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Supply response in Indian dairying

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ABSTRACT

Owing to several price and non-price factors, India's dairy sector has grown remarkably in the past four decades. In this paper, we assess relative contributions of such factors to the growth of diary sector. Our results showed that dairying, in terms of both animal stock and yield, is not much responsive to prices of output as well as inputs. However, in the long run, the yield responds positively to technological change in animal breeding, feed supplies, veterinary services and markets. These findings lead us to argue that the dairy policy should focus on pushing up adoption of yield-enhancing technologies, provision of animal health, breeding and extension services, and strengthening of market linkages.

Key words: Dairy, Markets, Prices, Services, Supply response, Technology

Indian dairying is typically a smallholder-dominated rural economic activity. Close to 95% of the dairy animals are concentrated in rural areas, and three-fourths of these are controlled by small landholders who cultivate land sizes not exceeding two hectares and comprise 85% of the total farm households (Birthal and Negi 2012). Despite land constraint, India's dairy sector has grown impressively over the past few decades, propelling country into self-sufficiency in milk in the early 1990s from a situation of acute scarcity in the 1960s and 1970s. Dairying is now the largest agricultural activity as it contributes more than one-fifth to the total value of output of agricultural sector, almost equal to the value of output of food grains.

The growth in dairy sector was fueled by a number of factors including technologies, institutions, infrastructures and investments. It is, however, the institutional change in milk marketing system that kick-started growth. Until 1970, the rural milk marketing system was mostly informal, dominated by local traders and vendors who often exploited small dairy farmers by paying less than the market price. To connect dairy farmers to remunerative markets or urban demand centers, the Government of India, with financial support from the World Bank, launched a programme called 'Operation Flood' in 1970 that led to evolving of a three-tier producer-driven cooperative value chain—dairy cooperative societies (VDCs) at village-level, federated into a milk union at the level of a district, and a federation of milk unions at state level.

For almost two decades, i.e. until 1991, dairy cooperatives were financially supported by the government and protected from internal and external competition (Birthal *et al*. 2017). Entry of private processors in dairy industry was regulated through licensing and zonal restrictions on milk procurement. Imports of dairy products were restricted through quotas and tariffs. Beginning 1991, as a part of the economy-wide reforms, dairy industry was gradually de-regulated from the government controls as to attract private investment in processing and value chains. A major change in dairy policy transpired in 2002–03 that did away with zonal restrictions on milk procurement, allowing private processors to source milk from outside their designated milkshed areas. This provided a stimulus to private investment in dairy industry (Birthal *et al*. 2017).

Dairy sector also underwent a technological transformation. Crossbreeding of low-yielding indigenous cows through artificial insemination using semen of exotic high-yielding breeds, such as Jersey, Holstein Friesian and Swiss Brown, was aggressively promoted. The breed improvement efforts were complemented by the increasing feed supplies, and investments in animal health and veterinary services (Birthal and Negi 2012).

There is hardly any study, except that of Munshi and Parikh (1994), that has assessed supply response in Indian dairying. Munshi and Parikh (1994) provided a sound theoretical basis for analyzing milk supply response, their estimated response functions are based on several assumptions related to prices and supply shifters. In this paper, we assess responsiveness of dairying to prices, and non-price factors that could have caused an upward shift in dairy production function.

MATERIALS AND METHODS

Data statistics and methodology: We estimated supply response functions using a panel data-set of 15 major milk producing states (These include Andhra Pradesh (including

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Telangana), Bihar (including Jharkhand), Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh (including Chhattisgarh), Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh (including Uttarakhand) and West Bengal) for the period from 1992–93 to 2014–15. This choice of period is largely governed by the availability of a continuous data series on key variables required for estimation of the supply response functions. Incidentally, this period also coincides with the period of economic reforms programme that began in 1991.

The key variables of our interest were number of in-milk animals and their yield, prices of milk and feed, proportion of crossbred cows in the total in-milk cows (a proxy of technological change), livestock units per veterinarian (an indicator of the adequacy of health services), and road density (a proxy of market access). Data on most of these variables or their proxies were not available at one place, and we compiled these from several published official sources. The main source of data was the 'Basic Animal Husbandry Statistics' (GoI various years a) that contained data on stock of dairy animals, i.e. in-milk cows (local and crossbred) and buffaloes and their yields, number and types of veterinary institutions (hospitals, polyclinics and dispensaries), and number of artificial inseminations performed.

Veterinary institutions differ in norms for manpower and facilities required for diagnostics and treatment, and there is significant variation in their composition across states. As per norms of the Veterinary Council of India (VCI), there should be at least two qualified veterinarians in a hospital or polyclinic, and one in a dispensary. To make veterinary services comparable across states, following the, VCI norms, we approximated the number of veterinarians in each state, and constructed an indicator of outreach of veterinary services in terms of livestock units (One livestock unit equals either one cattle, buffalo, camel, horse, donkey and mule or 10 sheep, goats and pigs. Population of these species has been collected from various Livestock Censuses (GoI various years)) per veterinarian.

Markets create incentives to produce more. The annual reports of the National Dairy Development Board (NDDB) provide information on state-wise number of VDCs and milk procured by these. This can be an important indicator of market access for dairy farmers. However, there also exists a strong presence of private sector in dairy industry; and the information on milk procured by the private sector is rarely available in the published sources. Therefore, we used road density (Road density is defined as the road length in km per thousand sq. km of geographical area) as proxy for farmers' access to markets. The information on road length was compiled from the Statistical Abstracts of India (GoI various years b).

Information on prices of output and inputs is also thinly available. There are sources, for example, 'The Agricultural Prices in India', a publication of the Ministry of Agriculture and Farmers' Welfare, that provide information on milk prices for important markets; the series is not consistently available for many states, and if available it is either for cow milk or buffalo milk differ significantly in their fat content (Buffalo milk contains 7.5% fat as compared to 4% in cow milk; and thus, fetches a higher price). The National Accounts Statistics provides data on value of milk produced but not by species (GoI various years c), we estimate price of milk by dividing its value by the level of production standardized at 4% fat-correction (Fat corrected milk = 0.4 × quantity of milk+ [(15 × fat %) × (quantity of milk)]).

As for milk, prices of feeds and fodders are also estimated implicitly. Coarse cereals, viz. pearl-millet, sorghum and maize or their byproducts; and cakes of soybean, cotton and rapeseed-mustard make up a sizeable proportion of the concentrate feed (Dikshit and Birthal 2010). It may be noted that dairying is practiced as a component of mixed farming system wherein animals derive most of their feed requirement from agricultural residues (straws) and farm-produced grains and their by-products like brans. Farmers do not purchase feed much, except the manufactured feed and oilcakes (Dikshit and Birthal 2010). We, therefore, assume the prices of coarse cereals and oilseeds to reflect the prices of concentrate feed that are estimated dividing their output values as reported in GoI (various years c) by their respective levels of production. Straws of cereals are generally used as fodder

Table 1. Summary statistics of key variables

Variable	Description of variable	1992–93	2003–04	2014–5
IN-MILK	Number of in-milk bovines ('000)	53277	62790	82413
YIELD	Milk yield (liters/in-milk bovine/day)	3.4	4.5	5.7
CROSW	Share of crossbred cows in to total in-milk bovines (%)	6.4	9.9	16.2
PMILK	Price of milk (₹/litre) at 2004–05 prices	11.2	10.9	15.4
PCCER	Price of coarse cereals (₹/kg) at 2004–05 prices	6.4	5.6	6.9
POILS	Price of oilseeds (₹/kg) at 2004–05 prices	17.0	17.4	20.7
PDFOD	Price of dry fodder (₹/kg) at 2004–05 prices	1.1	1.0	1.3
GFODT	Area under green fodder ('000 ha)	8205	8162	9101
GFODL	Green fodder area (hectares/in-milk bovine)	0.15	0.12	0.11
AIMB	Milch bovines artificially inseminated (%)	15.7	22.8	45.9
NVET	Number of veterinarians	25613	33578	42231
LUVET	Livestock units per veterinarian	11177	8357	7107
ROAD	Road density (km/'000 km^2)	909	1141	1662

for animals, and the availability was estimated using the grain: straw ratios (The quantity of dry fodder was estimated using grain : straw ratio of 1:5 for paddy, 1:2 for wheat and 1:8 for maize, pearl-millet and sorghum). To obtain the price of dry fodder, we divided the value of cereal straws by their availability so estimated. Cultivated green fodders make up 18% of the feed intake on dry matter basis (Dikshit and Birthal 2010). Yet, the information on their production and prices is rarely available. We, therefore, consider area under green fodders as a proxy of fodder supply. Data on area and production of cereals and oilseeds were compiled from the Statistical Abstract of India (GoI various years b).

Table 1 shows changes in key indicators of dairy development over the past two decades. We find a substantial increase in dairy stock the number of in-milk bovines increased from 53 million in 1992–93 to 82 million in 2014–15. During the same period, milk yield increased from 3.4 to 5.7 liters/in-milk bovine/day. The number of crossbred cows increased considerbly, raising their share in the total in-milk bovines from 6.4% to 16.2%. Apart from

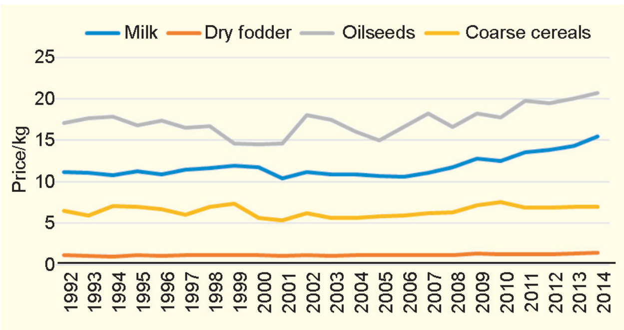

Fig. 1. Trend in prices of milk and feeds (1992–2014).

technological change in animal breeding, there has been a signifcant expansion of the veterinary services, leading to a decline in the number of livestock units per veterinarian from over 11,000 to about 7,000 not withstanding quantitative and qualitative in their provision across different production systems. Road density improved considerably, indicating an enhanced access of farmers' to milk markets or urban demand centres. Area under green fodder crops, however, did not increase much, suggesting a little or no improvement in the green fodder supply.

Figure 1 shows behaviour of prices of milk *vis-à-vis* feeds. Price of milk (at 2004–05 prices), after reamining muted for long, started increasing from 2006–07 onwards. The average price of oilseeds also exhibits a similar behavior as do the milk price, but the rise therein has been comparatively small. However, the prices of coarse cereals and dry fodders do not exhibit any signifcant trend, positive or negative.

Estimation method: Most studies have used Nerlovian type partial adjustment or adaptive expectation models to assess supply response of crops. A major limitation of these models is their assumption of stationarity in data series. Most time series tend to be non-stationary, that may lead to spurious regressions and inconsistent and indistinct short-run and long-run elasticities (Hallam and Zanoli 1993, Townsend 1997, McKay *et al.* 1999). To check for stationarity, we apply Levinlin-Chu, Im-Pesarn-Shin and Fisher type panel unit root tests. These tests (Table A1–Appendix) do not reject the null hypothesis of unit roots in the data series at level, but at first difference the series become stationary, i.e. a series is integrated of order one or I(1).

Given the problem of non-stationary in data series, the error correction model (ECM) is considered an alternative to Nerlovian type models (Hallam and Zanoli 1993). The ECM can be specified as:

$$\Delta y_{it} = \alpha + \delta \Delta x_{it} - l(y_{it-1} - \beta x_{it-1}) + v_{it} \qquad \ldots (1)$$

where y_{it} and x_{it} respectively represent state and time specific dependent and explanatory variables. v is the disturbance with zero mean, constant variance and zero covariance, δ measures the short-run effect of a change in x on y, and β measures the long run equilibrium relation between independent and dependent variables at a rate dictated by the value of λ.

$$y_{it} = \beta x_{it} + u_{it} \qquad \ldots (2)$$

$(y_{it-1} - \beta x_{it-1})$ captures divergence from long run equilibrium and corresponds to the residuals of lagged version of eq. (2). λ measures the extent of correction of such errors by adjustments in the dependent variable.

In this paper, y represents fat-corrected milk yield, and dairy stock (in-milk cows and buffaloes). A lack of time-series on non-lactating animals and off-springs precludes possibility of investment and disinvestment in bovine breeding; and therefore, we model in-milk stock directly as in Hallam and Zanoli (1993). x is a vector of explanatory variables as described in Table 1.

Validation of the error correction specification requires existence of a long-run relationship or co-integration between variables. For co-integration, individual time series should be integrated of the same order, or some linear combination of the series must have a lower order of integration than the original series (Engle and Granger 1987). In other words, if the variables are integrated of order

Table 2. Model specification tests

	In-milk bovine stock	Milk yield
F-test for joint significance state specific intercept	211.8*** (F 14, 323)	72.57*** (F 14, 306)
Hausman specification test (Fixed effects vs Random effects)	18.74*** (χ^2, 0.009)	–2.4 *** (χ^2, 7)
F-test for state specific trend vs no trend	303.43*** (F 15, 323)	450.29*** (F 15, 320)
Modified Wald test for group-wise heteroskedasticity	2060.59*** (c^2, 15)	1339.46*** (c^2, 15)
Test for serial autocorrelation	119.323*** (F 1, 14)	142.982*** (F 1, 14)

***Denotes significance at 1% level.

one, i.e. I (1) the error term from the co-integrating relationship should be integrated of order zero, i.e. I (0).

To test for panel co-integration, we apply Westerlund (2007) tests that unlike other panel co-integration tests (e.g., Kao test and Pedroni test) are based on structural rather on residual dynamics, do not impose any common factor restriction and control for cross-sectional dependence. Based on ECM, these provide four test statistics: group mean tests (Ga, Gt) and panel tests (Pa, Pt). The lead and lag orders have been selected based on minimum AIC (Akaike's Information Criterion). The results (The advantage of using bivariate statistics is that it is consistent with the problem statements and mitigates mis-specification issues in causality estimations) presented in Table A2 (Appendix) reject the null hypothesis of no co-integration, confirming that there exists a long-run relationship between dependent and independent variables.

RESULTS AND DISCUSSION

We begin checking robustness of the specification of the function that we have chosen for estimation of the supply response. We perform some important specification tests (Table 2). The F-test for joint significance of state fixed effects is statistically significant at 1% level, indicating the superiority of state fixed effects model over pooled regression. The c^2 statistic for Hausman test is highly significant, suggesting use of fixed effects model over random effects model. The F-test for state-specific trend versus a common trend suggests inclusion of state-specific trends in the model. We also check for heteroskedasticity

Table 3. Results of error correction model

Variable	Yield			In-milk bovine stock		
	Coefficient	Standard error	P value	Coefficient	Standard error	P value
			Short run			
ΔIN-MILK$_{t-3}$				0.141	0.153	0.000
ΔYIELD$_{t-3}$	0.107	0.026	0.001	–	–	–
ΔPMILK$_{t-1}$	0.019	0.015	0.248	–0.875	0.364	0.031
ΔPMILK$_{t-2}$	–0.013	0.007	0.116	0.361	0.175	0.058
ΔPCCER	0.011	0.006	0.094	0.002	0.046	0.955
ΔPOILS	0.001	0.001	0.523	0.038	0.026	0.174
ΔPDFOD	–0.005	0.010	0.625	–0.426	0.425	0.334
ΔGFODL	0.709	0.290	0.029	0.0001	0.0001	0.394
ΔLUVET	0.002	0.003	0.503	–0.038	0.077	0.624
ΔAIMB	–	–	–	–0.050	0.033	0.155
ΔCROSW	0.018	0.008	0.053	–	–	–
ΔROAD	0.00001	0.00003	0.736	0.001	0.001	0.338
ECM	–0.257	0.055	0.000	–0.220	0.045	0.000
Constant	–3.19	1.12	0.013	–143.39	19.02	0.000
R^2						
Within	0.38			0.36		
Between	0.06			0.76		
Overall	0.006			0.14		
Sigma_u	12.67			185.13		
Sigma_e	0.14			2.20		
Rho	0.99			0.99		
			Long run			
Time trend	0.144	0.006	0.000	1.752	0.118	0.000
PMILK	0.027	0.018	0.143	–0.382	0.559	0.505
PCCER	0.027	0.020	0.190	0.268	0.255	0.311
POILS	0.007	0.006	0.302	0.090	0.071	0.213
PDFOD	–0.018	0.056	0.755	0.179	0.805	0.827
GFODL	0.941	0.717	0.210	0.002	0.001	0.019
LUVET	–0.016	0.006	0.019	–0.003	0.140	0.979
AIMB	–	–	–	0.027	0.058	0.645
CROSW	0.014	0.008	0.112	–	–	–
ROAD	0.0001	0.0007	0.060	0.001	0.002	0.680
Constant	–155.51	17.89	0.000	–1660.53	280.93	0.000
R^2 Within	0.94			0.88		
R^2 Between	0.62			0.79		
R^2 Overall	0.54			0.71		
Sigma_u	130.30			2066.58		
Sigma_e	0.20			3.46		
Rho	0.99			0.99		

applying the modified Wald test, and the c^2 statistic indicates presence of heteroskedasticity in errors that may not affect estimates but would bias standard errors. The Wool dridge test indicates serial autocorrelation among variables. To correct for serial correlation and heteroskedasticity we estimate regressions with state-clustered standard errors.

Results of ECM are presented in Table 3. In lower panel of Table 3 we present results of Equation (2) that corresponds to the long-run relationship. Adjusted R^2 is quite high in both the equations, i.e. animal stock and yield. A high R^2 is a pre-requisite to minimize effect of small sample bias on parameter estimates of the co-integrating regression that otherwise may be carried to the estimates of ECM.

From long-run stock equation, we find coefficient on green fodder area positive and significant, indicating the critical role of feeds in farmers' decision regarding herd size. This is expected, as India faces chronic deficit in feeds and fodders, more so in green fodders (According to Ramachandra *et al.* (2007), the supplies of dry fodder, green fodder and concentrate feed are short by 11, 28 and 35% of their respective requirements). Dairy stock is not responsive to prices of output as well as inputs, and also to supply shifters. Nonetheless, dairy stock has been building up, as is implied by significantly positive time trend. These results although appear counterintuitive but are not. In India, dairying is concentrated among resource poor households, who generally maintain one or two animals on farm-produced crop residues and by-products to supplement their agriculture-based livelihoods.

In long-run yield equation, coefficient on milk price is positive but not so significant (at less than 15%). Milk yield is also not responsive to prices of feeds and fodders. Its response to non-price factors, however, is as expected. Coefficient on livestock units per veterinarian is negative and highly significant indicating a better response of yield to provision of veterinary services. Likewise, it responds positively and significantly to road density or market access. Coefficient on crossbreeding technology (crossbred cows) is positive though not so significant (at less than 15%). These results are as expected, as in the long-run the growth in milk production would be propelled by technological change, infrastructure and markets.

In upper panel of Table 3 we present results of ECM. The error correction term in both yield and stock equations is negative and highly significant, which is essential to justify application of ECM to the given data-set. Size of the coefficient on error correction term is quite large, implying that it would take a longer time to restore equilibrium to its steady state.

In short run equation, the coefficient on lagged dairy stock is positive and highly significant, indicating that farmers' decisions on herd size are influenced more by its previous level. As a dairy animal generally starts its first lactation at an age of about three years, hence we included a three-year lag in our model. Coefficients on one year and two-year lagged price of milk are significant but opposite in direction. It is negative for immediate lag, and positive for lag prior to it. Negative effect, however, outweighs positive effect, implying that with rising in milk price farmers tend to optimize their herd size matching the resources available with them.

Coefficient on lagged milk yield is positive and highly significant in the short run. Milk yield also responds positively to lagged milk price, but not significantly. Green fodder supplies have a significant positive effect on milk yield, as expected. However, neither milk yield nor animal stock responds to input prices. While, animal breeding technology appears to be an important factor in yield response coefficient on crossbred cows is positive and highly significant. Coefficient on artificial inseminations performed (in stock equation) is negative, but insignificant. Nonetheless, these results provide an indication that under feed constraints, technological change in animal breeding is crucial for optimization of dairy stock.

Our findings indicate an inelastic response of dairying to prices of both output and inputs. It, however, responds positively to technological change in animal breeding, feed supplies and access to veterinary services and markets. To the best of our knowledge, there is hardly any study on supply response in Indian dairying, except that by Munshi and Parikh (1994). Munshi and Parikh (1994) find a positive response of milk supply to technological change in animal breeding and penetration of dairy cooperatives or market access. Nonetheless, several of the studies that examine supply response of crops provide similar evidence as ours (Deb 2003, Mythili 2008, Kanwar 2005, Tripathi and Prasad 2009).

Price effect is a necessary but not a sufficient condition for increase in output, argue Chibber (1989) and Duncan and Howell (1992). There could be several reasons for an inelastic or a negative supply response in animal agriculture. A continuous technological change may shift milk supply function outwards even when its real price remains constant or has been declining. Real price of milk in India has remained muted for long, and it started showing a rising trend only recently (Fig. 1). It may be noted that milk is priced based on its fat and solid-non-fat contents. Dairy cooperatives often set the price, and other institutional buyers follow it to determine their own price offer to farmers. A muted price response clearly indicates a lack of price incentive for dairy development. On the other hand, there has been a continuous increase in the number of crossbred cows, average milk yield of which is almost three times more than of indigenous cows.

Just and Zilberman (1986) argue that even if output price increases, a large variability in it can cause a negative supply response if farmers are risk-averse and switch over or diversify towards other remunerative activities. India started an employment guarantee scheme called 'Mahatma Gandhi National Rural Employment Guarantee Scheme', in 2004–05 and since then rural labor markets have expanded considerably, pushing up the rural wages. This is evident from a rise in share of wages in the household income from 20% in 2004–05 to 33% in 2012 (Birthal *et al*. 2017). It appears that for a smallholder farmer, working on wages is more remunerative than small-scale dairying.

An insignificant response of dairying to input prices could also be due to asymmetric nature of factor demand. In periods of declining output price, there is a little if any possibility of adjustment of resources that may accompany the declining output price even if the input prices are constant (Johnson 1960). This is typical of a smallholder dairy production system, where animals have to be fed even if feed prices go up. Note, in mixed farming systems dairy animals derive most of their feed requirement from crop residues and byproducts; hence input prices do not influence supply response much.

To explain lack of supply response in dairying, Tauer and Kaiser (1988) separate out purchased and non-purchased inputs and include these in the production function. They find the cash constrained farmers use more of non-cash inputs even if milk price is stagnant or declining. In India, family labour and feed are two important non-cash inputs in dairy production. Birthal and Negi (2012) have reported family labour, mainly women, fulfilling most of the labour requirements of dairying. Likewise, most feed requirement is met from the own-farm produced grains and straws. Chang and Stefanou (1988) show that intertemporal profit maximization may also lead to a negative supply response.

Johnson (1960) argue that asset-specificity could be one of the reasons for lack of price response. Assets, once purchased, become fixed in production process over a range of output prices because of their low salvage value. Dairy animals are a form of fixed asset, and these once reproduced or purchased cannot be easily salvaged in countries like India where markets for live animals are under-developed, and cattle slaughtering is banned. Chang and Stefanou (1988) have empirically proven that when asset-specificity is high and adjustment of quasi-fixed factors is asymmetric, a decrease in milk price may cause oscillation in supply response that eventually flattens out.

In this paper, we analyzed response of Indian dairying to prices of output and inputs, and to non-price factors that cause an outward shift in production function. India's dairy production system is typically a smallholder system, primarily based on non-cash inputs, and our findings show that stock of animals as well as milk yield are inelastic to prices of both the output and inputs. Milk yield, however, responds positively to technological change in animal breeding, feed supplies, veterinary services and markets. India's dairy sector has not received much policy attention. It has remained underinvested, and also neglected by financial institutions and extension systems (Birthal and Negi 2012). Our results lead us to opine that dairy policy should concentrate on providing farmers improved technologies, quality feeds, support services and markets for sustainable increase in milk production.

Our prescriptions, however, do not undermine the importance of price incentives for the growth of dairy sector. Milk prices in India have remained subdued for long. Current system of milk pricing is based on fat and solid-non-fat contents, and does not consider cost of production. A suitable pricing policy is essential to create incentives for adoption of improved technologies, and use of quality inputs and services for achieving higher yield and optimization of herd.

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Table A1. Panel unit root tests

	Levinlin-Chu		Im-Pesarn-Shin		Fisher type	
	H0:Non-staionarity		H0:Non-staionarity		H0:Non-staionarity	
	Level	Difference	Level	Difference	Level	Difference
YIELD	0.994	0.000	0.938	0.000	0.001	0.000
PMILK	1.000	0.000	0.077	0.000	0.089	0.000
PCCER	0.005	0.000	0.000	0.000	0.000	0.000
POILS	0.023	0.000	0.000	0.000	0.000	0.000
PDFOD	0.002	0.000	0.000	0.000	0.000	0.000
AIMB	1.000	0.000	0.997	0.000	0.073	0.000
LUVET	0.771	0.000	0.004	0.000	0.000	0.000
ROAD	1.000	0.000	0.949	0.000	0.172	0.000
CROSW	1.000	0.000	0.772	0.000	0.112	0.000
GFODT	0.624	0.000	0.009	0.000	0.000	0.000
GFODL	0.222	0.000	0.006	0.000	0.000	0.000

Table A2. Westerlund panel co-integration (bivariate analysis)

Statistics		PMILK	PCCER	POILS	PDFOD	CROSW	LUVET	ROAD	GFODL
					Milk yield				
Gt	Z-Value	31.498***	–24.682***	–15.617***	–9.264***	–49.673***	–33.308***	–15.744***	–57.591***
Ga	Z-Value	–6.458***	–6.862***	–0.518	0.522	0.916	1.602	1.529	–2.901
Pt	Z-Value	–6.093***	–1.843*	–4.032***	–3.421***	–2.296***	–8.685***	–0.442***	–2.241
Pa	Z-Value	–9.193***	–7.305***	–6.153***	–11.206***	–6.567***	–3.334	–5.437***	–5.032***
H0: no co-integration									
					Dairy stock				
Gt	Z-Value	–16.444***	–13.426***	–14.296***	–10.380***	–28.069***	–10.095***	–39.523***	–21.926***
Ga	Z-Value	0.870	–1.878*	–6.623***	–1.018	–2.412**	–0.146	1.422	–2.346**
Pt	Z-Value	–11.935***	2.328	–0.917	5.784	4.678	8.650	9.721	3.731
Pa	Z-Value	–8.227***	2.076	0.100	1.445	1.564	5.404	6.055	1.837
H0: no co-integration									

Ga and Pa are based on Newey and West (1994) standard errors adjusted for heteroscedasticity and autocorrelation. Gt and Pt are based on the standard errors estimated in a standard way.