Macroeconomic and Welfare Effects of Livestock-Sector Interventions in India: A Computable General Equilibrium Analysis

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Abstract

India produced about 248 million tonnes of milk in 2024–25-roughly a quarter of world output and well ahead of the European Union and the United States yet it accounts for barely 0.25% of world dairy trade, a hundred-to-one gap between its production share and its trade share. Dairy dominates a livestock sector that contributes about one-third of India's agricultural value added and sustains the livelihoods of more than eighty million farm households. This paper quantifies the economy-wide and distributional consequences of livestock-sector interventions using a single-country, comparative-static computable general equilibrium (CGE) model calibrated to the IFPRI Social Accounting Matrix (SAM) for India, 2022–23. Seven cumulative policy experiments move from a farm-gate milk-productivity gain, through dairy-processing expansion and export promotion, to dairy-trade liberalisation alone and in combination with productivity gains. Productivity-and-processing interventions deliver the largest real-output and welfare gains: real GDP rises by up to 0.22%, dairy-processing value added by up to 8.7%, and returns to land by up to 2.9%, while the relative price of food declines in every scenario. Trade liberalisation benefits consumers and wage-earners through cheaper imports and a real depreciation but reduces farm incomes, compresses investment, and erodes the tax-to-GDP ratio; on its own it barely expands dairy and is regressive across the rural–urban divide. Liberalisation becomes broadly welfare-improving only when paired with the productivity package, the only configuration that raises real incomes across all household groups, including the poorest quintile and farm households. The results support a sequenced reform agenda value-chain development first, export promotion second, and trade liberalisation last-and show that the sequence of reforms matters as much as their content.

Keywords: computable general equilibrium; dairy value chain; trade liberalisation; agricultural productivity; household welfare; India.

JEL classification: C68; D58; Q17; Q18; F13.

1. Introduction

India is the world's largest producer and consumer of milk. Output reached approximately 248 million tonnes in 2024–25—about one-quarter of world production and well ahead of the European Union (≈150 million tonnes) and the United States (≈103 million tonnes)—and has grown by roughly 18% over just four years, against a world growth rate of about 1.3% per annum (DAHD, 2025; FAO, 2023). Per-capita availability, at 485 grams per day, is half as much again as the world average of about 328 grams, so the expansion is a structural surplus rather than a response to scarcity. Dairying is overwhelmingly a smallholder and cooperative activity that sustains more than eighty million farm households, and in the Social Accounting Matrix used in this study the livestock sector contributes 6.3% of GDP at factor cost about one-third of all agricultural value added—while raw milk alone accounts for 4.4%, the single largest primary-agricultural activity in the economy, larger than rice or wheat.

Successive interventions in animal genetics and health, in cooperative and private processing capacity, and in feed and fodder availability have driven sustained increases in milk yield, herd size and per-capita availability. As India integrates further into global agri-food markets, a central policy question arises: would trade liberalisation help or harm the domestic livestock sector, and how should productivity, processing and trade policy be sequenced? Partial-equilibrium analyses cannot answer this question fully, because the effects of a shock to a sector as large as dairy propagate through factor markets, relative prices, the real exchange rate and the external balance.

The policy question is sharpened by a striking asymmetry that frames this paper: India supplies about 25% of the world's milk but only about 0.25% of world dairy trade (APEDA, 2025) a hundred-to-one gap between its production share and its trade share. The gap is not for want of momentum: dairy exports rose by roughly 80% in 2024–25, to about US$493 million, led by ghee and butter. Rather, it reflects structural constraints that the simulations in this paper are designed to represent: average milk yields of about 1.1 tonnes per animal per year against 3.9–5.9 tonnes in Australia and New Zealand, which motivates the farm-gate productivity experiment; an organised sector that handles only about one-third of the marketable surplus, which motivates the processing experiment; and the unexploited external demand implied by the trade gap itself, which motivates the export-promotion experiment. The sensitivity of the question is equally concrete: concern for dairy livelihoods was a central reason for India's withdrawal from the Regional Comprehensive Economic Partnership negotiations in 2019, making the liberalisation experiments directly policy-relevant.

This paper addresses the question within a single-country, comparative-static CGE framework calibrated to the IFPRI Social Accounting Matrix for India, 2022–23. We design seven cumulative policy experiments and organise the analysis around three linked questions: (i) what is the economy-wide effect of raising milk productivity at the farm gate; (ii) how much additional value is created by expanding dairy processing and by promoting dairy exports; and (iii) does liberalising dairy trade help the sector, and under what complementary conditions?

The paper makes three contributions. First, it provides a comprehensive, SAM-consistent assessment of livestock-sector interventions for India that jointly reports macroeconomic, sectoral, factor-market and household-welfare outcomes, rather than focusing on a single margin. Second, by designing the experiments cumulatively, it isolates the marginal contribution of each policy lever-productivity, processing, exports and trade liberalisation so that the value of sequencing can be read directly from the results. Third, it documents a set of general-equilibrium mechanisms that are easily missed in partial analysis, including a 'productivity paradox' in which a positive milk-productivity shock depresses the return to sector-specific livestock capital, and an exchange-rate-driven reshuffle of competitiveness across protected food-processing activities when the dairy tariff is removed.

The remainder of the paper is organised as follows. Section 2 documents the scale, growth and structural features of India's livestock and dairy economy using the most recent official data. Section 3 reviews the related literature. Section 4 describes the model and the SAM, and Section 5 defines the simulations. Sections 6 through 9 present the macroeconomic, sectoral, factor-market and welfare results, respectively. Section 10 synthesises the findings and draws policy conclusions, and Section 11 discusses limitations and extensions.

2. India's livestock and dairy economy: scale, growth and the trade paradox

Three facts establish why livestock-sector policy carries economy-wide weight in India: the sector's sheer scale, the speed and breadth of its recent growth, and a pronounced asymmetry between India's position in world production and its position in world trade. Table 1 assembles the most recent official indicators, and Figure 1 displays the two facts at the heart of the paper.

Table 1. India's livestock and dairy sector at a glance, latest available indicators.

Indicator	Value	Reference
Milk production, 2024–25	≈248 million tonnes (world rank 1)	DAHD (2025)
Share of world milk output	≈25%	FAO (2023); DAHD (2025)
Production growth, 2020–21 to 2024–25	+18% (≈4%/yr vs ≈1.3% world)	DAHD (2025)
Per-capita availability, 2024–25	485 g/day (world ≈328 g/day)	DAHD (2025); FAO (2023)
Bovine population	≈300 million (world's largest)	DAHD (2023)
Farm households engaged in dairying	80+ million	GoI (2022)
Dairy share of national GDP	≈5%	NDDB (2024)

Indicator	Value	Reference
Livestock share of agricultural value added	≈34% (SAM 2022–23)	Authors' computation
Average milk yield	≈1.1 t/animal/yr (vs 3.9–5.9 in AUS/NZL)	FAO (2023)
Organised-sector share of marketable surplus	≈32%	NDDB (2024)
Share of world dairy trade	≈0.25%	APEDA (2025)
Dairy exports, 2024–25	113,350 t; US$493 m (+80% y/y)	APEDA (2025)

Note: Figures are the latest official or industry estimates at the time of writing and are rounded; the SAM-based share is the authors' computation from factor payments. Sources as indicated; full citations in the reference list.

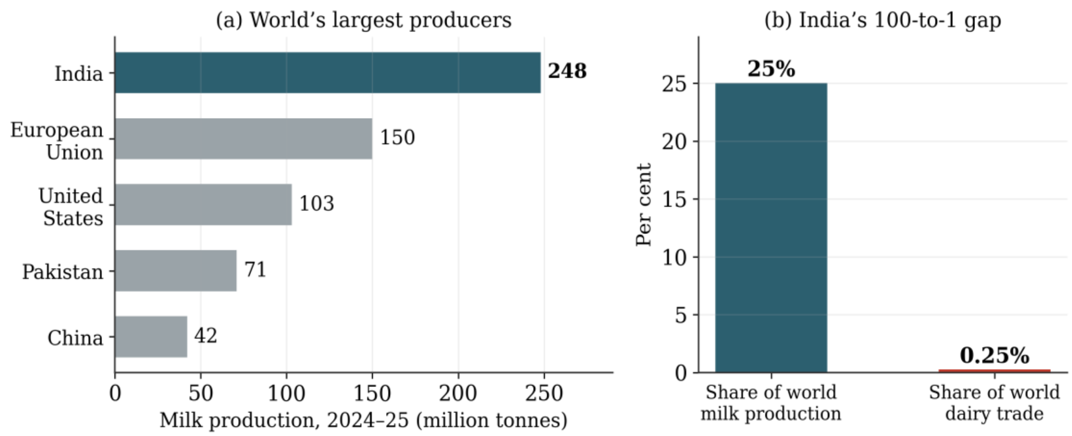

Figure 1. (a) The world's largest milk producers, 2024–25, and (b) the hundred-to-one gap between India's share of world milk production (≈25%) and its share of world dairy trade (≈0.25%). Sources: DAHD (2025); FAO (2023); APEDA (2025).

Scale and growth. India's 248 million tonnes of milk in 2024–25 exceed the output of the European Union and the United States individually and approach the two combined (Figure 1a). Production has expanded by about 18% in four years-adding nine to ten million tonnes annually, more than the entire annual output of many dairy-exporting countries and per-capita availability has risen from roughly 303 grams per day a decade ago to 485 grams in 2024–25, well above both the world average and India's own nutritional norm. The expansion has been achieved largely through a smallholder production system: the country's roughly 300 million bovines are held predominantly by small, marginal and landless households, for whom milk provides the counter-cyclical, near-daily cash income that crop agriculture cannot.

Socio-economic importance. Dairying contributes about 5% of national GDP and, in the SAM used here, livestock accounts for about one-third of agricultural value added, with raw milk alone the largest single primary activity in the economy. More than eighty million farm households are engaged in dairying, and the activity is disproportionately operated by women, so the incidence of dairy policy falls on precisely the households at the centre of rural development policy. These structural facts explain why the household-disaggregated welfare results of Section 9 are the analytical core of the paper rather than an appendix.

The trade paradox and what it implies for policy design. Despite its production dominance, India holds only about 0.25% of world dairy trade (Figure 1b): a structural surplus economy that scarcely exports. Each of the constraints behind the paradox maps onto one of the policy levers simulated below. Average yields of about 1.1 tonnes per animal per year against 3.9–5.9 tonnes in Australia and New Zealand indicate large feasible farm-gate productivity gains (simulation S1). Only about one-third of the marketable surplus passes through the organised processing sector, indicating headroom for value-chain development (S2). The trade gap itself, alongside the 80% surge in dairy exports recorded in 2024–25, indicates latent external demand that export promotion can mobilise (S3). And the political sensitivity of import competition a central factor in India's 2019 withdrawal from the Regional Comprehensive Economic Partnership makes the welfare incidence of liberalisation (S4–S7) the decisive policy question. The simulations are therefore not abstract experiments but quantified counterparts of the sector's observed constraints and opportunities.

3. Related literature

Computable general equilibrium models are the workhorse tool for quantifying the economy-wide effects of policy shocks in developing economies (Dervis, de Melo and Robinson, 1982; de Melo, 1988; Bandara, 1991). Their adoption for agricultural and trade-policy analysis has been facilitated by the growing availability of Social Accounting Matrices, which provide an internally consistent, economy-wide accounting of production, factor income, household demand and the external sector (Pyatt and Round, 1985; Round, 2003). The standard static formulation used here follows Lofgren, Harris and Robinson (2002), whose IFPRI template has become a common reference point for single-country applications.

A large literature applies CGE methods to agricultural trade liberalisation. Multi-region analyses using the GTAP framework have assessed the welfare effects of global trade reform and find that agricultural distortions account for a disproportionate share of the potential gains (Hertel, 1997; Anderson, Martin and van der Mensbrugghe, 2006). Single-country models complement this work by resolving the domestic incidence of reform across sectors, factors and household groups in greater detail than a global model can accommodate (de Janvry and Sadoulet, 2002). For India specifically, economy-wide analyses have examined trade reform, agricultural price policy and food security (Panda and Quizon, 2001; Pradhan and Amarendra, 2006; Ojha, Pradhan and Ghosh, 2013), while a separate strand documents the rising economic weight of the livestock and dairy economy and the role of processing and cooperatives (Birthal and Negi, 2012; Rakotoarisoa, 2011).

Two themes from this literature motivate our design. First, the welfare effects of liberalisation are highly sensitive to whether complementary productivity investments are in place, because trade opening reallocates resources toward sectors of revealed comparative advantage only if domestic supply can respond (de Janvry and Sadoulet, 2002; Anderson et al., 2006). Second, the distributional consequences of agricultural reform depend on whether households are net buyers or net sellers of the affected commodities, a distinction that a household-disaggregated SAM is well-suited to capture (Pyatt and Round, 1985). We build on both themes by treating productivity, processing, exports and trade as separable, sequenceable levers, and by reporting outcomes for fifteen representative household groups.

4. Model and data

4.1 The CGE model

The analysis employs a single-country, comparative-static CGE model in the neoclassical-structuralist tradition (Lofgren et al., 2002). Producers in each activity minimise costs subject to a nested production technology: value added is a constant-elasticity-of-substitution (CES) aggregate of primary factors, combined in fixed (Leontief) proportions with a CES aggregate of intermediate inputs. Output is allocated between domestic sales and exports through a constant-elasticity-of-transformation (CET) function, while domestic demand is met by a CES (Armington) composite of domestic and imported varieties, so that imports and domestic goods are imperfect substitutes. Households receive factor and transfer income and allocate it across commodities according to a linear expenditure system (LES) derived from a Stone–Geary utility function.

Three macroeconomic balances close the model. The current account is balanced by a flexible real exchange rate with foreign savings held fixed; the government balance holds tax rates fixed and lets government savings adjust; and the savings–investment balance is savings-driven, so that investment adjusts to available savings. Factors are fully employed. Labour is mobile across activities, whereas capital is activity-specific in the short run—an assumption that proves central to the factor-market results in Section 8. Because a CGE model determines only relative prices, the consumer price index is taken as the model numéraire; all results are therefore reported as real (CPI-deflated) deviations from the base equilibrium, and references to 'price' effects throughout denote movements in relative prices rather than in any absolute price level.

4.2 The Social Accounting Matrix

The model is calibrated to the IFPRI Social Accounting Matrix for India, 2022–23, a square, balanced matrix comprising 112 production activities and a matching set of commodities, primary factors, fifteen representative households, enterprises, government, a consolidated capital account, and the rest of the world. The activity structure provides a detailed agri-food disaggregation, with six livestock activities (cattle, raw milk, poultry, eggs, small ruminants and other livestock) and an explicit processing block that separates dairy, meat, fats and oils, sugar refining and grain milling. Primary factors comprise labour—disaggregated by four education levels and by rural and urban location—crop land, and four types of sector-specific capital (crop, livestock, mining and non-primary). Households are classified as farm, rural-nonfarm and urban, each by income quintile.

Table 2 summarises the economic structure implied by the SAM, and Figures 1 and 2 display it. Services account for 53.9% of GDP at factor cost, industry for 27.5%, and agriculture for 18.6%. Within agriculture, livestock (6.3% of GDP) is second only to crops (9.4%), and raw milk—at 4.4% of GDP—is the largest single primary activity in the economy (Figure 3). On the income side, capital earns 61.9% of factor income, labour 33.8% and land 4.3%; livestock-specific capital earns only 2.5% of factor income, a structural feature that explains why a milk-productivity shock can depress its return even as output rises (Section 8). Rural households receive 56.3% of total household income (farm 20.0%, rural-nonfarm 36.3%) and urban households 43.7%.

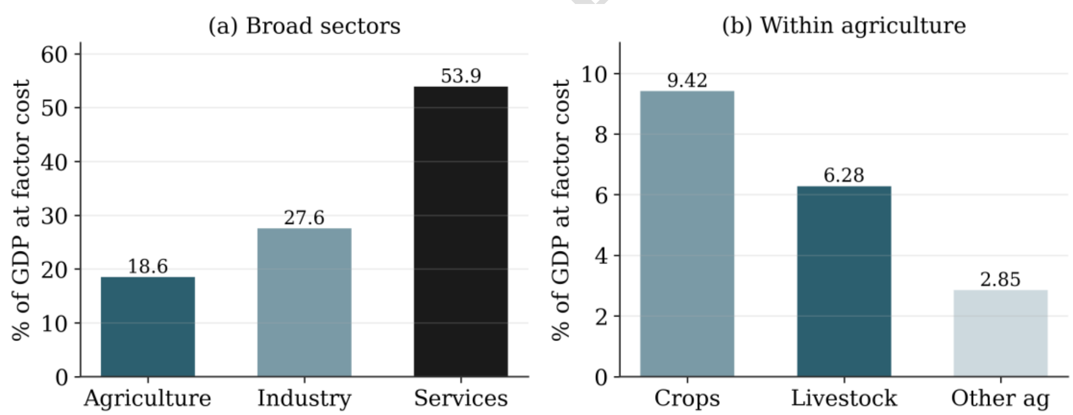

Figure 2. Economic structure from the IFPRI India SAM 2022–23: (a) broad sectors and (b) the composition of agriculture, as percentages of GDP at factor cost. Author's computation from SAM factor payments.

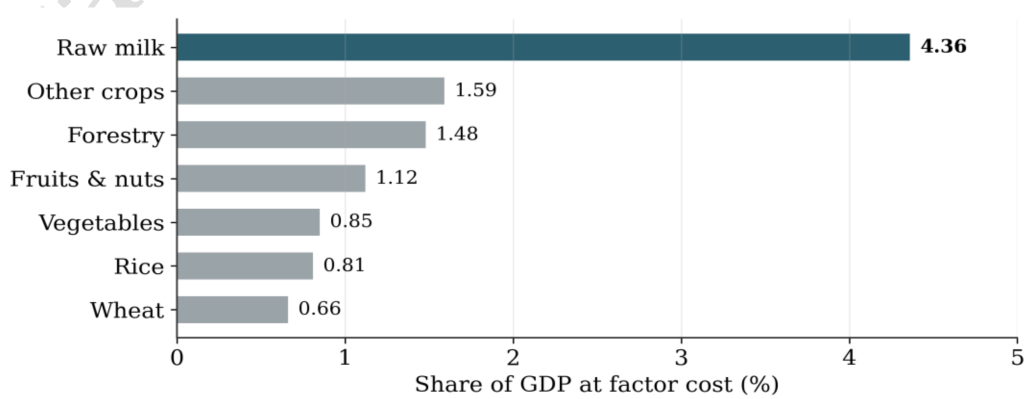

Figure 3. The seven largest primary-agricultural activities by share of GDP at factor cost. Raw milk is the largest single activity, exceeding rice and wheat.

Table 2. Selected structural indicators from the IFPRI India SAM, 2022–23 (% shares).

Indicator	Category	Share (%)
GDP at factor cost	Agriculture	18.6
	Industry	27.5
	Services	53.9
Agricultural value added	Crops	9.4
	Livestock	6.3
	of which: raw milk	4.4
	Dairy processing	0.10
Factor income	Capital	61.9
	Labour	33.8
	Land	4.3
	of which: livestock capital	2.5
Household income	Farm	20.0
	Rural-nonfarm	36.3
	Urban	43.7

Note: Shares are expressed as percentages of the relevant total (GDP at factor cost, agricultural value added, factor income or household income). Author's computation from the SAM.

4.3 Elasticities and calibration

Substitution and transformation elasticities are drawn from the empirical CGE literature for India and comparable economies. Armington and CET elasticities are set in the range 0.5–4 across commodities, with lower values for primary agriculture and higher values for processed and manufactured goods; CES value-added elasticities lie between 0.5 and 1.2; and LES income (Frisch) parameters are calibrated to base-year budget shares. The model is benchmarked to exactly replicate the 2022–23 SAM, and a homogeneity (numeraire) test confirms that a uniform scaling of all prices leaves real quantities unchanged. Section 11 discusses sensitivity of the results to these parameters.

5. Policy experiments

Seven simulations are designed cumulatively, in three policy families, so that the marginal effect of each lever is the difference between adjacent scenarios (Table 3). The productivity family raises total factor productivity (TFP): S1 applies a 5% gain to raw-milk production; S2 adds a 30% TFP gain in dairy processing and in fats and oils, representing value-chain development; and S3 adds an export-promotion shock that raises the world price facing dairy exports. The trade family removes the dairy import tariff fully (S4) or by half (S5), with no accompanying productivity gain. The combined family pairs the productivity package with full (S6) or partial (S7) tariff removal.

Table 3. Definition of the seven policy simulations.

Sim.	Label	Shock / impact channel
S1	Milk productivity (+5%)	Raw-milk TFP raised 5% (farm-gate intervention only).
S2	Processing expansion	S1 plus 30% TFP gain in dairy processing and fats & oils.
S3	Processing + export	S2 plus dairy export promotion (rise in the world export price).
S4	Free trade (−100%)	Dairy import tariff removed in full; no productivity gain.
S5	Partial free trade (−50%)	Dairy import tariff reduced by half.
S6	Productivity + free trade	Productivity package combined with full tariff removal.
S7	Productivity + partial FT	Productivity package combined with 50% tariff cut.

Note: All shocks are implemented as deviations from the 2022–23 base equilibrium. Productivity shocks shift activity-specific TFP; the export shock raises the world price facing the CET export function; tariff shocks reduce the dairy import duty.

6. Macroeconomic results

Table 4 and Figure 4 report the macroeconomic effects. The central result is that real output and real consumption rise in every scenario. Real GDP increases throughout, peaking at 0.22% under the value-chain scenarios (S2–S3), while real private consumption rises by up to 0.48%. Because a CGE model pins down relative rather than absolute prices, we summarise the price side through the model numéraire, the consumer price index, which falls in relative terms by between 0.12% and 0.36%; this reflects a fall in the relative price of food generated by the supply expansion, not consumer-price inflation in the macroeconomic sense. Real purchasing power therefore rises even where nominal magnitudes edge down, and real private consumption is positive in all seven experiments.

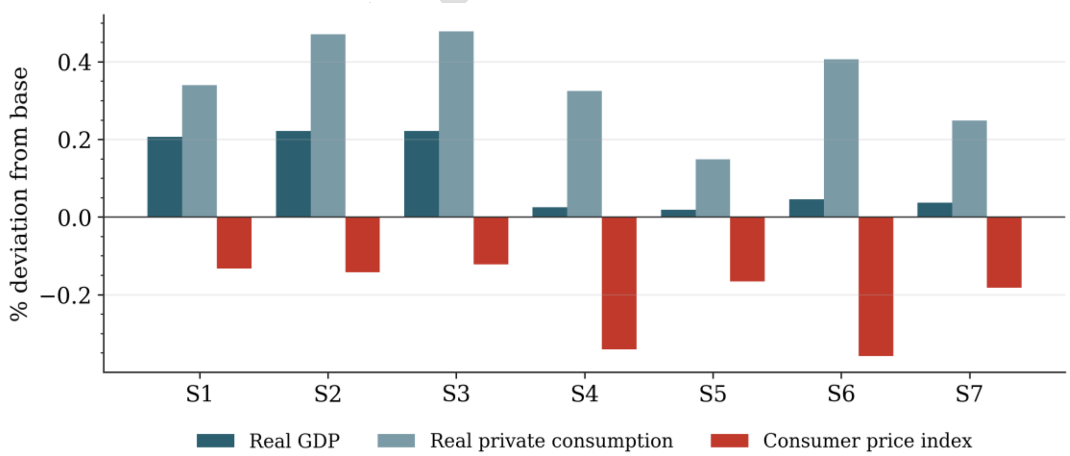

Figure 4. Macroeconomic effects of the seven simulations (percentage deviation from base).

Table 4. Macroeconomic effects (percentage deviation from base).

Indicator	S1	S2	S3	S4	S5	S6	S7
Real GDP (market prices)	**0.21**	**0.22**	**0.22**	**0.03**	**0.02**	**0.04**	**0.04**
Real private consumption	0.34	0.47	0.48	0.33	0.15	0.41	0.25
Real investment	−0.01	−0.19	−0.17	−0.52	−0.22	−0.60	−0.33

Indicator	S1	S2	S3	S4	S5	S6	S7
Real exports	−0.06	−0.19	−0.17	0.67	0.29	0.59	0.19
Real imports	−0.07	−0.15	−0.09	0.58	0.25	0.52	0.18
Consumer price index (numéraire)	−0.13	−0.14	−0.12	−0.34	−0.17	−0.36	−0.18
Real exchange rate	0.09	0.04	−0.02	0.33	0.15	0.30	0.11
Trade deficit / GDP (ppt)	0.06	0.05	0.05	−0.13	−0.06	−0.13	−0.06
Tax revenue / GDP (ppt)	0.04	0.01	0.00	−0.18	−0.07	−0.20	−0.10

Note: A positive real-exchange-rate value denotes a depreciation. Trade-deficit and tax lines are percentage-point deviations; all others are percentage deviations in real terms. The consumer price index is the model numéraire; because a CGE model determines only relative prices, its movement should be read as a change in the relative price of food, not as macroeconomic inflation. Source: model simulations.

Three features stand out. First, the productivity-driven scenarios (S1–S3) are unambiguously expansionary and lower the relative price of food, with the consumption gain deepening as processing and exports are added. Second, trade liberalisation (S4–S5) produces the largest price and external-sector effects: the dairy tariff cut generates the largest relative-price decline (−0.34% in the numéraire index, S4) and the largest real depreciation (0.33%), which raises both exports (0.67%) and imports (0.58%). Third, liberalisation is fiscally and investment-costly: removing the tariff lowers the tax-to-GDP ratio by 0.18 percentage points and compresses real investment by 0.52%, because lost tariff revenue reduces public savings and cheaper imports crowd out domestic capital formation under the savings-driven closure. The combined scenarios (S6–S7) blend these patterns, offsetting part of the fiscal drag while keeping real GDP positive.

7. Sectoral results

Table 5 reports the response of value added in the most affected activities, and Figures 4 and 5 display the two dominant mechanisms. The first is a value-chain channel that expands milk and dairy; the second is a trade channel that reshuffles competitiveness across protected food-processing activities once the tariff falls.

Table 5. Real value added of key activities (percentage deviation from base).

Activity (base GDP share)	S1	S2	S3	S4	S5	S6	S7
Agriculture (18.6%)	**1.15**	**1.21**	**1.22**	**−0.06**	**−0.02**	**−0.02**	**0.03**
Livestock (6.28%)	3.36	3.40	3.41	−0.00	0.00	0.02	0.02
Raw milk (4.36%)	4.83	4.88	4.89	0.00	0.00	0.03	0.03
Crops (9.42%)	0.03	0.12	0.13	−0.11	−0.04	−0.04	0.04
Food processing (1.21%)	**0.29**	**1.42**	**1.66**	**−1.08**	**−0.45**	**−0.28**	**0.43**
Dairy (0.10%)	3.06	7.43	8.67	0.10	0.05	3.12	2.99
Fats & oils (0.15%)	−0.03	4.67	5.67	−10.50	−4.66	−7.32	−0.89
Meat processing (0.01%)	−0.19	−3.41	−4.54	9.08	5.13	8.29	3.37
Industry (27.5%)	**−0.02**	**−0.04**	**−0.05**	**−0.14**	**−0.06**	**−0.14**	**−0.07**

Note: Base GDP shares in parentheses are percentages of GDP at factor cost. Source: model simulations.

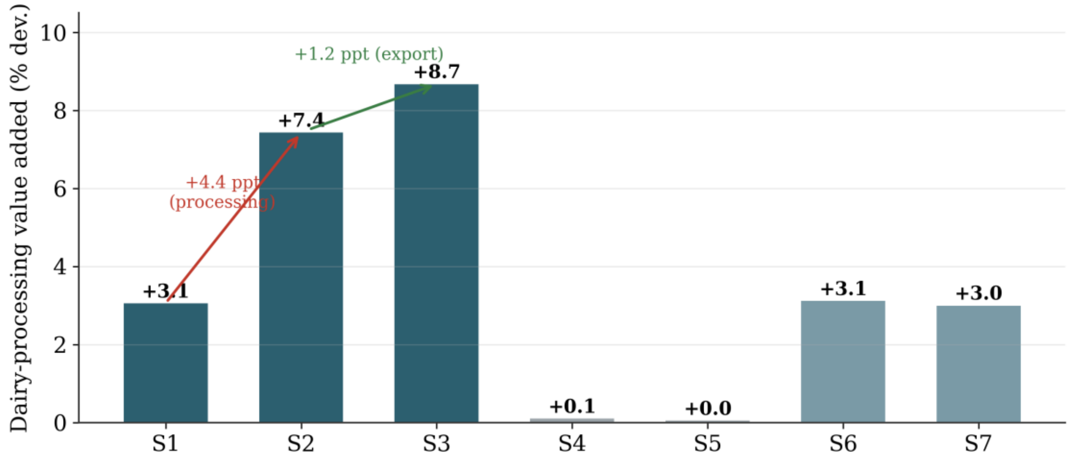

Figure 5. Decomposition of the dairy-processing value-added gain. Processing adds 4.4 percentage points (S1→S2) and export promotion a further 1.2 points (S2→S3).

The value-chain dividend. Dairy-processing value added rises from 3.1% under the milk shock alone to 7.4% once the processing TFP gain is added—a marginal contribution of 4.4 percentage points—and to 8.7% with export promotion (Figure 5). Because raw milk faces relatively inelastic demand, a farm-gate productivity gain on its own would tend to depress the producer price; building processing capacity and export demand absorbs the additional milk at a remunerative price. This provides direct quantitative support for a sequenced 'primary–processing–export' strategy. Pure liberalisation (S4–S5) leaves dairy essentially unchanged (+0.1%), while the combined scenarios restore dairy value added to about 3%, indicating that competitiveness rather than protection sustains the sector under open trade.

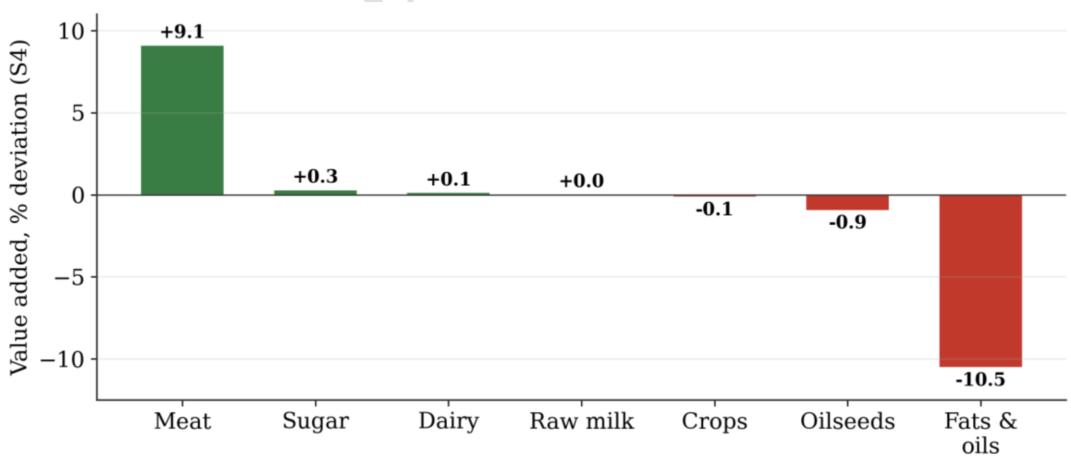

Figure 6. Sectoral reshuffle under full dairy-trade liberalisation (S4). Meat processing expands while fats and oils contracts sharply.

The trade reshuffle. Removing the dairy tariff (S4) barely affects dairy itself but triggers a pronounced reallocation within food processing: meat processing expands by 9.1% while fats and oils contracts by 10.5% (Figure 6). The mechanism is the real exchange rate. The tariff cut widens the trade deficit, the real exchange rate depreciates to restore external balance, and the depreciation exposes the heavily protected fats-and-oils activity to import competition while making export-capable meat internationally competitive. This pattern follows directly from the base-year trade structure: in the SAM, dairy is a near-unprotected net exporter (imports of 3.1 versus exports of 35.6, and negligible tariff revenue), whereas fats and oils is the economy's large protected import, carrying the bulk of food-processing tariff revenue. Industry and manufacturing contract slightly across scenarios as factors are pulled into the expanding dairy-food complex—a standard resource-pull effect.

8. Factor-market results

Factor returns (Table 6, Figure 7) reveal the mechanism behind the welfare results and resolve an apparent paradox: output expands, yet several factor returns fall.

Table 6. Factor returns (percentage deviation from base).

Factor	S1	S2	S3	S4	S5	S6	S7
Total labour	0.03	−0.01	−0.03	0.18	0.08	0.15	0.05
Crop land	1.00	2.65	2.94	−1.22	−0.57	−0.36	0.52
Total capital	−0.63	−0.47	−0.41	0.08	0.04	0.21	0.17
Livestock capital	**−9.08**	**−6.36**	**−5.73**	**−0.02**	**0.04**	**1.94**	**2.20**
Crop capital	−3.85	−1.46	−0.96	−1.08	−0.47	0.42	1.33

Note: Source: model simulations.

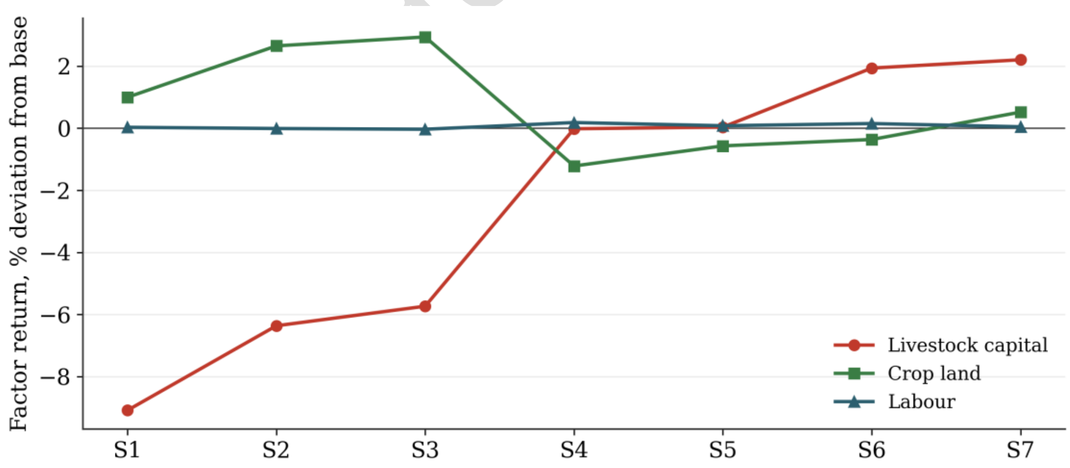

Figure 7. Returns to livestock capital, crop land and labour across the seven simulations.

The productivity paradox. Under the milk shock (S1), the return to livestock-specific capital falls by 9.1% even though milk output rises by 4.8%. Because milk faces relatively inelastic demand and a falling price, revenue per unit of the sector-specific capital that cannot relocate in the short run declines; and since livestock capital earns only 2.5% of factor income, the proportional loss is large. Processing expansion partly repairs this—the loss narrows to 6.4% in S2 and 5.7% in S3—and combining productivity with liberalisation turns the return positive (1.9–2.2% in S6–S7), as export and processing outlets absorb the additional output. Crop land, by contrast, gains 2.6–2.9% under the value-chain scenarios on stronger feed and fodder demand, while labour income gains most under liberalisation (0.18% in S4), where the depreciation-driven export expansion is relatively labour-intensive. Each policy therefore carries a distinct factor-incidence signature, and only the combined package makes the sector's own capital better off.

9. Household welfare and distribution

Table 7 and Figure 8 report household income outcomes in real (CPI-deflated) terms. Reporting real income is the appropriate welfare measure in a model that determines only relative prices: because the relative price of food falls, every group fares better in real terms than its nominal income alone would imply.

Table 7. Household income response (percentage deviation from base, real).

Household group (income share)	S1	S2	S3	S4	S5	S6	S7
All households	**−0.33**	**−0.09**	**−0.05**	**0.27**	**0.13**	**0.43**	**0.33**
Rural (56.3%)	−0.73	−0.20	−0.10	0.11	0.07	0.46	0.47
Farm (20.0%)	−1.47	−0.21	0.03	−0.29	−0.11	0.49	0.82
Rural-nonfarm (36.3%)	−0.33	−0.20	−0.17	0.33	0.16	0.44	0.28
Urban (43.7%)	0.18	0.06	0.01	0.47	0.22	0.40	0.14
Poorest quintile (Q1)	−0.47	0.01	0.09	0.07	0.05	0.38	0.41
Richest quintile (Q5)	−0.03	0.03	0.02	0.36	0.17	0.41	0.22

Note: Figures are real (CPI-deflated) income deviations, computed as the nominal income deviation net of the change in the numéraire price index. Source: model simulations.

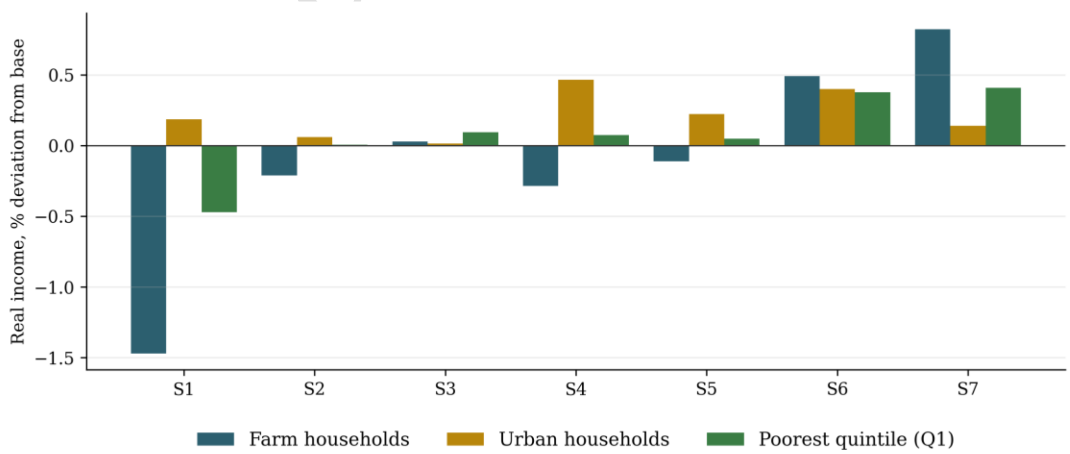

Figure 8. Household income by group (percentage deviation from base, real). Only the combined scenarios (S6–S7) raise real income for all groups shown.

The processing dividend for farmers. Comparing the processing scenario with the milk-only scenario isolates the welfare gain from value-chain development. Real farm-household income improves from

−1.47% (S1) to −0.21% (S2) and turns positive at 0.03% with export promotion (S3)—a gain of roughly 1.25 to 1.50 percentage points attributable to processing and exports. Processing thus converts a farm-gate productivity gain that would otherwise depress the producer price into a markedly more favourable real-income outcome, because the downstream demand it creates sustains the relative price of milk.

The equity tension of liberalisation. Pure free trade (S4) raises real incomes for urban households (0.47%) while farm households still lose in real terms (−0.29%): cheaper imported dairy benefits urban net buyers and squeezes net-seller farm households. This is the central distributional tension of unilateral liberalisation. By contrast, only the combined scenarios (S6–S7) deliver positive real income gains across all groups, and the gains are largest precisely for the households that lose under the other scenarios—farm households (0.49–0.82%) and the poorest quintile (0.38–0.41%). Pairing competitiveness-raising productivity with managed liberalisation aligns the efficiency and equity objectives.

10. Synthesis and policy implications

Read together, the seven simulations yield a coherent and actionable narrative. The answer to whether free trade helps the Indian livestock sector is conditional: liberalisation helps consumers and wage-earners and improves the external balance, but on its own it neither expands dairy meaningfully nor benefits farmers, and it carries real fiscal and investment costs. Liberalisation pays off for the sector only when paired with the productivity and processing investments that make domestic dairy competitive without protection. Table 8 summarises the scenario outcomes qualitatively.

Table 8. Qualitative scenario scorecard.

Scenario	Real GDP	Dairy	Farmers	Consumers	Fiscal
S1 Milk +5%	+	+	−	+	≈
S2 Processing	++	++	+	+	≈
S3 Proc.+Export	++	+++	+	+	≈
S4 Free trade	≈	≈	−−	++	−−
S5 Partial FT	≈	≈	−	+	−
S6 Prod+FT	+	++	+	++	−
S7 Prod+PT	+	++	++	+	−

Note: + positive, ++/+++ strongly positive, ≈ broadly neutral, − negative, −− strongly negative. Consumer effects are judged in real terms.

Four policy implications follow. First, value-chain development—combining farm-gate productivity with processing expansion (S2)—should be the priority: it delivers the largest real-output gain, the strongest dairy expansion of any non-trade scenario, rising land returns, and a positive income dividend for farmers. Second, export promotion (S3) is the natural second stage, raising dairy value added to its maximum at negligible macroeconomic cost. Third, trade liberalisation should be sequenced after, not before, competitiveness-building: introduced on its own it reduces farm incomes and is fiscally costly, whereas the same tariff reduction combined with the productivity package (S6–S7) becomes broadly welfare-improving and uniquely lifts incomes across all household groups. Fourth, because most scenarios compress investment and reduce the tax-to-GDP ratio, complementary measures—recycling efficiency gains into public investment or broadening the indirect-tax base—would protect the long-run growth path. The broader lesson is that the sequence of reforms can matter as much as their content.

11. Limitations and extensions

Several caveats bound the interpretation of these results. The model is comparative-static, so the reported figures are directional, medium-run deviations rather than dynamic forecasts; in particular, the static frame does not allow the investment decline observed in most scenarios to feed back into the capital stock and the growth path. The aggregate magnitudes are modest because dairy processing is a thin share of value added, so the policy interest lies in the sectoral and distributional reallocations, which are an order of magnitude larger than the macroeconomic deviations. The results are also conditional on the trade (Armington/CET) and factor-mobility elasticities; sensitivity analysis around these parameters indicates that the qualitative findings productivity raises welfare, processing compounds it, liberalisation alone is regressive, and the combined package lifts all groups are robust, while the magnitudes scale with the assumed elasticities.

Three extensions would strengthen the analysis. A recursive-dynamic specification would capture the investment and accumulation effects that the static model omits. A systematic sensitivity analysis would map the magnitude of the key results onto the elasticity space. Most importantly for the external dimension, embedding the experiment in a multi-region framework such as GTAP would endogenise the world dairy price here shocked exogenously and allow terms-of-trade effects, partner-country responses and non-tariff measures to be modelled explicitly. These extensions are left for future work.

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