HS_i is a vector of variables related to farm size and income, X_i is a vector of other socioeconomic household characteristics, V_i is a set of village-level variables and finally ε_i is the error term.

The variation in the results between Punjab and AP could be due to a combination of factors including profound differences in the structures of the two dairy markets. Many have pointed to Punjab's comparative advantage over AP in terms of dairy production, including climatic conditions, infrastructure, higher standards of living, and extensive government support (Chand, 1999; Staal et al., 2008). Dairy farm sizes are somewhat larger in Punjab than in the rest of India: 39% of dairy farmers had less than 2 ha of land, while the number increases to 69% for India as a whole (Kumar et al., 2011a). AP is a more populous and poorer state in the south of India. Dairy production in AP is driven by smallholders and landless poor, who own approximately 80% of the state's livestock population (Animal Husbandry Department Government of Andhra Pradesh, 2010).

The presence of multinational companies such as Nestlé in Punjab, and their absence in AP, the emergence of large modern dairy farms in Punjab[6] and the lack of such dynamics in AP, all reflect these differences and the level of maturity in these two markets in general. The presence of foreign direct investment in the domestic markets (in the form of a multinational in the case of Punjab) usually has great spillover effects in the form of technology diffusion. This has often occurred in newly emerging dairy markets where, due to employee turnover and learning effects, domestic companies have started to adopt strategies used by foreign companies (e.g. providing credit, milking machinery, training, etc.). This technology diffusion might have taken place not only through companies but through the emerging class of new modern large farmers in Punjab. These modern dairy farms could represent farmer leaders and innovators, who serve as important nodes of technology adoption among the wider population of traditional farmers. This is consistent with the literature on technology adoption through social learning, and social networking (Bandiera and Rasul, 2006; Conley and Udry, 2010; Genius et al., 2013; Moser and Barrett, 2006; Munshi, 2004). Although we can only speculate as to the extent of this pathway, based on our survey we indeed see a pattern where farmers were receiving an increasing amount of information on better hygienic practices from other farmers.

Despite significant improvements, there still appears to be a lot of room for improvement with respect to both on-farm hygienic practices and milk storage. Likewise, milk buyers could increase their provision of information.

6 Conclusion

Dairy products are a major part of Indian diets and milk production is a major production activity for many poor Indian farmers. Coupled with strong growth in dairy production and consumption in India over the past two decades, the introduction of the FSSA in the early 2010s was expected to transform India's dairy sector. Using two rounds of household survey data, this paper found that changes in public food safety standards did not lead to the emergence of complementary private standards in the dairy sector. Although considerable improvements in hygienic practices occurred in Punjab, and to a lesser extent in AP, these improvements were not due to participation in specific value chains or closer vertical coordination. Low provision of information and lack of on-farm inspections were observed in both regions. Higher improvements in on-farm hygienic practices in Punjab compared to AP were more likely a result of a combination of factors including better climatic conditions, higher standards of living and the emergence of large modern dairy farms. Ultimately, there is still significant room for farmers to further improve their on-farm hygienic practices and dairy companies to increase their provision of information.

Acknowledgement

Research on this project was financially supported by KU Leuven, long term structural funding – Methusalem funding by the Flemish Government; the Fonds Wetenschappelijk Onderzoek – Vlaanderen (FWO) and the Fonds de la Recherche Scientifique – FNRS under EOS Project No. G0G4318N (EOS ID 30784531); and by the European Union's Horizon 2020 research and innovation programme under grant agreement No 861932.

[6] This new class of dairy farms is very different from its traditional counterparts. The farms are larger in terms of herd size, only use modern technology, and are fully integrated in vertically coordinated value chains (Burkitbayeva et al., 2020).

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Appendix 1

More detailed description of the data collection process

For the survey in 2008, Punjab was divided into five regions: the north-west (Amritsar and Gurdaspur), the north-east (Hoshiarpur, Jalandhar, Kapurthala and Nawanshahar), the south-west (Bathinda, Faridkot, Ferozepur, Moga and Muktsar), the south-east (Mansa, Patiala and Sangrur), and the central region (Fatehgarh Sahib, Ludhiana and Ropar). In order to avoid oversampling of households in smaller districts, one district was selected at random in each region, with the probability of selection being proportional to the district's population share within that region. All villages in these districts were stratified according to the marketing channels operating in that area, based on their appearance in a list of procurement villages provided by Nestlé, respective milk unions if available, and otherwise on their proximity to cooperative sector cooling plants. We selected at random 15 "Nestlé villages", 15 "cooperative villages", five villages where both companies were expected to operate, and 15 villages where none of them were expected to operate. These 50 villages were spread over the five selected districts, resulting in a final selection of six villages in the district of Amritsar, six in Hoshiarpur, 14 in Ludhiana, 18 in Ferozepur, and six in Mansa. In each village, 20 households were stratified and randomly sampled using a prior village census. Households were categorized based on the number of DA they owned (0 DA; 1–2 DA; 3–10 DA; >10 DA) and their marketing channel. This sampling strategy allowed for oversampling of Nestlé and cooperative suppliers and large- and medium-size dairy farmers (as the majority of milk suppliers in Punjab have fewer than 3 DA) and to extrapolate to the level of Punjab, using the appropriate weighing factors.

For the survey in 2010, AP was subdivided into four zones based on milk production per rural capita and dairy production systems, which may correlate with weather and relative humidity conditions. Within each region, one district was sampled at random. In the selected districts, 50 rural villages were randomly selected[7]. In each village, a census was organized to record the number of DA each household owned to classify households into four categories. Households were categorized based on the number of DA they owned (0 DA; 1–2 DA; 3–5 DA; >5 DA). A fixed number of households was selected from each strata, so as to oversample households with larger herd sizes and obtain a set of 20 households per village.

For the second survey rounds, we were able to resurvey 90% of the households for the two states: 130 households (13%) in Punjab and 71 households (7%) in AP were not located. While the reasons for their resettlement are unknown, statistical analysis showed that the relocated households were no different from those households that were retraced. The final sample used for this analysis is a balanced panel containing 870 households for Punjab and 928 households for AP.

[7] Of which 7 in Chittoor, 12 in Cuddapah, 16 in Kurnool, and 15 in Guntur from the district-level list of villages which was obtained from the Government of AP (Government of Andhra Pradesh, 2009).

Appendix 2

Table A1.
Hygienic and food safety practices in Punjab (% of dairy farmers in sample)

	In 2008 (N=710)	In 2015 (N=671)
Panel A: Hygienic practices		
Cleaning hands		
Are the hands washed?		
Never	2.8%	0.5%
Only before milking	38.5%	36.9%
In between	58.7%	62.1%
Mode of washing hands		
No hand washing	2.8%	0.5%
Water only	83.6%	42.7%
Use soap/detergent/disinfectant	13.5%	56.8%
Hands dried with paper/cloth before milking?		
Yes	25.5%	66.4%
Cleaning of udder and teats		
Washed before milking?		
No washing	11.8%	4.6%
Water only	83.9%	90.2%
Cold water + soap/detergent/disinfectant	3.4%	5.4%
Dried with paper/cloth before milking?		
Yes	14.2%	23.4%
Cleaning of milk utensils		
How are milk utensils washed?		
Water only	80.4%	14.1%
Water + soap/detergent/disinfectant	17.4%	79.8%
Water + sand + ash	0%	6.3%
How often are the utensils washed?		
Less than once daily	3.1%	0.14%
Once daily	20.4%	1.6%
More than once daily	75.7%	98.3%
Before milking each new cow/buffalo	0.14%	0.14%
Panel B: Food safety practices		
How long does the milk stay on the farm before sale?	19 min	19.2 min
Method of milk preservation before sale		
Not treated	64.2%	61.9%
Boiling	1.5%	0.9%
Refrigerating/chilling	5.1%	7.9%
Other	8.3%	0.14%
Panel C: Received information on clean milk production	0.9%	18.6%
Sources:		
Other farmers	0%	13.3%
Government	0.3%	2.4%
Nestlé	0.4%	1.0%
Cooperative	0.2%	0.9%
Veterinary doctor	0%	0.2%
Informal milk trader	0%	0.4%
Other	0%	0.4%
Received inspection on farm	14.8%	5.2%
By:		
Milk buyer	5.6%	0.1%
Government	6.2%	1.9%
Other	3.0%	1.0%

Source: Survey data

Table A2.
Hygienic and food safety practices in AP (% of dairy farmers in sample)

	In 2010 (N= 729)	In 2016 (N=505)
Panel A: Hygienic practices		
Cleaning hands		
Are the hands washed?		
Never	3.4%	10.9%
Only before milking	92.2%	84.8%
In between	4.4%	4.4%
Mode of washing hands		
No hand washing	3.8%	5.5%
Water only	92.2%	85.7%
Use soap/detergent/disinfectant	4.0%	8.7%
Hands dried with paper/cloth before milking?		
Yes	22.2%	54.5%
Cleaning of udder and teats		
Washed before milking?		
No washing	4.7%	5.0%
Water only	94.1%	90.7%
Cold water + soap/detergent/disinfectant	1.2%	4.4%
Dried with paper/cloth before milking?		
Yes	25.1%	37.8%
Cleaning of milk utensils		
How are milk utensils washed?		
Water only	58.6%	59.8%
Water + soap/detergent/disinfectant	31.1%	23.2%
Water + sand + ash	6.4%	12.9%
How often are the utensils washed?		
Less than once daily	9.6%	9.3%
Once daily	8.0%	3.0%
Twice daily	58.6%	86.9%
More than twice daily	23.2%	0.4%
Before milking each new cow/buffalo	0.7%	0.4%
Panel B: Food safety practices		
How long does the milk stay on the farm before sale?	17.6 min	28.4 min
Method of milk preservation before sale		
Inside the house	82.9%	77.8%
Outside the house	4.4%	11.3%
Other	12.8%	10.9%
Panel C: Received information on clean milk production	3.3%	3.8%
Sources:		
Other farmers	0.1%	0.2%
Government	1.2%	2.0%
Private Milk buyer	0.3%	0.2%
Cooperative	0.4%	1.0%
Veterinary doctor	0.1%	0.2%
Other	1.1%	0.2%%
Received inspection on farm	0.5%	0.8%
By:		
Milk buyer	0.1%	0.2%
Government	0.1%	0.2%
Other	0.3%	0.4%

Source: Survey data

Table A3.
Summary statistics of variables used in econometric analysis by sample year

a. Punjab

		2008 sample		2015 sample	
Hygiene	Index	0.53	(0.13)	0.69	(0.14)
Farm size and income					
Total no. of DA	No.	4.14	(4.3)	3.52	(4.88)
Land	Acres	8.27	(10.4)	9.77	(13.94)
Asset index	Index	0.31	(0.95)	0.32	(1.00)
HH characteristics					
Age HH head	Years	50.53	(11.99)	54.35	(14.10)
HH head is female	%	3.0	(17.1)	6.32	(24.36)
HH head education	Years	5.37	(4.60)	7.48	(5.04)
HH size	No.	6.18	(2.58)	5.96	(2.54)
HH members over 55	No.	0.73	(0.84)	0.95	(0.98)
No. of female adults in HH	No.	2.25	(1.08)	2.17	(1.14)
Village level HI (excluding self)	Index	0.53	(0.09)	0.69	(0.07)

b. Andhra Pradesh

		2010 Sample		2016 Sample	
Hygiene Index	Index	0.50	(0.14)	0.57	(0.12)
Farm size and income					
Land	Acres	4.07	(5.94)	2.28	(3.14)
Total no. of DA	No.	3.43	(2.44)	3.11	(2.56)
Asset index	Index	0.10	(0.99)	0.18	(1.15)
HH characteristics					
Age HH head	Years	47.00	(10.7)	51.95	(11.0)
HH head is female	%	0.07	(0.25)	0.09	(0.28)
HH head education	Years	3.36	(4.45)	3.96	(4.62)
HH size	No.	5.24	(2.06)	5.03	(1.98)
HH members over 55	No.	0.50	(0.69)	0.75	(0.91)
No. of female adults in HH	No.	1.64	(0.89)	1.65	(0.92)
Village level HI (excluding self)	Index	0.51	(0.1)	0.57	(0.05)

Note: Standard deviation in parentheses. The table is based on all households that had DA in both sample years.
Source: Survey data

Table A4.
Hygiene index and value chains in Punjab and AP

	In Punjab (FE)		In AP (FE)	
Supply chain:				
Nestlé	0.055**	(0.023)		
Cooperative	0.009	(0.019)	0.039	(0.027)
Private domestic firm	0.024	(0.022)	0.043	(0.028)
Informal milk traders	0.028	(0.021)	0.063**	(0.028)
Informally to households	-0.003	(0.022)	0.031	(0.035)
Farm size and income				
Total No. of DA	0.022	(0.020)	-0.038*	(0.022)
Land	0.019	(0.013)	0.014	(0.013)
Asset index	-0.040***	(0.010)	0.003	(0.009)
HH characteristics				
Age HH head	-0.000	(0.001)	-0.000	(0.002)
HH head is female	0.045	(0.037)	-0.028	(0.048)
HH head education	-0.001	(0.001)	0.000	(0.003)
HH size	-0.002	(0.004)	-0.002	(0.007)
HH members over 55	-0.008	(0.007)	0.004	(0.016)
No. of female adults in HH	0.007	(0.007)	-0.002	(0.013)
Change HHH	-0.026	(0.032)	0.015	(0.028)
Year 2015	0.185***	(0.012)	0.059***	(0.017)
Observations	1,359		1,106	
R-squared	0.462		0.134	
Number of hhid	740		734	

Note: (FE) - Fixed effects models.
Robust standard errors (clustered at individual level) in parentheses *** p<0.01, **p<0.05, * p<0.1

Table A5.
Effect of staying in marketing channels on % change in hygiene index (OLS)

	Punjab % change in HI		AP % change in HI	
Supply chain: HH stayed in				
Nestlé	0.018	(0.033)		
Cooperative	0.007	(0.033)	0.063	(0.042)
Private domestic firm	-0.031	(0.070)	0.050	(0.060)
Informal milk traders	-0.001	(0.089)	0.098**	(0.046)
Informally to households	0.132***	(0.046)	-0.054	(0.189)
Convergence				
Hygiene Index in 2008	-2.011***	(0.112)	-1.991***	(0.112)
Farm size and income				
Total No. of DA	0.010	(0.024)	-0.015	(0.028)
Land	0.023	(0.016)	-0.001	(0.016)
Asset index	-0.013	(0.012)	0.006	(0.013)
HH characteristics				
Age HH head	0.002*	(0.001)	0.000	(0.001)
HH head is female	-0.008	(0.037)	-0.011	(0.051)
HH head education	0.003	(0.002)	-0.001	(0.003)
HH size	0.003	(0.005)	0.016*	(0.009)
HH members over 55	0.005	(0.013)	-0.011	(0.020)
No. of female adults in HH	-0.006	(0.013)	-0.020	(0.018)
Change HHH	0.000	(0.029)	0.011	(0.035)
Village level indicators				
Total Village population	-0.000	(0.000)	0.000	(0.000)
Distance to closest town (in km)	0.002	(0.001)	0.002	(0.002)
District fixed effects	yes		yes	
Observations	621		433	
R-squared	0.631		0.612	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A6.
Effect of switching marketing channels on % change in hygiene index (OLS)

	Punjab % change in HI		AP % change in HI	
Supply chain: HH switched to				
Nestlé	-0.015	(0.041)		
Cooperative	-0.029	(0.027)	-0.059	(0.045)
Private domestic firm	-0.048	(0.042)	-0.042	(0.038)
Informal milk traders	0.002	(0.030)	0.003	(0.068)
Informally to households	-0.058**	(0.024)	-0.041	(0.040)
Convergence				
Hygiene Index in 2008	-2.018***	(0.112)	-1.975***	(0.111)
Farm size and income				
Total No. of DA	0.009	(0.024)	-0.017	(0.029)
Land	0.024	(0.015)	-0.003	(0.016)
Asset index	-0.015	(0.013)	0.005	(0.014)
HH characteristics				
Age HH head	0.002*	(0.001)	0.000	(0.001)
HH head is female	-0.006	(0.035)	-0.005	(0.050)
HH head education	0.002	(0.002)	-0.000	(0.003)
HH size	0.003	(0.004)	0.014	(0.009)
HH members over 55	0.007	(0.013)	-0.006	(0.021)
No. of female adults in HH	-0.004	(0.012)	-0.016	(0.018)
Change HHH	-0.003	(0.028)	0.015	(0.036)
Village level indicators				
Total Village population	-0.000	(0.000)	0.000	(0.000)
Distance to closest town (in km)	0.002	(0.001)	0.001	(0.002)
District fixed effects	yes		yes	
Observations	621		433	
R-squared	0.634		0.607	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1