How environmentally harmful are agricultural policies?

Towards a model-based, cross-country and policy instrument typology of the climate impacts of agricultural support instruments

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Abstract

With public budgets constrained and pressure mounting to accelerate the sustainability transition of agrifood systems, repurposing agricultural support has become a priority in research and policy. Yet reforms often lack a consistent basis for prioritization: impacts differ in magnitude, mechanisms, and distribution across countries. This paper develops an operational, model-based typology of climate-harmful agricultural support that captures heterogeneity across country–instrument combinations and emissions pathways.

The typology is built from a systematic assessment of greenhouse gas (GHG) effects using the global computable general equilibrium model MIRAGRODEP, calibrated with the latest AgIncentives information and a reworked GTAP 12 database. We run harmonized counterfactual simulations removing each instrument, one at a time, for each country to isolate marginal impacts while retaining general-equilibrium feedbacks. Additional scenarios assess coordinated multi-country reform by instrument category.

To ensure comparability, model structure, baseline, horizon, and emissions scope are held constant across runs. Coverage spans product-specific and non-product-specific measures, input and output support, factor-based payments, and market access instruments. Emissions responses are decomposed by source (production versus land-use change) and location (domestic versus foreign), distinguishing scale and composition effects, land adjustments, and international leakage via trade and price transmission.

The resulting database supports a data-driven classification of environmentally harmful support using both expected impacts and their dispersion, drawing on decision-making under uncertainty. The typology translates model outputs into reform guidance by identifying instruments that are consistently damaging versus context-dependent, and by flagging where complementary measures are needed to prevent offsetting emissions shifts. Linking instrument design to emissions channels and cross-border spillovers informs prioritization, differentiation, and sequencing of repurposing strategies.

Keywords: Agricultural policy support; policy typology; public support repurposing; greenhouse gas emissions; land-use change; emissions leakage; computable general equilibrium

1 Introduction

In a context of limited public resources and the need for a sustainable agrifood system transformation, repurposing agricultural support has gained increasing attention in both academic and institutional work (FAO et al. 2021; Gautam et al. 2022; Glauber et Laborde 2023). An important issue is identifying which policy instruments should be repurposed first, based on how environmentally harmful they are (Cao et al. 2023; Ding et al. 2021; Ganda 2023; Himics et al. 2018; Jansson et al. 2021; Lankoski et al. 2025; Malins et al. 2020; Mamun et al. 2021; Sieber et al. 2013a; Springmann et Freund 2022; Valin et al. 2023), while also distinguishing how and where their impacts arise, and how these patterns vary across countries. Developing a typology of climate-harmful agricultural support that jointly reflects country-instrument combinations and the nature of their emissions impacts is therefore essential (Gocht et al. 2017; Guerrero et al. 2022; Henderson et Lankoski 2019; Laborde, Martin, et al. 2021; Ash 2022).

This paper proposes such a typology, derived from a systematic assessment of the GHG impacts of different types of agricultural support instruments. The analysis employs the global computable general equilibrium (CGE) model MIRAGRODEP (Bouët et al. 2022) and integrates the most recent AgIncentives data (AgIncentives Consortium 2025) with a recalibration of the GTAP 12 database (Aguiar et al. 2025) to capture latest policy developments. In this setting we quantify the removal of seach country–instrument combination. This systematic looping ensures that each instrument is evaluated separately, while capturing cross-country differences linked to agrifood system structures and country specificities. A final set of scenarios assess collective and coordinated reform for each instrument.

Holding the model structure, baseline data, time horizon, and emissions scope constant across scenarios allows for consistent comparisons across instruments and countries, avoiding the heterogeneity that typically limits inference in systematic literature reviews. The analysis covers all types of agricultural support reported in AgIncentives, including product-specific and non-product-specific measures, input- and output-based support, factor-based support, and market access measures, with market access proxied by the Nominal Rate of Protection.

The resulting database provides a detailed mapping of the greenhouse gas impacts of agricultural support across countries and policy instruments. It also decomposes emissions by source (land-use vs agricultural production components) and location (domestic vs foreign). This dual structure makes it possible to identify not only which instruments tend to be more environmentally harmful in terms of GHG emissions, but also the channels through which these impacts arise, and whether they originate within or outside national borders. It therefore distinguishes between cases where environmentally harmful support primarily drives land-use change, production intensification, or emissions leakage across borders.

Building on these results, a data-driven typology of environmentally harmful policies is developed, using both expected impacts and their variance, drawing on decision-making under uncertainty. These model-based results are compared to the existing literature, and meta-analysis conducted by various institutions (JRC, OECD) to inform existing attempts at classification. By clarifying both the magnitude and the nature of emissions associated with each country–instrument combination, the findings inform the classification, prioritization, differentiation and sequencing of repurposing options across national contexts and highlight where complementary measures may be required to ensure effective and durable agrifood system transformation.

2 Literature review

2.1 Heterogeneity of Agricultural Support and Conceptual Climate Pathways

Agricultural producer support is highly heterogeneous in both form and incidence across countries. Governments use a wide array of support measures – from trade protections and price guarantees, to input subsidies, payments and tax concessions – and the mix of support varies substantially by country and commodity (AgIncentives Consortium 2025)

This heterogeneity has important implications for the environment: because instruments vary in how directly they incentivize production, input use, and land expansion, they are expected to differ in GHG impacts. In other words, "agricultural support" is not a homogeneous object. Recent analyses stress the importance of disaggregating support by instrument type to identify which policies are most climate-distorting, rather than treating farm support as a single aggregate or comparing only broad policy packages (Ash 2022). This motivates an instrument-based approach to reform prioritization and sequencing.

Underpinning this approach is a conceptual framework for how support policies translate into GHG emissions. Several mechanisms or pathways have been identified:

- **Scale effect** (production volume): Subsidies that lower producers' costs or raise output prices encourage greater overall agricultural production than would occur otherwise. Ceteris paribus, higher production generates proportionally more GHG emissions from farm activities because a larger quantity of food is produced. This scale effect is a first-order way that many supports (especially those coupled to output or inputs) impact emissions.
- **Composition effect** (commodity mix): By changing relative incentives across products, policies also alter what is produced. Support measures often favor certain commodities (e.g. staple grains, dairy, beef) over others, thereby shifting the production mix. If a policy encourages a move towards more GHG-intensive products (for instance, from pulses to beef, or from rainfed crops to paddy rice), it can raise emissions even without an aggregate output increase. Conversely, reducing distortionary support could lead to a reallocation towards less emission-intensive crops or activities. Thus, the net GHG impact depends not only on total output changes but also on the substitution between higher- vs. lower-emitting products.
- **Technique effect** (emissions intensity): Policies influence how agricultural goods are produced, affecting GHG emissions per unit of output. Some subsidies promote practices that are more emissions-intensive – for example, inexpensive fertilizer and energy can encourage over-application of nitrogen or flood irrigation, increasing emissions per hectare or per ton (Ding et al. 2021). In contrast, support directed at innovation, efficiency, or climate-friendly practices can improve emissions intensity by accelerating the adoption of cleaner technology (Mamun et al. 2021). Over the long run, general income support might also indirectly affect technology (e.g. wealthier farmers may invest in modern equipment), though the direction of effect on emissions intensity can vary.
- **Location and land-use change**: Agricultural support determines where production takes place – both within a country (which lands are brought under cultivation or pasture) and across countries (via international trade effects). When a policy stimulates production, it may require additional land area, leading to the conversion of forests, peatlands, or other natural ecosystems into agricultural use. Such LUC results in potentially large one-time CO2 emissions from biomass and soil carbon losses. Certain policies are closely linked to deforestation and land expansion; for instance, price

supports or cheap credit that make it profitable to farm marginal land have contributed to forest clearance in some tropical regions (Malins et al. 2020). Conversely, a policy that boosts yields or intensifies production on existing farmland could spare land domestically (reducing pressure on forests), although it might also lower world prices and thus induce expansion abroad. Indeed, in an open global market, national policies create international spillovers: if one country's support increases its output, world prices decrease, potentially discouraging production (and deforestation) elsewhere; if a country removes support and its output falls, prices rise and incentivize production (and possibly land clearing) in other countries. This leakage effect means that unilateral subsidy reforms can have offsetting impacts outside national borders (Jansson et al. 2021).

In sum, the location channel has two aspects – domestic land-use change (extensification vs. intensification internally) and foreign leakage (shifting of production and emissions across countries) – both of which are critical for evaluating the true global impact of support policies. Any assessment of a support instrument's climate effect must consider not only emissions from on-farm production (scale, composition, technique) but also emissions from land-use change and how these are distributed between domestic and foreign domains. These conceptual pathways are well recognized in the literature, though individual studies often focus on one or another in isolation (e.g. analyses of trade liberalization emphasize leakage, while mitigation studies in land-use models emphasize the split between LUC and non-LUC emissions).

2.2 Evidence by Broad Instrument Category

A growing body of empirical and modeling work has examined how different types of support policies relate to GHG emissions. Despite differences in scope and methods, some patterns emerge. In general, policies that are strongly coupled to production – whether by output or input – tend to have greater adverse GHG effects, whereas policies that are decoupled or linked to environmental objectives have smaller (or even neutral/positive) impacts on emissions (Henderson et Lankoski 2019; Ash 2022). This section synthesizes findings instrument by instrument:

Market price support.

Measures that raise domestic market prices above world prices (such as import tariffs, import quotas, export subsidies, or administered minimum prices) encourage domestic producers to expand output of the protected commodities and thus boost domestic agricultural emissions (Laborde, Mamun, et al. 2021). For example, a high import tariff on dairy in a country will stimulate more domestic milk production (hence more methane from enteric fermentation) than under free trade. However, the net global effect of price support is ambiguous, because MPS simultaneously depresses domestic consumption (due to higher internal prices) and can thus reduce import demand or increase exportable surplus, affecting production abroad. In a net-importing country, a tariff-induced output rise at home may be largely offset by output declines (or slower growth) in exporter countries who now face a smaller market – meaning some emissions are essentially transferred rather than newly created.

Historical analysis further shows that the direction of price distortions has not been uniform: in the mid-20th century many developing countries taxed their farmers (negative support), which kept their production and emissions lower than otherwise; later reforms shifted to positive support, contributing to higher global output and emissions (Laborde, Mamun, et al. 2021; Mamun et al. 2021).

Modeling studies indicate that completely eliminating all MPS and trade distortions would yield only a modest reduction in global agricultural GHG emissions (often on the order of 1–3%) if undertaken unilaterally or piecemeal, because production shifts to more competitive regions rather than disappearing (Laborde, Mamun, et al. 2021; Himics et al. 2018). In other words, the leakage from isolated removal of price support can be significant.

Output-based (coupled) payments.

Direct output subsidies or other payments coupled to the current production of specific commodities are viewed as highly climate-unfriendly support instruments. By directly rewarding additional output, these policies unambiguously generate a scale effect in the supported commodity. Numerous studies confirm that coupled output payments for GHG-intensive products lead to higher production and emissions than would otherwise occur (Ash 2022; Henderson et Lankoski 2019)

A concrete example is provided by (Jansson et al. 2021), who examine the European Union's voluntary coupled payments for ruminant livestock: their modeling suggests that removing these payments would reduce EU agricultural non-CO_2 emissions by roughly 2–6%, depending on the member state and commodity, as cattle and sheep inventories decline without the subsidy. Notably, Jansson et al. also find that about 75% of the emissions abated in the EU are offset by emission increases in other countries – a clear case of leakage via higher world prices as EU output falls. Even so, the policy change yields a net reduction in global emissions.

Input subsidies.

Support policies that subsidize key inputs – notably fertilizer, fuel, electricity, and irrigation water – also have strong negative environmental impacts. By reducing the private cost of inputs, these subsidies may encourage over-utilization beyond what would be privately optimal, leading to increased emissions and other pollution per unit of land or output.

Fertilizer subsidies exemplify this: making nitrogen fertilizer artificially cheap often results in farmers applying more than the crop can absorb, with the surplus nitrogen emitting nitrous oxide (N_2O) and leaching into water systems. Empirical evidence from South Asia and other regions shows that large fertilizer subsidy programs have contributed to significant growth in N_2O emissions without commensurate yield gains (Ding et al. 2021). Similarly, subsidies for fossil fuel (e.g. diesel for farm machinery) or electricity (often used to pump groundwater) lower the cost of energy-intensive operations, encouraging practices like deep tillage or continuous pumping that increase CO_2 emissions and deplete resources. Cheap electricity for irrigation, for instance, has led to unsustainable groundwater extraction and indirectly higher energy-related emissions in some countries.

Area-based and factor payments (coupled vs. decoupled).

Many countries provide subsidies based on fixed factors of production – typically land area or livestock numbers – rather than output. The climate impact of these payments depends crucially on whether they are coupled or decoupled from production decisions.

Coupled area payments (e.g. a payment per hectare currently planted with a certain crop) and headage payments (e.g. a subsidy per livestock head owned) effectively act like output incentives because they reward maintaining more land in production of the target crop or more animals in the herd. These tend to inflate production and emissions, similarly to output subsidies. For example, a subsidy per dairy cow directly encourages farmers to keep larger herds than market conditions alone would merit, increasing methane emissions. In contrast, decoupled area payments – those given per hectare of land regardless of current output (often based on historical entitlements or simple landholding) – are intended not to influence production decisions at the margin.

Evidence from major policy reforms supports the notion that decoupling greatly diminishes the production stimulus of subsidies. A notable instance is the European Union's 2003 Common Agricultural Policy reform, which converted most cereal, oilseed, and livestock payments into decoupled Single Farm Payments. Studies observed that after decoupling, output levels in these sectors were only marginally affected, indicating that farmers treated the payments largely as income support rather than a reason to expand production (Gocht et al. 2017; Sieber et al. 2013b).

However, decoupled payments can have subtler effects: for example, by providing a revenue cushion, they might slow the exit of marginal producers or delay land-use change (keeping some less-productive land in agriculture that might otherwise be abandoned or converted to other uses). Such effects are generally small and context-dependent. The literature consistently finds that decoupled support ranks as one of the least harmful forms of support for the climate (Henderson et Lankoski 2019; Mamun et al. 2021).

Environmentally targeted (green) support.

An increasing share of agricultural support is now explicitly aimed at environmental outcomes or conditioned on meeting certain environmental criteria – often referred to as agri-environmental payments, "green" subsidies, or conditional support. Examples include payments for adopting specific conservation practices (cover cropping, organic farming, integrated pest management), subsidies for emissions-reducing investments (such as biogas digesters or solar irrigation pumps), and programs paying farmers for ecosystem services like carbon sequestration, habitat provision, or watershed protection. In principle, these types of support should reduce net emissions or other environmental harms relative to traditional subsidies, since they incentivize positive actions or at least require compliance with environmentally friendly practices.

The literature evaluating such programs finds that the outcomes are highly dependent on design. When environmental payments are well-targeted and adequately funded, they can yield meaningful GHG reductions. For instance, incentives for wetland restoration or agroforestry can sequester carbon, and subsidies for improved rice cultivation techniques can cut methane emissions (Ding et al. 2021). Increased agricultural R&D spending – often counted as a "green" support – can also indirectly lower future emissions by boosting productivity (thus potentially sparing land) and by generating mitigation technologies (Valin et al. 2023). However, if the conditions attached to payments are weak or too easy to satisfy, the environmental impact may be negligible. Empirical and modeling studies around the 2003 EU Common Agricultural Policy reform (which shifted from coupled to decoupled payments) found that the removal of crop and livestock coupling dramatically reduced the incentive to over-produce; farmers largely treated the decoupled aid as income support, with only a small residual effect on output (Gocht et al. 2017).

It should be noted that the climate impact of any given instrument can vary with context and policy design. The magnitudes of emissions responses depend on factors like the commodity mix of a country's agriculture, the biophysical characteristics (emission intensity, land availability) of that system, and whether complementary policies (such as environmental regulations or caps on land expansion) are in place. Analyses emphasize that instrument effects are not one-size-fits-all but mediated by local conditions and policy specifics (Lankoski et al. 2025; Henderson et Lankoski 2019; Guerrero et al. 2022).

2.3 Methodological Approaches in the Literature

Researchers have employed a range of methodological approaches to study the link between support policies and emissions.

Empirical (reduced-form) studies.

These studies use observed data (cross-country panels, time series, or case studies) to estimate the relationship between agricultural support and emissions, without imposing a detailed structural model. For example, (Ganda 2023) analyzes panel data for OECD countries to test how changes in overall producer support levels correlate with changes in agricultural CO_2-equivalent emissions. Such empirical analyses have the advantage of reflecting real-world outcomes, integrating all behavioral responses and market feedbacks implicitly. Ganda's findings illustrate both the promise and the challenge of this approach: in the short run, higher support is associated with higher agricultural emissions (consistent with scale expansion), but over longer periods the relationship appears to weaken or even reverse sign, suggesting that other factors (technological change, structural adjustments possibly facilitated by past subsidies) offset the initial emissions increases. Empirical studies can thus reveal dynamic or complex effects that models might miss.

However, identification is a major hurdle – support policy changes are not randomly assigned, and countries with certain policies may systematically differ in other ways (e.g. richer countries both subsidize more and adopt greener technology, confounding simple correlations). Endogeneity and omitted variables make it difficult to draw causal conclusions. Furthermore, data limitations mean that empirical studies often rely on aggregate support measures and aggregate emissions, rather than isolating individual instruments or specific emission sources. This limits the granularity of insights. Moreover, empirical analyses usually cannot cleanly decompose the emissions effect by channel (they observe net outcomes) and rarely capture international leakage unless the data explicitly cover multiple regions and policies jointly.

Partial-equilibrium (PE) and sectoral models.

These are simulation models that represent the agricultural sector (or a subset of it) in detail, often including commodity markets, farm decision-making, and land-use allocation, while keeping the rest of the economy exogenous. Examples include the CAPRI model for Europe (Gocht et al. 2017), which has high spatial and farm-type resolution, or global agricultural land-use models like GLOBIOM. PE models are well-suited to capture sector-specific dynamics: they can incorporate rich agronomic detail (yield response to inputs, crop rotations, pasture vs cropland competition) and often link to biophysical environmental modules. This allows them to estimate environmental indicators (emissions, land-use change, nutrient runoff) with more realism at the micro level. For instance, a PE model can simulate how removing a coupled livestock payment in the EU would affect herd sizes region by region, how that in turn reduces manure methane and frees up pasture land, and possibly how much of that land is afforested or taken up by other crops. Such models have shown, for example, that fairly modest policy changes (like the EU's 2015 greening requirements) have only minor impacts on land use and emissions, whereas more drastic changes (like eliminating all coupled payments) have larger regional effects (Himics et al. 2018; Jansson et al. 2021).

The strength of PE models lies in their ability to attribute outcomes to specific policy levers within the modeled region and to provide a detailed decomposition of results. They can distinguish production vs. land-use emissions within the region, thus addressing the source decomposition. However, a fundamental limitation is their treatment of market feedbacks and trade. Many PE models either assume fixed world prices or use a simplified representation of trade, meaning they do not fully capture how a policy change in one region affects production and emissions in other regions. In scenario analyses, this is sometimes handled by imposing price changes or coupling to a global model, but leakage effects may be only partially accounted for. Additionally, PE models typically do not consider economy-wide resource reallocation (labor, capital) or consumer income effects, so they may overestimate production responses in the long run (Himics et al. 2018; Guerrero et al. 2022).

Computable general equilibrium (CGE) models:

CGE models are able to capture economy-wide and international interactions of policy changes, including shifts in trade patterns, cross-sector factor movement, and impacts on consumption and prices. For the question of subsidy reforms, global CGE models can endogenously determine the extent of emissions leakage: if one region's output falls, the model will show how much output (and emissions) rise in other regions as a result of higher world prices. They also capture how resources freed from agriculture might be employed elsewhere, and how changes in income and prices affect food demand (which can either dampen or amplify emissions changes).

Over the past few years, CGE analyses have been central to quantifying the potential climate implications of repurposing agricultural support. A consistent finding is that uncoordinated removal of support tends to yield relatively small net reductions in global emissions, because production shifts to regions where support remains or where comparative advantage leads to expansion (Laborde, Mamun, et al. 2021; Valin et al. 2023). For instance, Laborde et al. (2021) simulate removing all current agricultural subsidies and trade protections worldwide and find only about a 1–2% decrease in global agricultural non-CO_2 emissions in the near term – essentially, cuts in subsidizing countries are largely offset by increases elsewhere and by increased food demand due to lower prices in previously protected markets.

The trade-off, however, is that CGEs often use aggregated representations of the agricultural sector to keep the model tractable. They may not distinguish fine-grained policy instruments unless explicitly incorporated, and environmental processes like deforestation are typically modeled in a stylized way. This can introduce uncertainty or understate certain impacts. Additionally, CGE results can be sensitive to parameter choices (e.g. elasticities of substitution, which govern how easily consumers or producers respond to price changes) and the baseline projections (especially for long-term scenarios). Thus, while CGE models are powerful for broad comparisons and for ensuring internal consistency, their precision in estimating absolute emission changes for specific instruments is limited by their level of aggregation and modeling assumptions. They are best used for insight into direction and relative magnitude, and for exploring interactions (such as leakage or terms-of-trade effects) that other approaches cannot capture as well.

Reviews and meta-analyses:

Recognizing the scattered nature of the evidence, some works have attempted to synthesize results across studies. (Henderson et Lankoski 2019) combined modelling with an extensive literature review to qualitatively rank support measures by environmental harm. (Ash 2022) reviews the literature on trade- and production-distorting subsidies and highlights those consistently linked to higher GHG emissions, calling for a more standardized evaluation across studies. A meta-analysis by (Lankoski et al. 2025) is compiling empirical and modeled estimates of the impacts of various support policy reforms on outcomes like production, land use, and emissions.

These reviews, while extremely useful in mapping out the landscape, encounter the comparability problem: the individual studies they draw upon differ in methods, scenarios, and metrics, making it challenging to aggregate or directly compare quantitative estimates. Meta-analysts must therefore standardize results or restrict comparisons to similar studies, and often resort to qualitative judgments. Nonetheless, the exercise of literature synthesis has helped solidify some consensus points (as noted above) and identify where evidence is thin or inconsistent.

2.4 Limits of Existing Evidence and Remaining Gaps

Taken together, the existing literature clearly indicates that different support instruments have different environmental impacts, and it provides numerous pieces of partial evidence on these impacts from farm-level, sectoral, and global perspectives. However, translating this body of knowledge into operational guidance – for example, a concrete prioritization of which subsidies to reform first in a given country – remains difficult. Two main limitations have been identified:

- **Heterogeneity of frameworks and assumptions**: Studies analyzing similar questions often use different modeling frameworks (empirical vs. PE vs. CGE), include different subsets of emissions (some account for land-use change CO_2, others only farm-level CH_4/N_2O), and make varying assumptions about key economic responses (land mobility, trade elasticities, baseline demand growth, etc.). Even within CGE models, differences in parameters (e.g., how easily land can be converted to agriculture, or how international markets transmit shocks) can lead to different leakage rates and emission outcomes. They also draw on different data sources for representing subsidies. For instance, one global model might use subsidy rates implicit in a social accounting matrix (with no detailed breakdown by instrument), while another incorporates line-item OECD Producer Support Estimate or AgIncentives data for specific policies (Valin et al. 2023; Glauber et Laborde 2023). These differences can lead to non-trivial inconsistencies in results. A policy scenario may produce a certain percentage change in emissions in one model and a different result in another, not necessarily because the policy effects truly conflict, but because of how the scenario was implemented or what baseline was assumed. As a consequence, it is challenging to compare quantitative estimates across studies or to aggregate them.
- **Bundling of policies and incomplete attribution**: Many analyses evaluate composite policy packages rather than isolating individual support measures. These provide valuable big-picture insights but make it hard to discern the contribution of any one instrument or sub-instrument within the bundle. Very few studies attempt a systematic decomposition (one example is the decomposition of EU mitigation from different CAP measures in (Henderson et Lankoski 2019)). Moreover, results are often reported at an aggregate level (national or global emissions change), without a breakdown by channel (production vs. land-use) or by location (domestic vs. leakage), especially in multi-country models. This aggregated reporting means that even if the underlying model tracked those details, the findings available in the literature do not always specify them. Consequently, the current evidence, while rich, is fragmented in a way that hampers the formulation of clear, data-driven reform priorities.

In summary, existing research has established that the climate impacts of agricultural support are notable and instrument-specific. However, because of divergent methods and the bundling of policies in analyses, the evidence is difficult to synthesize into actionable guidance on which exact policy to change, by how much, and with what expected outcome in a given context. The literature recognizes the importance of evaluating emissions by source (on-farm vs land-use change) and by location (domestic vs international leakage), but so far these dimensions have typically been addressed separately (for example, leakage in trade studies, and land-use vs production in AFOLU mitigation studies) rather than in a unified assessment for each policy instrument.

3 Analytical modelling framework

3.1 Introduction

The MIRAGRODEP model is a multi-region, multisector computable general equilibrium model (CGE model). It builds on MIRAGE, a multisector CGE model of the global economy (Decreux et Valin 2007) and is specifically designed for the analysis of agricultural sectors, food systems, and distributional impacts. MIRAGRODEP can be linked to complementary modules to assess impacts on poverty, food security, nutrition, land use, and greenhouse gas emissions, making it particularly suitable for the assessment of agrifood system reforms.

The MIRAGRODEP model is based on an input–output framework and its theoretical structure is derived from optimizing behavior of economic agents, particularly households and firms. The model assumes perfect competition in all sectors, enabling detailed geographic and sector decompositions. A detailed and complete documentation of the model is provided in (Bouët et al. 2022)

The primary data source for MIRAGRODEP is the GTAP12 database (fully documented in (Aguiar et al. 2025), a database comprising world macroeconomic accounts and trade flows for the reference year 2023). Specifically, it describes the values of production, intermediate and final consumption of commodities and services for 145 countries or regions and 65 sectors. The database also provides information on global bilateral trade patterns, international transport margins, and protection matrices allowing for an accurate representation of linkages between individual countries and regions.

Regarding the supply side, the production function is modeled for each sector as a Leontief function of intermediate inputs and value-added. The intermediate input bundle is represented by a constant elasticity of substitution (CES) function across commodities, allowing for substitution among intermediate inputs in response to relative price changes. The level of substitutability is assumed to be constant for any pair of intermediate goods. Similarly, value added is a CES function of unskilled labor, land, natural resources, and a bundle of skilled labor and capital. This nesting structure enables the model to capture the lower substitutability between capital and skilled labor compared to other factors.

In each region the demand side is modeled with a representative agent who is assumed to own all factors of production, have a constant propensity to save and seek to maximize utility by purchasing goods. The agent's utility function is a linear expenditure system-constant elasticity of substitution (LES-CES) function to capture his preferences between goods and determine the allocation of expenditure across those goods. The LES-CES function allows for different income elasticities of demand across goods. It can therefore capture changes in consumption patterns as income levels evolve across regions. This is particularly relevant for modeling agricultural and non-agriculture sectors since income elasticities for food tend to be lower than those for manufactured goods and services. Additionally, the elasticity of substitution among sectoral consumptions is constant only above a minimum level, which can vary by region, such as developing versus developed countries.

The model captures international economic linkages through international trade in goods and services, and capital flows, thereby providing a comprehensive and consistent representation of economic and trade relations between countries. MIRAGRODEP is a bilateral trade model that is consistent with the Armington assumption, which posits that commodities are heterogeneous based on their origin and thus, imperfect substitutes for each other. The model uses nested CES functions to reflect preferences for varieties originating from different countries. This approach allows for countries to import and export the same product simultaneously, reflecting consumers' preferences for specific varieties.

MIRAGRODEP also explicitly models the government as a separate agent from private households and firms. The government's income comprises taxes on production, factors of production, exports, imports, consumption, and households' income. The model assumes that the government aims to maximize a Cobb-Douglas utility function, where its expenditure on each commodity is a fixed share, in value, of the total public expenditure on goods and services.

The recursive dynamic version of the model was used for this analysis. The model incorporates a capital accumulation framework, where the capital for year t+1 is based on the capital of year t, increased by the previous year's investment and adjusted for depreciation. The model is then solved sequentially, moving the equilibrium from one year to another.

3.2 Four main assumptions

The model rests on four major assumptions: the factor market closure, the private account closure, the external account closure and the government account closure.

With respect to the factor market closure, total employment is assumed to remain constant as a proportion of the active population, which is defined as individuals aged between 15 and 60 years old. Labor markets are differentiated by gender, accounting for an imperfect substitution between male and female labor within each skill category. Skilled labor is perfectly mobile, while unskilled labor has imperfect mobility between agricultural and non-agricultural sectors, as determined by a constant elasticity of transformation (CET) function. Natural resources are the only factor with a fixed supply over time. Land supply, on the contrary, is endogenous and depends on the real remuneration of land. Additionally, it is assumed that land has imperfect mobility between agricultural sectors. Finally, installed capital and natural resources are modeled as sector specific.

Regarding the private account closure, the model makes the neo-classical assumption that the marginal propensity to save remains constant. Consequently, variations in income result in variations in savings, which, in turn, bring variations in investment. Investments are therefore savings-driven.

For the external account closure, it is assumed that the current account balance remains stable as a proportion of global GDP. Hence, the real exchange rate adjusts through different changes in domestic prices across various regions, referred to as competitive disinflation.

Finally, with respect to the public account closure, it is assumed that the government budget remains a fixed share of the national GDP, and that the real public expenses per capita are held constant to ensure a constant provision of public goods. There are therefore no changes in the size of the public sector and no crowding-out effect on private investment. To keep the government budget and the real public expenses per capita at a constant level, a consumption tax is adjusted. The magnitude of this tax thus measures the cost of maintaining a steady supply of public goods.

3.3 Poverty and environmental aspects

Beyond its core general equilibrium structure, MIRAGRODEP can be linked to complementary modules to analyze poverty, land-use change, and greenhouse gas emissions.

The poverty analyses were carried out using the POVANA household model, as documented in (Laborde, Martin, et al. 2021). The POVANA model is based on the POVANA dataset which provides the full income distribution for approximately 300,000 households. The model captures the endogenous evolution of households' real income in response to changes in multiple factors, such as employment, prices of goods and services, wages, and productivity. Additionally, the comprehensive information on household consumption patterns within the POVANA dataset enables the estimation of the effects of economic shocks on household costs, including the costs of food.

Regarding land use, the models builds on the AEZ approach of (Hertel et al. 2009) and evaluates land use change across agroecological zones defined for each region in the model. Within each agroecological zone, the model reallocates land between forest areas and various types of agricultural land in response to changes in returns. Specifically, a constant elasticity of transformation (CET) specification is used to represent the competition for land between forestry and agricultural uses. Land is then redistributed between agricultural activities based on changes in relative prices.

Finally, the model includes a post-solution module to compute the impact on greenhouses gas (GHG) emissions. This module is based on a GHG database that maps GHG emissions to crop and livestock production, by region. The database was developed by (Laborde Debucquet et al. 2021), and subsequently updated with research by (Tubiello et al. 2021). Additionally, the database is used to calculate GHG emissions resulting from land use change, such as the conversion of forestland to grazing or cropland.

4 Data

The main source of data for the model is GTAP 12 Data Base, developed within the Global Trade Analysis Project (GTAP) coordinated by the Center for Global Trade Analysis at Purdue University. It constitutes a fully documented, publicly available global economic database designed for applied general equilibrium analysis. It provides a consistent representation of the world economy for multiple reference years, integrating detailed information on production, consumption, and bilateral trade flows across countries and regions. GTAP 12 distinguishes 145 individual countries and aggregated regions and covers 65 goods and services sectors, offering broad sectoral and geographical coverage suitable for global and regional economic analysis. The model is calibrated on the year 2023.

The main modification of the database is the introduction of the Agricultural Incentives Database to represent agricultural polciies. It is a structured analytical repository designed to document, classify, and compare policy-induced incentives affecting agrifood systems across countries and over time. The database draws on a harmonized compilation of the datasets brought together by the FAO (MAFAP dataset), OECD and IDB, with the complementary efforts of the World Bank. These inputs are standardized to ensure internal consistency and cross-country comparability.

The database is organized around a clear conceptual framework that distinguishes incentives by policy instrument (e.g. market price support, input subsidies, budgetary transfers, tax and regulatory measures), by point of intervention along the value chain, and by affected commodities or production systems. Each entry is coded to capture both the nature of the policy measure and its intended economic channel, allowing for disaggregated analysis of how incentives influence production decisions, input use, market integration, and resource allocation.

A key structural feature of the database is the separation between nominal policy measures and their analytical classification. Raw policy data are preserved at the highest possible level of detail, while derived indicators are constructed using transparent methodological assumptions. This dual structure allows users to replicate results, adjust assumptions, or develop alternative aggregation schemes depending on the analytical purpose. The design also enables linkage with complementary datasets on trade, prices, environmental indicators, and food security outcomes.

By providing a consistent and traceable mapping of agricultural incentives, the database serves as a foundational input for empirical analysis of policy coherence, market distortions, and distributional effects within agrifood systems. Its structure is intentionally flexible, supporting both descriptive monitoring and integration into quantitative modeling frameworks used to assess policy impacts under conditions of economic volatility, external shocks, or structural transformation.

All the subsidies and tax rates of the GTAP database are replaced by the AgIncentives instruments, and the individual national Social Accounting Matrices are recalibrated accordingly. The value of production of each agricultural sector is kept constant during the process.

5 Scenario

Forthcoming.

6 Results

Forthcoming.

7 Conclusion

Forthcoming.

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