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Article

Cereal Production Volatility, National Commodity Availability and Dietary Indicators in Ireland: A Descriptive Time-Series Analysis

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Highlights

- Growth-rate and detrended measures separate trend; milk availability varies most.
- Principal-cereal production varies more; availability-to-production ratio is 0.33.
- Pulse availability is more volatile than the dietary indicators.
- Annual commodity-diet associations remain exploratory with 12 paired changes.
- Short series limit inference; production, trade and stocks need joint monitoring.

Abstract

Background: National commodity availability can vary differently from domestic production and processed dietary indicators. This descriptive ecological time-series study distinguishes short-term volatility from whole-period dispersion and avoids causal claims. **Methods:** We analysed 14 annual observations of Irish national availability for cereals excluding beer, bovine meat and milk excluding butter (2010–2023), an official Central Statistics Office (CSO) principal-cereal production series for the same period, and 13 matched observations for four processed dietary indicators (2010–2022). The primary volatility measure was the sample standard deviation of annual logarithmic changes; median absolute change, log-linear detrending and a segmented milk trend were sensitivity analyses. Commodity–diet associations were examined using 12 paired annual changes. **Results:** Annual-growth volatility was 5.75% for cereal availability, 7.10% for bovine meat and 15.96% for milk. Principal-cereal production volatility was 17.36%, compared with 5.75% for cereal availability (attenuation ratio, 0.33; annual-change correlation, −0.08). Dietary indicators were heterogeneous: volatility was 0.85% for diet diversity, 3.25% for total dietary intake, 4.16% for vegetables and 22.78% for pulses. The all-zero dietary cereal series was excluded as invalid. **Conclusions:** Lower variability in cereal availability is consistent with attenuation between production and national availability, but different commodity scopes and unavailable trade and stock components prevent attribution to trade buffering. The dietary results show no consistent commodity–diet association. Rural resilience was not measured.

Keywords: annual growth rates; cereal production; diet diversity; food balance sheets; Ireland; national commodity availability

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1. Introduction

Ireland's agri-food economy is internationally integrated and strongly oriented towards dairy and beef, while tillage occupies a smaller and economically exposed position. This structure matters because stability at one point in the food system need not imply stability elsewhere (Allen & Prosperi, 2016; FAO, 2021; Tendall et al., 2015). National commodity availability may be maintained through domestic output, trade and stock adjustments even when farm-level production, input costs or incomes fluctuate. Conversely, stable aggregate dietary indicators cannot demonstrate that rural enterprises are resilient, which requires explicit economic, social or recovery indicators (Ryan et al., 2016).

Three analytical distinctions are therefore essential. First, FAOSTAT Food Balance Sheet domestic supply quantity is an accounting measure of national availability, not a synonym for domestic farm production. Second, long-run expansion and short-run instability are different

phenomena; a raw coefficient of variation can be inflated by a trend, as is likely for Irish milk after EU milk quotas ended in 2015. Third, a weak annual association between national availability and a dietary indicator is not evidence that trade caused buffering. Testing that mechanism requires separate production, import, export and stock series.

Existing Irish work provides important economic, environmental and nutritional comparisons of crop systems. Merlo et al. (2024), for example, assess crop production and rotations across these dimensions. The present study adds a narrower time-series contribution: it compares alternative descriptive measures of annual variation in selected national commodity-availability and dietary series and benchmarks cereal availability against an independently documented CSO production series, while making the evidential boundary explicit. It does not estimate farm income effects, household consumption, mediation by trade, or causal responses to policy.

The study addresses four questions: (1) how do raw dispersion, annual-growth volatility and detrended variability differ for cereal, bovine-meat and milk availability in 2010–2023; (2) is variability in official principal-cereal production attenuated at the national-availability layer; (3) how variable are the available dietary indicators in 2010–2022; and (4) do exploratory annual changes show a consistent commodity-dietary association? The linked diet analysis contains only 13 annual levels and 12 annual changes; all interpretation is descriptive.

2. Materials and Methods

2.1. Design and Analytical Scope

This retrospective ecological time-series study used annual national data for Ireland. Commodity availability was analysed for 2010–2023 (n = 14). The matched commodity-diet analysis ended in 2022 because dietary indicators were unavailable for 2023 (n = 13 levels; n = 12 annual changes). The unit of analysis was the country-year. No individual-level, farm-level, or regional inference is warranted.

2.2. Data Sources and Variable Meaning

The supplied analytical file wb_fao_ireland_with_changes.csv contained annual series labelled cereals excluding beer, bovine meat and milk excluding butter. The companion merged_cleaned.csv contained those variables plus TDI, DDI, pulse availability, and vegetable availability. The commodity labels follow Food Balance Sheet aggregation. In FAOSTAT accounting, domestic supply quantity is generally constructed from production, imports, exports, and stock variation, with item-specific balancing; it represents national availability for uses such as food, feed, processing, seed, losses, and other utilisation (FAO, 2017, 2025). It is therefore called national commodity availability throughout this paper. It is not farm production, and it is not necessarily human food consumption. The dietary indicators were supplied as harmonised, processed variables associated with Global Dietary Database methods (Imamura et al., 2015; Miller et al., 2022), but their original export metadata were not retained.

The uploaded files report the commodity series on a tonne scale but do not retain the complete FAOSTAT extraction metadata (dataset release, element/item codes, unit flags, and download date). They also do not contain separate production, import, export, or stock components. This prevents a reproducible decomposition of national availability or calculation of self-sufficiency from the supplied material. The dietary variables are retained under their processed column names because their source units and transformations were not recoverable from the files. Their results are interpreted as relative changes in processed indicators, not as grams, kilocalories, or observed individual intake.

To add an independently documented production benchmark, principal-cereal production (wheat, oats and barley) was obtained from CSO PxStat table AQA04, Crop Yield and Production, updated 1 May 2026. The table reports production in thousand tonnes for 2008–2025; the common 2010–2023 observations were used. The CSO aggregate is narrower than FAOSTAT cereals excluding beer, so comparisons are labelled contextual and are not an accounting decomposition. The source URL, update date, and extracted values are supplied in the reproducibility folder (Central Statistics Office, 2026).

2.3. Data Processing and Validation

The processing pipeline enforced integer calendar years, checked duplicate country-years, selected named columns, and joined the commodity and dietary tables by an inner one-to-one merge on year. Commodity trend analyses used 2010–2023. Linked analyses used the intersection 2010–2022. No interpolation or imputation was applied. The wide inputs also retain numerous World Bank socioeconomic, demographic, and Food Balance Sheet fields unrelated to the four research questions; these fields were preserved for provenance but excluded from analysis and

interpretation. The cereal dietary column was zero in all 13 rows. Because a structural zero across every year was implausible and no codebook established that zero was meaningful, it was treated as invalid and excluded. This means the direct cereal-availability-to-cereal-diet relationship is untestable in this dataset.

2.4. Statistical Analysis

Raw CV was retained only as a whole-period measure of relative dispersion: CV = 100(SD(X)/mean(X)). It was not interpreted as short-term volatility. The primary volatility measure was the sample SD of annual logarithmic changes, where $g(t) = 100[\ln X(t) - \ln X(t-1)]$. The median absolute annual log change provided a robust sensitivity measure. A second sensitivity analysis estimated a log-linear time trend and reported the SD of residuals multiplied by 100. For milk, an additional segmented log trend allowed the slope to change from 2015 onward; this was a descriptive sensitivity check, not a causal estimate of quota abolition. Influence was assessed by removing each annual log change in turn and recalculating its SD, producing a minimum-to-maximum range for each commodity.

Pearson correlations were computed between commodity and dietary annual log changes for 2011–2022. They are reported as exploratory effect-size summaries only. With n = 12, a two-sided test at alpha = 0.05 requires approximately $|r| = 0.576$ even before considering multiple comparisons; non-significance cannot be interpreted as evidence of no relationship. Level correlations, which are vulnerable to common trends, were moved to Appendix A. No machine-learning model, HP filter, OLS mediation model, or causal time-series model was fitted: the sample is too short for reliable training/validation, and trade components required for the proposed mechanism are absent.

For the contextual cereal comparison, the same annual-log-change SD was calculated for CSO principal-cereal production. An attenuation ratio was defined as SD(change in national cereal availability)/SD(change in principal-cereal production). A value below 1 is consistent with smoothing between layers, but it cannot identify the responsible mechanism. The annual-change correlation was also reported. Analyses were implemented in Python 3 using pandas, NumPy, and Matplotlib; the submission includes code, inputs, outputs, and a data dictionary.

2.5. Computational Reproducibility

The analysis was executed in Python 3.12.13 using NumPy 2.3.5, pandas 2.2.3 and Matplotlib 3.10.8. The accompanying script reproduces the validation checks, annual-change, influence and detrended measures, correlations, attenuation comparison, tables and figures from the supplied CSV files. A pinned requirements file, Conda environment file, input hashes and runtime metadata are supplied.

3. Results

3.1. National Commodity Availability

Across 2010–2023, mean national availability was 1.769 million tonnes for cereals, 0.197 million tonnes for bovine meat and 1.868 million tonnes for milk. The raw CV was highest for milk (25.18%), but that statistic includes its strong expansion. Annual-growth SD reduced the contrast while preserving the ordering: milk 15.96%, bovine meat 7.10% and cereals 5.75%. Log-linear detrending produced 12.48%, 5.98% and 5.45%, respectively (see Table 1). Allowing a post-2015 slope change reduced the milk residual SD to 11.75%. Thus, milk remained the most variable by the tested short-term measures, but its raw CV materially overstated volatility by conflating growth with fluctuation.

Table 1. Dispersion and corrected volatility of national commodity-availability series, 2010–2023.

Series	n	Mean (t)	Raw CV (%)	SD annual log change (%)	Median absolute change (%)	Log-trend residual SD (%)	Segmented residual SD (%)
Cereals excluding beer	14	1,768,658	5.49	5.75	2.22	5.45	-
Bovine meat	14	197,471	10.64	7.10	2.89	5.98	-
Milk excluding butter	14	1,867,648	25.18	15.96	7.35	12.48	11.75

Note: Sample SDs. The segmented measure was prespecified only for milk and allows a slope change from 2015; dash = not calculated. Raw CV is not used as the primary volatility measure.

Cereal availability peaked in 2016 and reached its minimum in 2021. Bovine-meat availability rose over the later years but fluctuated around that increase. Milk showed the clearest structural movement after 2015. Event markers in Figures 1–3 provide chronology only; they do not attribute causality to quota removal, drought, the pandemic or the war in Ukraine.

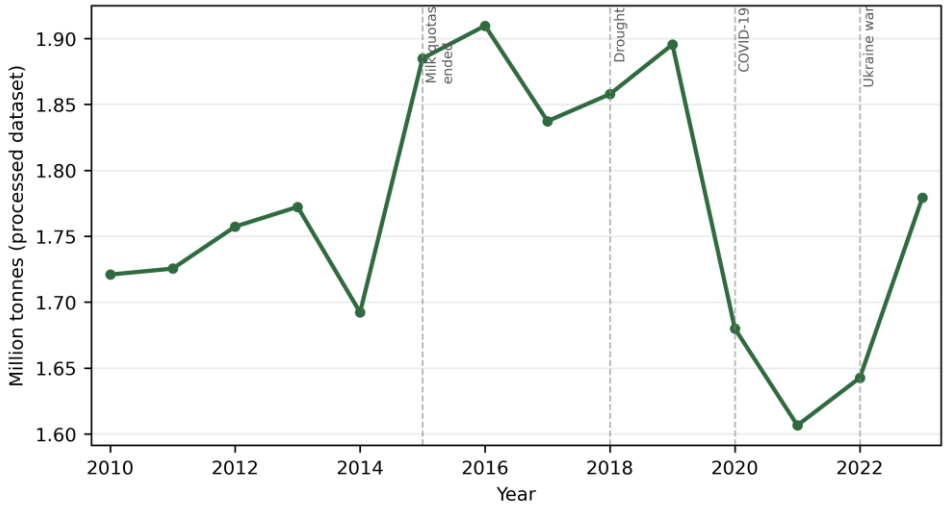


Figure 1. National cereal availability (excluding beer), Ireland, 2010–2023. Dashed event markers supply context only: 2015 EU milk-quota abolition, 2018 drought, 2020 COVID-19 disruption and 2022 war in Ukraine. Source: processed supplied dataset; values labelled in tonnes.

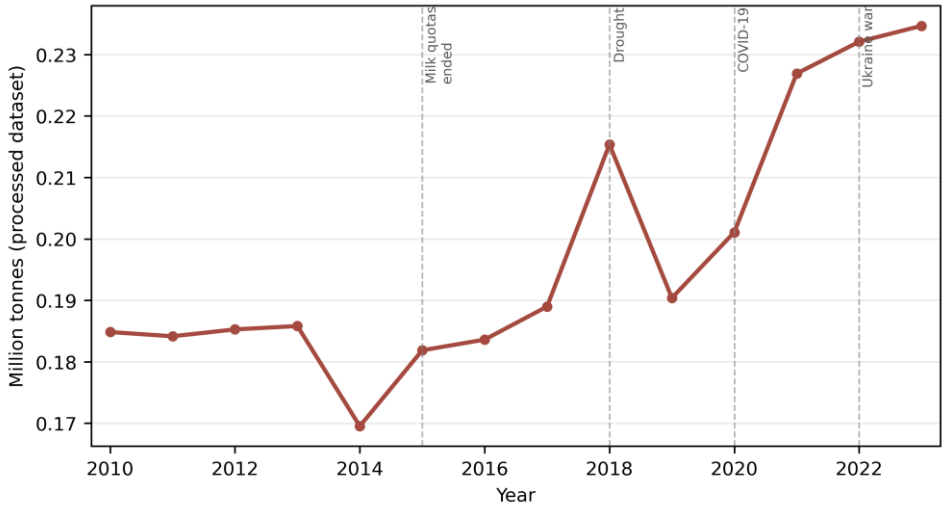


Figure 2. National bovine-meat availability, Ireland, 2010–2023. Event markers are contextual and are not causal estimates. Source: processed supplied dataset; values labelled in tonnes.

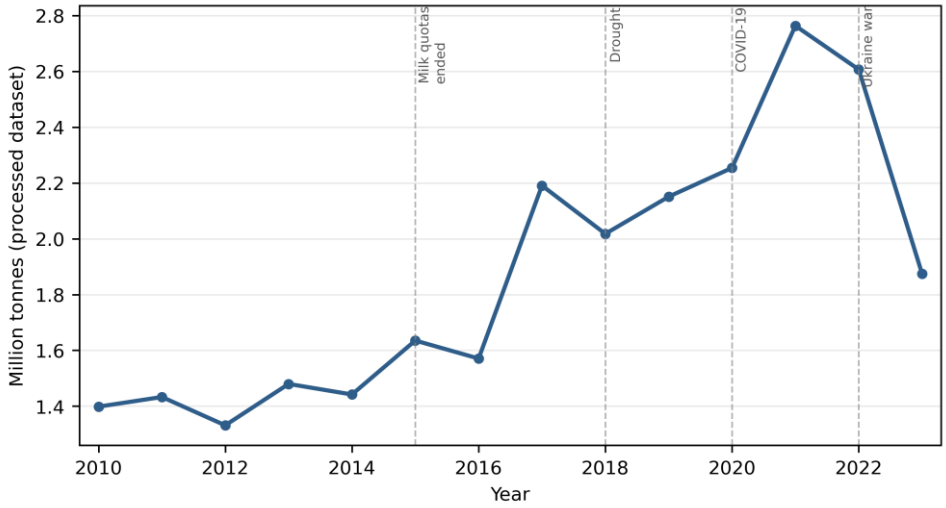


Figure 3. National milk availability excluding butter, Ireland, 2010–2023. The post-2015 expansion motivates trend-adjusted volatility measures. Event markers are contextual and are not causal estimates. Source: processed supplied dataset; values labelled in tonnes.

The leave-one-annual-change-out analysis preserved the volatility ordering. Recalculated SDs ranged from 12.49% to 16.67% for milk, 5.93% to 7.41% for bovine meat and 4.60% to 6.01% for cereals. Milk fell by 28.07% in level terms in 2023, corresponding to an annual log change of −32.94 log points; however, excluding any single annual change still left milk above the maximum leave-one-out volatility of either other commodity. Because the processed series lacks original source flags and revision metadata, no causal or data-quality interpretation is assigned to the 2023 endpoint.

3.2. Dietary Indicators

Dietary indicators were not uniformly stable. DDI was the smoothest series (annual-growth SD 0.85%), followed by TDI (3.25%) and vegetable availability (4.16%). Pulse availability was substantially more variable (22.78%), exceeding every commodity series on this metric (Table 2). The earlier broad contrast between volatile agriculture and stable diets is therefore unsupported; the defensible result is heterogeneity across both domains.

Table 2. Dispersion and annual-change volatility of processed dietary indicators, 2010–2022.

Indicator	n	Mean	Raw CV (%)	SD annual log change (%)	Median absolute change (%)
Total dietary intake	13	0.1301	5.71	3.25	2.08
Diet diversity index	13	1.8913	1.58	0.85	0.38
Pulse availability	13	0.0141	25.72	22.78	14.06
Vegetable availability	13	0.0300	8.56	4.16	2.92

Note: Values are unitless processed indicators because source units were not recoverable from the supplied files. They must not be interpreted as measured individual intake. Dietary cereal availability was excluded because all values were zero.

3.3. Exploratory Annual-Change Associations

The 12-observation correlations varied in sign and magnitude (Table 3). Cereals had small positive correlations with TDI, DDI, and vegetables, but essentially none with pulses. Bovine-meat changes were moderately negatively correlated with DDI, while milk changes were moderately negatively correlated with vegetables. Only the milk-vegetable coefficient exceeded the approximate $|r| = 0.576$ threshold for an unadjusted two-sided 5% test, and none should be interpreted confirmatorily because 12 correlations were inspected in a very small sample. This scattered pattern does not identify a stable transmission mechanism. Figure 4 illustrates the annual-change patterns.

Table 3. Exploratory Pearson correlations between annual log changes, 2011–2022.

Commodity series	TDI	DDI	Pulses	Vegetables
Cereals excluding beer	0.248	0.267	−0.033	0.370
Bovine meat	0.047	−0.482	−0.345	−0.143
Milk excluding butter	0.078	−0.256	−0.098	−0.589

Note: n = 12 paired annual changes. No p-values are emphasised because the analysis is underpowered, exploratory, and involves multiple comparisons. Non-significance is not evidence of no relationship.

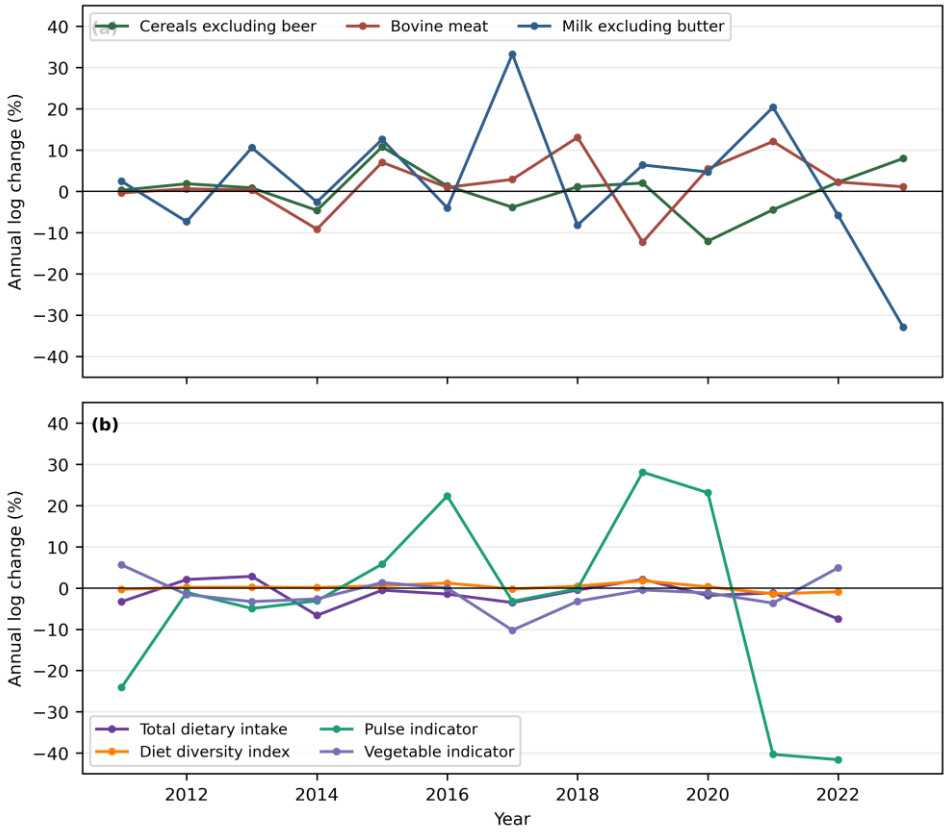


Figure 4. Annual log changes in national commodity availability and processed dietary indicators. (a) Commodity-availability changes; (b) dietary-indicator changes. Both panels use the same vertical range. The figure reports annual log changes rather than a base-year index and does not establish causal transmission.

3.4. Cereal Production and Availability Attenuation

Official CSO principal-cereal production was substantially more variable than the processed national cereal-availability series over the common 2010–2023 period. Annual-log-change SD was 17.36% for production and 5.75% for availability, giving an attenuation ratio of 0.33 (Table 4; Figure 5). Their annual-change correlation was −0.08. The lower availability variability is consistent with attenuation between production and the national-availability layer, but it does not identify trade as the cause. The comparison is contextual because CSO principal cereals comprise wheat, oats and barley, whereas the availability series is labelled cereals excluding beer.

Table 4. Contextual comparison of cereal production and national-availability variability, 2010–2023.

CSO production SD (%)	Availability SD (%)	Attenuation ratio	Annual-change correlation
17.36	5.75	0.33	−0.08

Note: SD is the sample standard deviation of annual log changes. Ratio = availability SD/production SD. The aggregates are not commodity-identical, so this is not a trade decomposition or causal estimate.

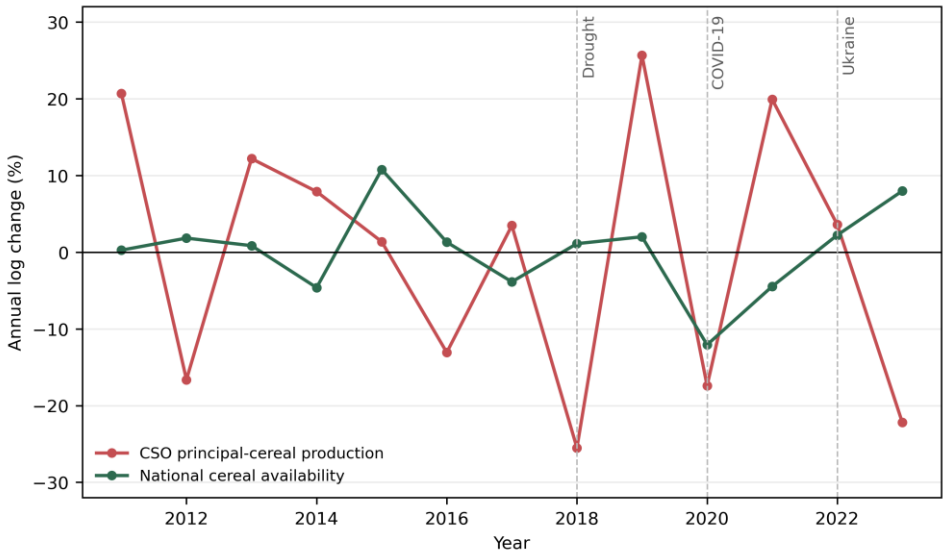


Figure 5. Annual log changes in CSO principal-cereal production and the processed national cereal-availability series, 2011–2023. The production series is more variable, but different aggregate scopes and absent trade/stock components prevent causal attribution. Event markers are contextual.

3.5. Evidence Boundary

Figure 6 summarises the evidence boundary: the production, availability and dietary series are observed, whereas trade and stock mechanisms and rural outcomes are not directly measured.

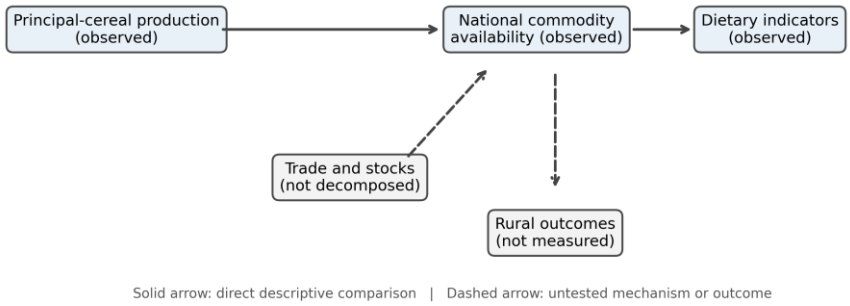


Figure 6. Evidence boundary for this revision.
Note: Principal-cereal production, national commodity availability, and dietary indicators are observed. Solid arrows denote direct descriptive comparisons; dashed arrows denote unobserved trade and stock mechanisms or unmeasured rural outcomes.

4. Discussion

4.1. Principal Findings

Correcting the volatility definition materially changes the interpretation. Raw CV correctly describes dispersion around the whole-period mean but not annual instability when a series trends. Growth-rate and detrended results show that milk remained the most variable selected availability series, yet the magnitude is appreciably below its raw CV. Bovine meat, not cereals, was the second most volatile availability series. Among dietary indicators, DDI, TDI and vegetables were relatively smooth, while pulses were not. The new external comparison adds a clearer result: principal-cereal production varied much more than the national cereal-availability series. The central empirical message is heterogeneous variation and descriptive attenuation across layers, not proof of a universal supply-diet mismatch or a specific causal mechanism.

4.2. What the Data Do not Show about Buffering

A Food Balance Sheet describes commodity accounting at national scale. If the source element is domestic supply quantity, trade and stock movements may already be embedded. The attenuation ratio now shows that the national cereal-availability series varies less than the CSO production benchmark, which is consistent with smoothing somewhere between production and availability. It cannot isolate whether imports rose when production fell, stocks were released, or allocations to feed and processing changed. A causal buffering estimate, self-sufficiency ratio, or mediation model still requires matched production, import, export and stock series for the same commodity definition. Those components are absent, and the two observed cereal aggregates differ in scope. Trade buffering therefore remains a plausible explanation, not a demonstrated mechanism.

4.3. Relation to Irish Evidence and Rural Exposure

Merlo et al. (2024) show why crop choice and rotation should be evaluated jointly across economic, environmental and nutritional dimensions. The present analysis complements that framework by showing how conclusions about temporal instability depend on the metric and data layer. It cannot measure rural resilience. However, external Irish evidence makes tillage exposure a legitimate policy context: Teagasc's National Farm Survey reported average family farm income of EUR 41,471 for tillage farms in 2024, compared with EUR 108,672 for dairy farms, and direct payments represented 84% of tillage family farm income (Dillon et al., 2025). These external statistics are contextual, not outcomes of our model.

4.4. Alternative Explanations for Smooth Dietary Indicators

Several mechanisms could smooth aggregate dietary indicators without trade being the sole cause: substitution across foods, retail contracts, processing and inventories, aggregation across population groups, and the composition of an animal-source-oriented food system. In addition, GDD-derived indicators are modelled estimates that pool information across sources, countries and years; such construction can smooth trajectories relative to raw survey observations (Miller et al., 2022). Because units and transformations were not retained in the uploaded merged file, measurement architecture is a particularly important alternative explanation.

5. Policy Implications

5.1. Monitoring Before Inference

The immediate policy need is an auditable Irish commodity dashboard that keeps production, imports, exports, stock variation, domestic supply, food use, feed use, farm-gate prices and landed-import prices separate. DAFM and CSO data could be linked to FAOSTAT with codes, units, revisions and download dates preserved. This would permit annual self-sufficiency and import-dependency ratios and direct comparison of production-shock volatility with availability volatility.

5.2. Place-Based Tillage Support

Policy recommendations should build on existing instruments rather than create generic new categories. Food Vision 2030 and the Food Vision Tillage Group's 28 actions, including its 400,000-hectare ambition, provide a national frame (Department of Agriculture, Food and the Marine [DAFM], 2021, 2024a). Within Ireland's CAP Strategic Plan 2023–2027, Protein Aid is Voluntary Coupled Support, not an eco-scheme (DAFM, 2024b). Appropriate options include evaluating payment adequacy and uptake for protein crops; strengthening Teagasc demonstrations and whole-farm rotation advice; supporting producer coordination, drying, storage and food-grade processing; and using public procurement trials where reliable demand can be specified. Monitoring should include farm income, hectares, exits, employment, environmental performance and market development, consistent with a multidimensional food-security perspective (High Level Panel of Experts on Food Security and Nutrition, 2020).

5.3. Transparent 30% International-Price Stress Test

Because import shares, landed prices, and demand elasticities are absent, a predictive scenario would be spurious. A transparent algebraic stress test is nevertheless possible. Let s be the imported share of a commodity, p the pass-through of an international price shock to the national basket, and e the absolute demand elasticity. Under a 30% external price shock, the first-round basket-price exposure is 0.30sp, and the illustrative quantity response is −e(0.30sp). Table 5

shows a sensitivity grid using p = 0.50 and e = 0.20 solely to demonstrate scale; these are scenario parameters, not estimates for Ireland.

Table 5. Illustrative sensitivity analysis for a 30% international-price shock.

Imported share (s)	Pass-through (p)	Elasticity (e)	Basket-price exposure	Illustrative quantity response
25%	50%	0.20	3.8%	−0.8%
50%	50%	0.20	7.5%	−1.5%
75%	50%	0.20	11.3%	−2.3%

Note: Illustrative arithmetic only, not a forecast. A submission-grade calibrated result requires observed import shares, landed prices, substitution possibilities, and empirically supported elasticities. No direct dietary effects are inferred.

6. Limitations and Research Priorities

This study has seven material limitations. First, 14 annual commodity observations and 13 matched dietary observations preclude causal inference and reliable machine learning. Second, national availability is not farm production. The CSO benchmark improves the production comparison, but principal cereals and cereals excluding beer are not identical aggregates. Third, imports, exports, stocks, food use, and feed use cannot be separated in the supplied files, so the attenuation ratio does not identify trade buffering and self-sufficiency remains unmeasured. Fourth, the all-zero cereal dietary series makes the cereal-to-diet link entirely untestable; excluding it may understate carbohydrate-source variation and prevents any claim about direction or magnitude. Fifth, the dietary indicators lack a recoverable codebook, units, and transformation history and may be model-smoothed. Sixth, event annotations are contextual rather than causal. Seventh, no rural income, employment, exit, diversification, or recovery outcome was modelled.

Priority follow-up work should re-extract FAOSTAT data with release metadata and separate elements, validate cereal food supply in kg/person/year or kcal/person/day, link CSO/DAFM/Teagasc price and farm-income series, preregister a larger country-year panel, and test attenuation by comparing annual production and domestic-supply changes. Only then should mediation, distributed-lag, or price-transmission models be considered.

7. Conclusions

Using growth-rate and detrended measures, milk showed the greatest short-term variability among the three national commodity-availability series, followed by bovine meat and cereals. Official principal-cereal production was much more variable than the processed cereal-availability series: the descriptive attenuation ratio was 0.33. This is evidence consistent with smoothing between production and national availability, but it is not proof of trade buffering because the commodity scopes differ and trade and stock components were not decomposed. Dietary indicators were heterogeneous: DDI, TDI and vegetables were comparatively smooth, while pulses were highly variable. The analysis therefore supports separate monitoring of production, national availability, diets and rural outcomes rather than a single stability narrative.

Supplementary Materials: The full reproducibility package supporting the findings of this study is available for download at https://sccpress.com/ars/libraryFiles/downloadPublic/10. The package includes a reproducibility folder containing the two supplied analytical CSV files, the documented CSO AQA04 production extract, a data dictionary, pinned requirements and Conda environment, executable analysis code, input hashes, runtime metadata, machine-readable audit results and all generated tables.

CRediT Author Statement: This is a single-author paper, and the author takes sole responsibility for all aspects of the work, including concept development, study design, data analysis, manuscript drafting, and revision.

Data Availability Statement: The original deposited data are available at https://doi.org/10.5281/zenodo.17614796. The FAOSTAT extraction metadata absent from the supplied files cannot be reconstructed retrospectively.

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independently reviewed the source data, verified the calculations and references, critically evaluated all generated content, and accepts full responsibility for the final manuscript. No generative model was used to create, impute or alter observations.

Abbreviations

The following abbreviations are used in this manuscript:

CAP	Common Agricultural Policy
CSO	Central Statistics Office
CV	Coefficient of variation
DAFM	Department of Agriculture, Food and the Marine
DDI	Diet Diversity Index
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO statistical database
GDD	Global Dietary Database
SD	standard deviation
TDI	Total Dietary Intake

Appendix A. Level Correlations

Level correlations are retained for transparency but excluded from the main interpretation because common trends and scale effects can create misleading associations.

Table A1. Pearson level correlations, 2010–2022.

Commodity series	TDI	DDI	Pulses	Vegetables
Cereals excluding beer	0.175	0.058	0.004	0.193
Bovine meat	−0.761	0.511	0.135	−0.749
Milk excluding butter	−0.877	0.768	0.369	−0.933

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