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Gender dimensions in agricultural and livestock interventions: A review of economic modelling approaches

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ABSTRACT

This study identifies innovations and gaps in quantifying gender dynamics in agricultural and livestock sectors using Computable General Equilibrium (CGE), Partial Equilibrium (PE), or micro-simulation (MS) models. These modelling approaches are widely applied to assess policy and market interventions in low- and -middle-income countries (LMICs). A semi-systematic review protocol was developed to retrieve, select, and analyse relevant literature from ScienceDirect, JSTOR, and Google Scholar. Inclusion criteria required that studies: (1) were published within a defined 40-year period, (2) applied at least one of the specified economic modelling methods, and (3) included at least one indicator related to sustainable development. From an initial pool of 17,000 articles identified through title screening; 49 were selected for abstract review, and 22 for full-text analysis. Of these, 16 CGE-based studies captured gender-specific impacts, such as women's employment and income outcomes. Two MS-based studies tracked specific measures of women's empowerment, while the only PE-based study linked agricultural system characteristics—such as seasonality and distribution networks - to gender-related indicators of food security and nutrition. Additionally, three studies using hybrid modelling approaches demonstrated the value of methodological integration. Such models offer enhanced capabilities to reflect the diversity of gender roles and impacts in policy analysis. The findings highlight the potential of integrated modelling approaches, not only for methodological innovation in gender-disaggregated impact analysis, but for informing evidence-based policies that prioritize gender equity. They offer actionable insights to better inform and prioritize interventions that promote women's empowerment and equity in agricultural and livestock development in LMICs.

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1. Introduction

Livestock are vital assets for improving rural and peri-urban livelihoods in low- and middle-income countries (LMICs). The rearing of livestock and processing of livestock products generate income, create employment opportunities and contribute to food and nutrition security for millions of households across various production systems and value chains (Baltenweck et al., 2020; Herrero et al., 2013). Given its economic significance in rural settings, the livestock sector is regarded as a strategic focus for agricultural development in LMICs, with important implications for sustainable development (Herrero et al., 2013; Kozicka et al., 2022; Mehrabi et al., 2020). It also offers considerable potential to support poverty reduction efforts, making it a key candidate for targeted investment in sustainable development initiatives (World Bank, 2021). However, the livestock sector presents challenges and opportunities that are gender-specific, with direct consequences for farmer empowerment, household food security, and the resilience of rural livelihoods (Njuki & Sanginga, 2013). Emerging evidence suggests that investing in livestock can enhance women's empowerment and serves as a critical pathway for promoting gender equity in agricultural and food systems (Njuki et al., 2013; Staal et al., 2020).

Development strategies in the agricultural sectors of LMICs frequently include livestock-related interventions aimed at improving livelihoods. These interventions range from animal disease control and feed availability efforts to the provision of livestock to households during emergencies for productivity gains

Key policy highlights

- Advancing gender equity in agriculture and livestock sectors of low- and middle-income countries (LMICs) necessitates the use of appropriate economic modelling frameworks to inform policymaking.
- General equilibrium models are critical for analysing gender-differentiated labour market effects and broader macro-economic dynamics.
- Partial equilibrium models are more suitable for capturing seasonal variations and other structural features specific to livestock systems.
- Microsimulation models are essential for evaluating policies that address intra-household heterogeneity in women's access to resources.
- Strategic public investment is required to build and diversify economic modelling capacity in LMICs, enabling integrated analyses of the multiple dimensions of gender equity in agriculture and livestock.

(FAO, 2016). However, initiatives intended to improve women's access to livestock and protect their rights have often failed to deliver expected benefits (Njuki & Sanginga, 2013). Women, though central to agriculture and rural economies, face greater constraints than men in accessing productive resources, markets, and services (Njuki et al., 2022). Despite decades of development efforts, poverty disproportionately affects women, who also shoulder the greatest burden of unpaid labour at home and on farms (IFAD, 2016; Omore et al., 2009). Women and girls represent around 60 percent of the chronically hungry (WFP, 2015), and while they play key roles in livestock production, they remain overrepresented among poor livestock keepers (FAO, 2011; Staal et al., 2020).

Gender disparities are particularly evident along livestock value chains. Men tend to dominate high-return roles such as animal health services and marketing, while women are concentrated in lower-value segments (Coles & Mitchell, 2011). In milk value chains, for example, men more often occupy aggregation and technical roles, leaving women with limited opportunities for economic advancement (Baltenweck et al., 2016). Intensification and commercialisation of livestock systems frequently worsen these inequalities, reducing women's control over income and household consumption decisions (Tavener et al., 2019). Women's access to services, inputs, and training remains limited, further hindering their full participation in the sector (Bonis-Profumo et al., 2022; Kyotos et al., 2022; Mensah & Fosu-Mensah, 2020; Njuki & Sanginga, 2013). Addressing these barriers is crucial for boosting productivity and improving livelihoods, especially among smallholder women livestock farmers.

Government policies and investment strategies play a vital role in shaping livestock sector outcomes in LMICs. To address gender-specific constraints effectively, interventions must be better targeted across key areas such as animal breeding, health, marketing, and decision-making (a core component and indicator of instrumental agency). As the livestock sector undergoes rapid changes, its implications are both complex and gender differentiated. This calls for the development and application of quantitative scenario planning and foresight tools that assess gendered impacts across different scales - from local to national. Such tools would empower policy analysts to help design inclusive strategies that address the specific needs of both men and women within the livestock sector.

Despite clear gendered dynamics in agriculture and livestock systems, many interventions remain gender-blind (Mawia et al., 2025). These programmes often fail to acknowledge women's contributions and overlook the targeted support needed to ensure they benefit from sector advancements (Njuki & Sanginga, 2013; Njuki et al., 2022). Women continue to face barriers in asset ownership, access to inputs and services, and participation in decision-making (Enahoro et al., 2021; FAO, 2011; Galab & Rao, 2003; Njuki & Mburu, 2013; Sinn et al., 1999). Moreover, gender-blind programmes can unintentionally undermine women's existing control over resources (Baltenweck et al., 2024). To counter this, gender-sensitive planning must integrate disaggregated indicators and variables that reflect power dynamics, cultural norms, and economic roles. However, most economic modelling frameworks in agriculture and livestock have insufficiently incorporated gender-disaggregated impacts, limiting their ability to capture the differentiated roles, vulnerabilities, and contributions of women.

This study reviews how economic models have been used to assess gendered impacts of technological, institutional, and policy interventions in agriculture and livestock. It synthesises findings from modelling studies that distinguish outcomes for men and women in areas such as labour, income, productivity, and well-being. These insights, drawn from both sector-specific and broader macroeconomic analysis, inform

better integration of gender into foresight modelling. By highlighting promising approaches, this paper aims to support the design of gender-equitable interventions, contributing to more inclusive and sustainable livestock systems in LMICs, and a resilient global food system. By highlighting disparities in employment, income, empowerment, and food security, the study demonstrates how methodological integration can generate evidence that informs agricultural policies aligned with broader social and community development goals, ensuring that gender equity is treated as a central driver of sustainable progress in LMICs.

1.1. A review of relevant literature

While this study is a literature review, it is still important to highlight key studies that shape its analytical approach. In their review of the relationship between trade policies and poverty, Winters et al. (2004) included literature on CGE modelling. They emphasised the advantage of CGE models in overcoming limitations of econometric approaches, particularly in assessing the effects of commodity price shocks on poor households. CGE models were found to be especially useful for examining the impacts of policies on different household types and for capturing behavioural responses - capabilities that are particularly relevant to gender-sensitive analysis in agriculture and livestock (Baltenweck et al., 2024; Njuki et al., 2013).

Fontana et al. (2020) reviewed the applied CGE modelling literature with the specific aim of identifying model features suitable for analysing distributional impacts related to care work, including its provision and financing. Their study, which offers valuable insights for designing gender-equalising policies, focused on three main areas: (1) a review of the strengths and weaknesses of a sub-class of CGE models known as computable gender general equilibrium models; (2) an assessment of general CGE models—those not specifically developed for gender analysis; and (3) a review of modelling approaches for capturing gender dimensions in long-term processes such as human capital investment. Finding that existing approaches were limited in scope, Fontana et al. (2020) proposed several improvements, including paying special attention to how production activities and labour factors are represented in Social Accounting Matrices (SAMs), and developing more nuanced representations of the interactions between the non-market care sector and market sectors. These recommendations are also likely to be relevant for applying CGE models to the analysis of gender equity in the livestock sector.

Using a systematic review approach, Wei and Aaheim (2023) analysed the application of CGE models to climate change impacts and adaptation. While agriculture featured prominently - accounting for 59 of the 97 articles reviewed - only one addressed the livestock sector, potentially underestimating its role in climate adaptation in low- and middle-income countries (Bonilla-Cedrez et al., 2023; Thornton & Herrero, 2015). The review also gave little attention to gender-related dimensions of adaptation. Nonetheless, it emphasised the value of CGE models in linking micro- and macro- level climate indicators and concluded that CGE models are increasingly important for climate adaptation studies due to their interdisciplinary capacity and ability to track sectoral interactions. These features are highly relevant to gender equity in food systems, including livestock (Njuki et al., 2022), and thus support the use of CGE models in designing gender-equitable policies.

Ahmed and O'Donoghue (2007) argued that global economic shifts since the 1990s have increased demand for tools that integrate macroeconomic trends with household-level impacts. Their review examined efforts to link CGE and microsimulation (MS) models in studying income distribution and gender equity. CGE models, which rely on SAMs, have low data requirements and capture economy-wide interactions. MS models, on the other hand, can simulate individual or household behaviour. The study found that despite technical challenges, linking the two models is promising for analysing poverty and inequality. The authors highlighted data quality, model stability and advances in computing as key factors influencing future uptake of integrated CGE-MS approaches.

Wiebe et al. (2023) evaluated macroeconomic modelling tools for analysing wellbeing, inclusion, and sustainability and economy (WISE) dimensions in the face of climate and inequality challenges. They reviewed five model types - general equilibrium, macro-econometric, stock-flow consistent, integrated assessment, and system dynamics models—and proposed an integrated framework combining their

strengths. The potential of CGE and MS models to disaggregate impacts by gender was specifically noted. While the study did not focus on livestock, integrating gender-equity concerns in livestock with environmental interactions will be important (Herrero et al., 2013).

Dagoumas and Koltsaklis (2019) reviewed the models employed to integrate renewable energy sources in generation expansion planning, focussing on the advantages and disadvantages of the different methodological approaches. This approach aligns with the rationale of the present review, which seeks to examine how various modelling frameworks incorporate gender into livestock sector analysis. The Dagoumas and Koltsaklis (2019) study highlighted the strengths and limitations of PE models—particularly their detailed sectoral focus but lack of inter-sectoral feedback. Linking PE to macro models was proposed to address this shortcoming. This application to the energy sector, and prior reviews of PE model applications in forestry (Latta et al., 2013) and biofuels (Witzke et al., 2008) provide important lessons to our review of how livestock models have addressed gender integration.

1.2. Current trends, gaps and methodological challenges

The strengths and evolving applications of CGE, PE, and MS models emerge across the reviewed literature, demonstrating the growing relevance of these model types for policy analysis but also highlighting potential areas of underutilisation. Applications of CGE models often do not capture the gendered dynamics of unpaid care and livestock systems, limiting their relevance in accounting for women's labour and nutrition pathways (Fontana et al., 2020; Wei & Aaheim, 2023). Secondly, many models treat households as unitary agents, obscuring intra-household bargaining, control over income, and decision-making that drive gendered outcomes (Fontana et al., 2020; Njuki et al., 2013). Further, gendered impacts are often captured only through employment and income, with insufficient proxies for agency, asset control, time autonomy, and nutrition security (Baltenweck et al., 2024; Fontana et al., 2020). Hybrid models such as combinations of CGE with microsimulation (MS) have previously been applied to obtain gender-disaggregated insights of macro shocks but such model combinations are not widely applied.

Similarly, although studies have linked climate change to food system impacts, both livestock and gender adaptation are typically underrepresented, particularly in the contexts of LMICs, limiting the effectiveness of policies that may emerge from such studies and from their underlying models (Bonilla-Cedrez et al., 2023; Thornton & Herrero, 2015; Wei & Aaheim, 2023).

Methodological challenges in applying CGE, PE, or MS models to gender-sensitive agricultural and livestock analysis lie in their limited abilities to capture the complexity of gendered dynamics across households, markets, and communities (Table 1). Despite their individual strengths in economywide CGE, sector-specific (PE) or micro-level (MS) modelling and policy scenario testing, several interconnected issues persist:

- constructing input data sets (such as SAMS for CGE models) that adequately represent male and female labour, unpaid care sectors, and asset ownership is technically demanding and often constrained by incomplete data.

Table 1. Comparative summary of CGE, PE and MS modelling approaches to quantifying gender.

Approach	Core assumptions	Typical gender indicators	Strengths for gender analysis	Limitations for gender analysis
CGE	Economywide equilibrium; market clearing; representative agents; calibrated to SAM	Employment by sex; wages/income by sex; sectoral participation; time use (if care provision is modelled)	Captures indirect effects, cross-sector linkages, policy shocks; can disaggregate labour/households	Often unitary households; limited care sector; data-heavy; empowerment hard to encode
MS	Micro-level heterogeneity; behavioural rules at household/individual level	Control over income; asset ownership; decision-making; time-use; nutrition outcomes	Rich distributional detail; intra-household analysis possible; flexible proxies for gender empowerment	Weak macro feedbacks; requires detailed microdata; scenario scaling is complex
PE	Focused market or sector equilibrium; partial feedbacks	Sectoral employment by sex; price/pass-through effects on food security; seasonal labour	Targeted sector-policy analysis; simpler data needs; supply chain linkages	Misses economywide interactions; has limited differentiation between households

Source: Authors, based on multiple sources, including Fontana et al. (2020); Wei and Aaheim (2023).

- estimating gendered elasticities of production functions (e.g. for PE models), labour supply and time allocation requires extensive data collection and/or the use of mixed methods approaches and careful calibration.
- static models struggle to capture seasonal labour shifts and long-term impacts like human capital development, which are critical for gender analysis in agriculture.

2. Methodology

2.1. Key approaches to quantifying gender in economic models

Three main approaches are commonly used in the literature to simulate, ex-ante, the impacts of policies and interventions affecting agriculture, industry, and labour markets (Davis, 2004). These are: Computable General Equilibrium (CGE) models, which can analyse complex linkages across markets and sectors affected by macroeconomic shocks (Fontana & Van Der Meulen Rodgers, 2005); Partial Equilibrium (PE) models, which are valuable for microeconomic analysis of specific industries or commodities (Zhang, 2016); and microsimulation (MS) approaches, which replicate policy impacts at the individual or household level within theoretical models (Dixon et al., 1996; Polette & Robinson, 1997). Brief descriptions of the analytical approaches and typical applications of these models are provided below. A more detailed discussion, including the theoretical frameworks underlying the models, can be found in Appendix 1.

General equilibrium approaches—encompassing SAMs, Input-Output frameworks, and CGE models—are widely used to allocate resources and prioritise investment projects or programmes. Kavese (2015) highlighted their utility in assessing macroeconomic benefits, social and environmental impacts, and financial returns from agricultural or livestock-related investments. While SAMs are effective for measuring the economy-wide effects of government policies, they assume full employment and fixed prices for capital and labour—limitations that CGE models can address. Unlike SAMs, CGE models allow simulation of changes in factor markets, enabling a more comprehensive analysis of economic impacts (Lofgren et al., 2001).

CGE models enhance understanding of how macroeconomic policies affect poverty by simultaneously analysing multiple sectors and their interlinkages using empirical data. This makes them powerful tools for studying broad-based impacts of policy interventions.

Partial equilibrium models focus on the market directly affected by a given policy and do not account for interactions with other markets. As a result, they could require less data than CGE models (Francois & Hall, 1997). Their flexibility allows for the use of complex functional forms to capture production and sectoral activities in detail. This makes PE models particularly useful in data-constrained environments for analysing disaggregated impacts—such as the gender-specific effects of sectoral interventions on women—without needing data on intersectoral linkages.

Microsimulation models by contrast, are most effective when evaluating aggregate effects of policy on individuals or households, such as changes in taxes or transfers. As noted by Harding (2007), MS models aggregate “individual experiences” to assess how demographic, behavioural, and policy changes affect outcomes at the micro level. When applied with gender-disaggregated data, MS models can simulate impacts on variables such as women’s incomes and diets. Their ability to model detailed individual-level outcomes makes them well-suited to evaluating how demographic and economic trends influence women’s incomes and assets.

2.2. Article search criteria

To assess the literature on quantitative modelling of gender dynamics in the context of agricultural and livestock sector changes, we developed a structured literature review process designed to cover a wide range of relevant studies while minimising bias (Snyder, 2019). Our approach adapted a semi-systematic literature review methodology, involving a clearly defined search and selection strategy tailored specifically to the topic (Snyder, 2019; Zunder, 2021).

This method offers broader thematic coverage than a systematic review, whilst still aiming to reduce selection bias (Wong et al., 2013). Given the challenge of reviewing every potentially relevant article—and the inherent uncertainty in capturing all available data—the semi-systematic approach enables the

identification and interpretation of a wide array of studies with implications for the research focus (Wong et al., 2013).

A protocol was developed to identify and synthesise articles most relevant to the study's topic, guided by pre-determined inclusion and exclusion criteria. The process began with the selection of scientific databases, article types, and publication periods aligned with the objectives of the review (see Figure 1). Next, key inclusion criteria were defined and translated into search terms using Boolean operators to retrieve documents from the selected databases.

Articles retrieved were first screened for relevance based on their titles, followed by abstract content. Those deemed relevant underwent a full-text review. Articles for which full texts could not be accessed—either through public platforms or after reasonable effort (including attempts via extensive institutional access of the co-authors) - were excluded from the review.

For this study, scientific articles were accessed electronically from ScienceDirect and JSTOR, both of which host a wide range of publications in agriculture, economics, and related inter-disciplinary fields, with global geographic coverage. The literature review focused on studies assessing socio-economic impacts on women, separate from men, resulting from structural or policy changes in the livestock sector. Only studies employing CGE, PE, or MS modelling approaches were included.

To qualify, studies had to meet the following criteria:

- Include a low- and middle-income country (LMIC) in the analysis.
- Address gender or women as a central focus.
- Analyse either the entire agricultural or livestock sector, or a specific intervention within it.
- Measure socio-economic impacts using indicators such as food consumption, diet quality, nutrition, income, or employment.

The search process incorporated appropriate key words, Boolean operators ("AND" "OR" "NOT"), and truncation techniques (e.g. using "agric" to capture both "agriculture" and "agricultural").

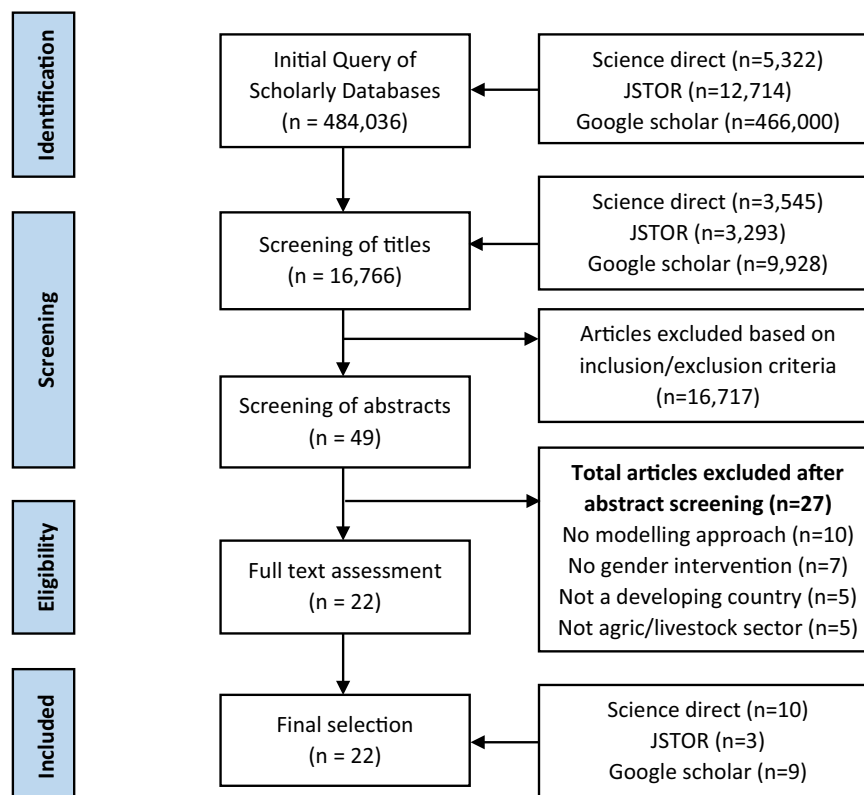


Figure 1. Illustration of article selection process.

Using the advanced search function in ScienceDirect, the following query was applied:
(equilibrium OR simulation) AND (women) AND (livestock OR "agric") AND (income OR employment OR consumption OR "food security").

This search yielded 5,322 results. A similar query on JSTOR yielded 12,714 results. To further supplement the database searches, a targeted search was conducted via Google Scholar using the terms:

(equilibrium OR simulation) AND (gender OR women) AND (livestock OR agriculture) AND (employment OR welfare OR poverty OR consumption OR "food security").

2.3. Inclusion criteria

To be included in our review, published studies had to meet the following criteria:

- (a) The study was published between 1980 and 2022. This period was chosen to balance the inclusion of both established and emerging modelling approaches, while excluding overly dated studies that may not reflect current policy contexts. The starting year of 1980 was selected to ensure relevance and manageability; with the assumption that more recent work would build upon earlier foundational research. This period also captures the era following the Structural Adjustment Programmes (SAPs) of the 1980s, which brought significant changes to agricultural and rural sectors across LMICs. Notably, this period saw growing scholarly attention to gender dimensions of such sectoral transformations (Haddad et al., 1995). Extending to 2022 captures the evolution of economic modelling techniques from early SAM-based analyses to more sophisticated CGE, PE, and MS frameworks, allowing the review to trace methodological shifts and emerging gender-sensitive innovations.
- (b) The study examined interventions in rural, agricultural, or livestock sectors in one or more LMICs. It needed to include a comparative scenario—i.e. a no-intervention baseline versus an alternative intervention within the same sector, or in a different sector.
- (c) The study had to demonstrate a clear focus on gender—either by analysing gender-differentiated interventions or the gendered impacts of broader interventions.
- (d) The study assessed development-relevant outcomes, such as employment, income generation, diet, human nutrition, or health.
- (e) The study employed CGE, PE or MS models, or a combination of these modelling approaches in its methodology.

Applying the inclusion criteria (a) to (e) yielded 3,545 articles from ScienceDirect, 3,293 from JSTOR, and 9,928 from Google Scholar.

ScienceDirect articles were drawn from subject areas including economics, econometrics and finance, social sciences, environmental science, agricultural and biological sciences, and business, management, and accounting. Articles retrieved from JSTOR were primarily from the fields of agriculture, development studies, economics, and gender studies.

An initial Google Scholar search yielded approximately 466,000 results. Applying the publication year filter (a) reduced this number to 228,000. These were further screened using inclusion criteria (b) to (e), resulting in 9,928 relevant articles (see [Figure 1](#)).

Duplicate entries and clearly irrelevant studies were removed based on title screening. This process narrowed the selection to forty-nine articles which were then reviewed in greater detail. At this stage, abstracts were screened to ensure that each article fully met all inclusion criteria.

Following this round of screening, twenty-seven articles were excluded for the following reasons:

- Lack of gender-related intervention focus ($n = 7$)
- Absence of any of the three required modelling approaches (MS, PE, or CGE) ($n = 10$)
- Not conducted in a developing country ($n = 5$)
- Unrelated to the agricultural or livestock sectors ($n = 5$)

This led to a final selection of twenty-two articles that met all predefined criteria and were included in the full review.

To improve accuracy, these articles were cross validated by two team members. While the initial screening and coding were conducted by a primary reviewer, all included studies were re-evaluated collaboratively to confirm alignment with the inclusion criteria and consistency in gender-related coding. This step minimised individual bias and strengthened the rigour of the thematic synthesis. These articles are the basis of the discussion of findings.

Although the structured protocol minimised selection bias through predefined inclusion/exclusion criteria and Boolean search strategies, reliance on specific databases (ScienceDirect, JSTOR) and electronic access may have excluded relevant studies not indexed or available in full text. This limitation is consistent with broader critiques of semi systematic approaches, which, while offering thematic breadth, cannot guarantee exhaustive coverage (Wong et al., 2013).

2.3.1. Data retrieval and review of findings

The full texts of the twenty-two selected articles were re-read and hand-coded using a structured data extraction protocol (see Table 2 and Appendix 2). Each article was categorised based on both general information—including author, year of publication, geographical focus, and country - and technical details, such as the paper's objective (or gender-specific objective), sector of interest, modelling approach, variables analysed, type of intervention, and the gender-related dynamics or impacts assessed.

The coding of gender dimensions was undertaken using structured data extraction tables, with each article systematically hand-coded to capture gender-specific objectives, variables, and socio-economic outcomes (e.g. employment, income, diet quality, nutrition). Gender was operationalized as a central analytical category, enabling a clear distinction between studies that explicitly modelled gender-targeted

Table 2. Locations and modelling approaches represented in the review.

Geographic Location	Country	Modelling Approach	Paper
Africa	14 Countries in Western (Ghana, Niger, Nigeria, Mali, Senegal), Eastern (Ethiopia, Kenya, Sudan, Uganda, Tanzania) and North Africa (Tunisia, Morocco, Algeria, Egypt)	Combines Computable General Equilibrium (CGE) with Partial Equilibrium (PE)	Frija et al., 2020
	Egypt	Combines CGE and Micro-Simulation (MS) techniques	Hendy and Zaki (2013)
	South Africa	CGE	Kinyondo and Mabugu (2009)
	Mozambique	CGE	Arndt and Tarp (2000)
	Tanzania	CGE	Arndt et al. (2011)
	Burkina Faso	MS	Latorre (2016)
	Ethiopia	PE	Smith & Chavas, (1997)
	Zambia	CGE	Bakker et al. (2018)
	Malawi	MS	Fontana and Wood (2004)
	Morocco	CGE	Fontana and Van Der Meulen Rodgers (2005)
	Ghana	CGE	Harttgen et al. (2016)
	Senegal	CGE	Filipski et al. (2017)
	Uganda	CGE	Cockburn et al. (2008)
	India	CGE	Cockburn et al. (2008)
	Philippines	Recursive dynamic PHILGEM Model (A SAM-based General Equilibrium Model)	Sinha and Khan (2008)
	Bangladesh	CGE	Sinha and Sangeeta (2000)
	Sri Lanka	Combines CGE with MS	Corong (2014)
	Nepal	CGE	Fontana and Wood (2004)
	Iraq	CGE	Fontana and Van Der Meulen Rodgers (2005)
Middle East	Pakistan	CGE	Liyanaarachchi et al. (2016)
	Yemen	CGE	Fofana et al. (2005)
	Brazil	CGE	Al-Haboby et al. (2016)
South America	Dominican Republic	CGE	Siddiqui (2009)
	Honduras	CGE	Breisinger and Ecker (2014)
			de Souza and Domingues (2015)

Source: Authors, based on this study.

interventions and those that examined gender-differentiated impacts of broader agricultural or livestock policies. This approach ensured that gender was not treated as incidental but rather as a primary lens of analysis, thereby reinforcing the methodological rigour and thematic coherence of the review.

These tables were then used to interpret the findings of the review along key thematic areas, applying an inductive approach. Articles were grouped based on the impact areas addressed, the modelling approaches used, the assumptions underlying the simulations, and the calibration methods employed. This allowed for the identification of common methodological limitations, particularly in relation to how gender was integrated—or not—into the modelling frameworks.

Following this analysis, the study draws on broader literature to explore how these modelling approaches can be improved to better reflect gender-differentiated impacts of livestock sector processes and interventions.

3. Results and discussion

Of the twenty-two studies included in the review, sixteen employed CGE models to integrate gender dynamics within the agriculture or livestock sector. Two studies used MS, and one applied PE modelling. Additionally, three studies combined CGE with either MS or PE approaches (see [Figure 2a](#)).

In terms of sectoral focus, nine studies addressed both agriculture and livestock, while thirteen focused solely on agriculture. None of the studies examined the livestock sector exclusively.

Geographically, most studies focused on countries in Africa, including Ethiopia, Egypt, South Africa, Zambia, Burkina Faso, Mozambique, Morocco, Senegal, Uganda, and Tanzania. Seven studies were based in Asia (Sri Lanka, the Philippines, Bangladesh, Iraq, India, and Nepal), while three studies focused on the Middle East (Yemen, Iraq and Pakistan). Two studies were based in Central America (Dominican Republic and Honduras), and one study focused on South America (Brazil) (see [Figure 2b](#)).

The studies were distributed throughout the selected review period (1980–2022), with the highest number published in a single year being four, in 2016 ([Figure 2c](#)).

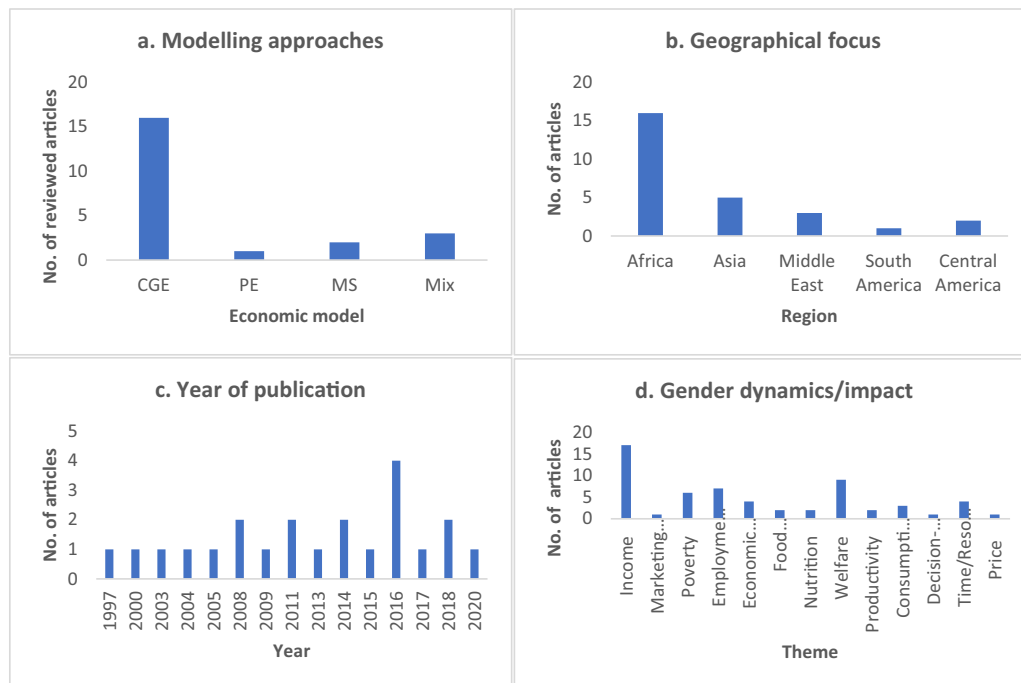


Figure 2. Distribution of papers by (2a) modelling approach, (2b) geographical location, (2c) year of publication and (2d) gender impact area.

The most frequently analysed themes were income (covered in seventeen studies) and welfare (covered in nine studies) (see [Figure 2d](#)).

Further details and individual summaries of each study, including modelling approach, sectoral focus, variable evaluated, and key finding are presented in [Table 2](#) and Appendix 2.

The reviewed studies examined a range of interventions, including agricultural research development, productivity improvements (often driven by technological change), policy reforms such as trade liberalisation in agriculture, manufacturing, and industry, as well as price liberalisation in the agricultural sector and broader strategies for economic growth.

Trade liberalisation was typically modelled as reductions in tariffs and the removal of regulatory barriers, with studies assessing the resulting impacts on production, consumption, poverty reduction, and women's employment and incomes (Filipski et al., 2011; Siddiqui, 2009). A common finding across these studies was the heightened vulnerability of women and poor households to food insecurity, often attributed to policy failures that disproportionately disadvantage rural women.

Women's roles in the livestock sector through their participation in agricultural production (Arndt & Tarp, 2000) and time allocated to reproductive responsibilities (Smith & Chavas, 1997). Gender-specific impacts were assessed using selected outcome indicators:

- Consumption: Arndt and Tarp (2000); Bakker et al. (2018); de Souza and Domingues (2015); Fofana et al. (2005); Harttgen et al. (2016); Siddiqui (2009); Sinha and Khan (2008); Sinha and Sangeeta (2000);
- Incomes: (2017); Arndt et al. (2011); Breisinger and Ecker (2014); Cockburn et al. (2008); Filipski et al., (2011; Fofana et al. (2005); Latorre (2016); Siddiqui (2009);
- Employment: Arndt and Tarp (2000); Latorre (2016); Liyanaarachchi et al. (2016);
- Producer incomes: Latorre (2016);
- Nutrition: Bakker et al. (2018); Breisinger and Ecker (2014); Harttgen et al. (2016).

The results of the review are presented below, organised by modelling approach and by the sector interventions or shocks simulated.

3.1. Gender dynamics across CGE, PE and MS models

The reviewed studies demonstrate that economic models do more than quantify sectoral shocks. They also reveal how structural changes filter through gendered roles, responsibilities, and opportunities. Computable general equilibrium (CGE) models capture gender dynamics by disaggregating labour and household categories and tracing economywide shocks. Their key contribution lies in showing systemic impacts of trade, productivity, and policy reforms on women's employment, wages, and welfare. However, they risk oversimplifying intra-household bargaining processes and care responsibilities, treating gender largely as a labour input rather than a dynamic social construct.

Partial equilibrium (PE) models on the other hand, focus more narrowly on sectoral detail and functional relationships through which women's roles are affected. They highlight gender-specific effects of agricultural research and development, seasonality, and distribution networks. Their strength is in quantifying targeted impacts at the sectoral level, but they miss cross-sector spillovers and broader empowerment pathways that link local interventions to systemic change.

Micro-simulation (MS) models operate at the household level, modelling heterogeneity and intra-household negotiations. They reveal how policies reshape women's control over resources, their allocation of time, and their vulnerability to shocks. Their contribution is in exposing lived realities and bargaining dynamics often invisible in aggregate models. Yet, these models lack macroeconomic feedbacks and depend heavily on detailed microdata, which can limit scalability.

Despite their limitations, the three modelling approaches offer complementary insights into gender dynamics. Whilst CGE models highlight systemic structures, PE models capture sectoral specificity, and MS models reveal lived realities at the household level. Together, these models show that gender dynamics occur over multiple scales, interacting with macroeconomic shocks, sectoral interventions, and intra-household negotiations.

3.1.1. Gender modelling using general equilibrium approaches

3.1.1.1. Trade policies. Fofana et al. (2005) simulated the effects of trade liberalisation on male and female incomes, welfare, market shares, and the allocation of time and resources. Their findings indicated that the complete removal of tariffs on imported goods benefited women more than men in terms of income generation, but it also led to a reduction in women's leisure time.

Latorre (2016) examined the impacts of tariff reforms, deregulation of domestic and foreign firms, and the entry of new firms on employment and wages by gender. Similarly, Sinha and Khan (2008) analysed how changes in trade policy—particularly tariff reductions—affected women's welfare, measured through income, consumption, and output, as well as broader economic indicators such as imports, exports, prices, inflation, and overall welfare.

Filipski et al. (2011) conducted a related study assessing the effects of eliminating agricultural import tariffs under the Dominican Republic-Central American Free Trade Agreement (DR-CAFTA). They evaluated the policy's impact on employment and wages in female-headed versus male-headed households.

Sinha and Sangeeta (2000) also explored the consequences of import tariff reductions on women's welfare in India, focusing on how such policy changes influenced real consumption among households earning income from the formal sector.

An adapted CGE model by Hendy and Zaki (2013) was used to investigate the effects of trade liberalisation on wage inequality, accounting for individual household and sector characteristics. Their results showed a decrease in wage inequality among urban and rural skilled men, as well as among skilled and unskilled women in urban areas. However, they also found an increase in wage inequality between skilled and unskilled men, and between skilled and unskilled women in rural areas.

This approach mirrored that of Fontana and Wood (2004), who employed gendered Social Accounting Matrices (SAMs) and CGE models to demonstrate that differences in resource endowments, labour market institutions, and socio-cultural norms shape the gendered impacts of trade expansion. Their study also revealed that gender gaps in the labour market tend to narrow with increased years of formal education for both men and women.

3.1.1.2. Labour and employment. de Souza and Domingues (2015) used a dynamic general equilibrium model to assess the role and growing importance of women's labour in the Brazilian economy. They disaggregated labour into six categories based on gender and skill level—low-, medium-, and high-skilled male and female workers—and analysed the sectoral effects of labour market changes on economic behaviour, income, consumption, and women's overall well-being.

Latorre (2016) further illustrated that skilled male and female workers tend to benefit more from real wage increases. As sectors become more oriented toward business services, the demand for educated workers rises, leading to higher wages for skilled labour relative to unskilled labour. The study concluded that narrowing the gender wage gap could be achieved through greater investment in female education, thereby enhancing women's human capital and employability in technologically advanced and service-oriented sectors.

3.1.1.3. Productivity gains. Productivity improvement was assessed primarily through labour productivity (Bakker et al., 2018; Latorre, 2016). In the agricultural sector, increases in production—both crops and livestock—were simulated based on growth in factors of production (Breisinger & Ecker, 2014) and total factor productivity (Al-haboby et al., 2016; Kinyondo & Mabugu, 2009).

To evaluate the broader economic effects of productivity gains, particularly on gendered employment, wages, income, and welfare in South Africa, Kinyondo and Mabugu (2009) employed the IFPRI standard CGE model (Lofgren et al., 2001). They introduced gender distinctions into labour categories (men and women, further disaggregated by skill level: skilled, semi-skilled, and unskilled). The model also differentiated factors of production and earnings by gender. Their findings showed that economy-wide productivity increases led to output growth and job creation across all skill levels for both men and women. However, unskilled and semi-skilled women benefited more than their male counterparts, largely because women, when unemployed, are more likely to accept lower wages.

Similarly, Al-haboby et al. (2016) used a dynamic CGE model to explore how productivity-driven growth in agricultural subsectors could accelerate overall economic growth and improve household income

distribution. Their model disaggregated households by location and labour markets by gender and skill level.

Sinha and Sangeeta (2000) examined the impact of increased agricultural productivity on women's income and welfare in India. The study found that as women transitioned from domestic to paid work, their incomes rose—though the gains were smaller compared to those experienced by men.

Arndt and Tarp (2000) assessed the impact of technological improvements in cassava production on rural women and the broader economy, considering scenarios with and without risk-reducing behaviour. Their analysis focused on how innovations—such as drought-tolerant and disease-resistant varieties and improved farming practices—affected production risks, insurance costs, and household consumption.

Bakker et al. (2018) evaluated the direct and indirect effects of climate change, economic shifts, and policy interventions—including food aid, cash transfers, consumer and producer subsidies, and infrastructure expansion—on food security. In their study, food security was measured through consumption and nutrition outcomes, disaggregated by income, age, and gender.

3.1.2. Gender modelling using partial equilibrium approaches

Studies employing partial equilibrium (PE) models offer valuable insights into the ex-ante effects of livestock sector-specific interventions on gender-disaggregated outcomes. However, these models typically quantify employment and income contributions from agriculture and livestock only through linkages with general equilibrium (GE) models.

3.1.2.1. Seasonality and distribution networks. For instance, Bakker et al. (2018) utilised the Food Distributed Extendable Complementarity (Food-DECO) model—a PE model formulated as a Mixed Complementarity Problem (MCP)—to assess how seasonality and regional distribution networks affect human nutrition, disaggregated by gender and per capita income. The model captured nutritional outcomes by disaggregating consumption by income level, age, and gender. Their findings showed that higher-income individuals consumed significantly more calories than those in lower-income brackets, and men consumed more calories than women, reflecting both physiological needs and intra-household food allocation practices.

3.1.2.2. Research investments. Frija et al. (2020) combined PE and CGE models to evaluate the medium- and long-term impacts of alternative agricultural research and development investments on male and female employment across 14 African countries. Their simulations revealed that increased participation of women—especially those with higher qualifications—significantly boosted domestic demand, which in turn stimulated growth in sectors linked to household consumption. The study used employment-to-GDP elasticities, adapted from Kaspos (2005), to estimate the employment effects of GDP growth. It concluded that countries with a higher agricultural share of GDP and greater potential for productivity gains from agricultural investment are more likely to generate employment and reduce gender disparities in labour participation.

3.1.3. Gender modelling using micro-simulation approaches

3.1.3.1. Price changes and policies. Smith & Chavas, (1997) applied a micro-simulation model to estimate the effects of price liberalisation policies in Burkina Faso. Using a non-pooling household model that incorporated intra-household negotiations over resource control, they examined how price increases influenced women's control over resources, as well as their time and income allocation between income-generating and reproductive roles. The liberalisation policy modelled included exchange rate devaluation and price deregulation implemented between 1981 and 1985. The study concluded that agricultural liberalisation, when paired with targeted efforts to enhance the profitability of women's income-generating activities, could significantly improve women's welfare.

Harttgen et al. (2016) used a micro-simulation approach to analyse the effects of food price changes and short-term income shocks on households in Malawi. Drawing on data from the Second Integrated Household Survey (IHS-2) 2004/2005, the model assessed impacts on food consumption and food poverty, with a focus on women. The study identified vulnerable populations and provided insights for designing programmes to mitigate the effects of future food and income shocks.

Micro-simulation techniques have also been integrated with CGE models to assess the gendered impacts of trade and price liberalisation policies. Liyanaarachchi et al. (2016) examined how trade liberalisation affects poverty using a combined general equilibrium and micro-simulation framework. Their model assessed how gender status influences employment probabilities, with labour participation disaggregated by skill level. The results indicated that trade liberalisation led to increased income inequality at both national and urban-rural levels.

3.2. Methodological assumptions and model calibration

3.2.1. Strengths and limitations of model assumptions

CGE-based models (Breisinger & Ecker, 2014; Frija et al., 2020; Hendy & Zaki, 2013; Kinyondo & Mabugu, 2009; Liyanaarachchi et al., 2016) commonly assume market-clearing conditions—where all goods and services produced are sold within the same period—and perfect competition, where identical products are traded freely without barriers, and no single actor can influence prices. However, these assumptions often fail to reflect the realities of LMIC economies, where monopolistic structures, informal sectors, and labour market rigidities (e.g. high unemployment in South Africa, informal labour in Egypt) are prevalent.

Similarly, the partial equilibrium model by Bakker et al. (2018) and the microsimulation model by Harttgen et al. (2016) assumed predictable household responses to shocks, overlooking non-market coping mechanisms such as food sharing and remittances, as well as intra-household dynamics like gender-based resource allocation. Static models also fall short in capturing long-term structural changes—such as capital accumulation, technological diffusion, and labour market transitions—thereby limiting their ability to assess the sustained impacts of policies like trade liberalisation (Corong, 2014; Hendy & Zaki, 2013; Liyanaarachchi et al., 2016) or productivity growth (Kinyondo & Mabugu, 2009), where dynamic effects are crucial.

Most models did not account for external shocks such as climate change (except for Frija et al. (2020), which included a single climate scenario), global price volatility, or political instability. For example, Breisinger and Ecker (2014) and Hendy and Zaki (2013) did not fully incorporate the effects of Yemen's post-2011 conflict or Egypt's Arab Spring, respectively. These shocks significantly influence economic and social outcomes but were often treated as exogenous or ignored altogether.

While gender-disaggregated analysis was a notable strength across the reviewed studies, many models failed to incorporate gender-specific constraints such as occupational segregation, childcare responsibilities, and patriarchal norms (e.g. Corong, 2014; Hendy & Zaki, 2013; Smith & Chavas, 1997). Additionally, non-income dimensions of welfare—such as access to education and healthcare—were rarely included, limiting the comprehensiveness of poverty and welfare assessments (e.g. Harttgen et al., 2016; Liyanaarachchi et al., 2016).

Finally, the assumption of uniform shock impacts—such as price increases (Harttgen et al., 2016) or tariff reductions (Hendy & Zaki, 2013)—across regions and households overlooked critical spatial variations in market access, price transmission, and vulnerability. This is particularly problematic in countries with diverse economic and geographic contexts.

3.2.2. Strengths and limitations of model calibration approaches

The models reviewed were generally calibrated using context-specific data, including household surveys (e.g. Malawi's IHS in Harttgen et al., 2016; the Philippines' FIES in Corong, 2014; Egypt's HIECS in Hendy & Zaki, 2013) and Social Accounting Matrices (SAMs) (e.g. South Africa's 2003 SAM in Kinyondo & Mabugu, 2009; Yemen's 2009 SAM in Breisinger & Ecker, 2014). These data sources provided empirical grounding and allowed for detailed disaggregation by sector, gender, and household type.

Key parameters—such as demand and trade elasticities and production functions—were often estimated econometrically or drawn from existing literature. For example, Harttgen et al. (2016) applied the Almost Ideal Demand System (AIDS) to model food demand, while CGE models typically used nested Constant Elasticity of Substitution (CES) functions to flexibly represent production and trade behaviour. Most studies (e.g. Bakker et al., 2018; Breisinger & Ecker, 2014; Corong, 2014; Frija et al., 2020; Hendy & Zaki, 2013; Kinyondo & Mabugu, 2009; Liyanaarachchi et al., 2016) conducted sensitivity analyses to test the robustness of their results to variations in key parameters, enhancing the credibility of their findings.

However, several limitations were evident. Some models relied on outdated data (e.g. 1984/85 ICRISAT in Smith & Chavas, 1997; 2000 SAM in Corong, 2014; 2004/05 data in Hendy & Zaki, 2013), reducing their relevance for more recent policy contexts, especially considering significant economic, political, and climatic changes. Informal sector activities and non-market income sources were often underrepresented, potentially biasing labour market and poverty estimates.

Transparency in parameter estimation was also limited in some cases, reducing confidence in the accuracy of model outputs. While sensitivity analyses were conducted, they often focused narrowly on a limited set of parameters (e.g. elasticities, productivity shocks), neglecting broader uncertainties such as informal sector dynamics, external shocks, or policy implementation challenges. These omissions constrain the robustness of the models, particularly for gender-focused analysis.

In models assessing nutritional outcomes (e.g. Breisinger & Ecker, 2014; Harttgen et al., 2016), the assumption that food consumption directly translates into nutritional status ignored key factors such as food quality, preparation losses, and health conditions. Moreover, non-income dimensions of welfare—such as empowerment, education, healthcare access and time poverty (Seymour et al., 2019)—were rarely integrated, limiting the models' ability to provide a holistic assessment of poverty and well-being.

4. Discussion

Despite the growing use of economic models in agricultural and food system analysis, current modelling approaches fall short in capturing complex, gender-differentiated impacts of livestock sector interventions. This review identified three major challenges in the application of CGE, PE and MS models: (1) weak representation of informal economies; (2) static or overly simplified assumptions, and (3) inadequate integration of gender-disaggregated indicators.

MS models help with capturing heterogeneity and provide much more detailed accounting for the complexity of agricultural systems (Peichi, 2016). However, they lack the broader market and policy linkages captured by CGE and PE models. On the other hand, due to their focus on aggregate levels, CGE models provide macroeconomic consistency but typically ignore individual-level heterogeneity and informal economic activity -spaces where women are highly concentrated in livestock systems. They may also be expensive and time consuming to use for analysis. CGE models ignore individual actors' variations of characteristics and choices, resulting in biased estimates. They give no insight into how economic aggregate changes affect different individuals (Peichi, 2016). PE models, while useful for sectoral detail in that they can show more disaggregated sector impacts, often miss critical cross-sector interactions (Boland, 2014). Further, PE models are limited by data requirements such as elasticities, which may be gender-neutral or outdated.

Critically, most reviewed studies fail to incorporate the informal sector, despite its dominance in rural economies and its centrality to women's livestock-related livelihoods. For example, small-scale poultry production or home-based milk processing—activities primarily managed by women—are frequently excluded from formal data sources and therefore underrepresented in models. This omission biases outputs and undermines policy relevance for gender-inclusive development. In Harttgen et al. (2016), assumptions about market-based responses did not include reliance on non-market food sources and factors that significantly influence food entitlements were not explicitly modelled. Informal economies, characterised by unregistered activities like small-scale livestock trading or home-based poultry production, are significant in LMICs, and particularly for women (FAO, 2009).

The reliance on static models further restricts the ability to account for dynamic adjustments to shocks such as trade disruptions or climate events. These shocks have distinctly gendered impacts: women often lack access to coping mechanisms such as savings, markets, or insurance. Harttgen et al. (2016)'s modelling of static household behaviour, and uniform price shocks did not fully capture the complex socio-economic and environmental context (of Malawi). Models like those used by Frija et al. (2020) and Bakker et al. (2018) also assume uniform productivity shocks, ignoring localised gendered vulnerabilities and differential capacities to adapt. Consequently, model outputs may underestimate the risks to women's income, food security, and resilience.

Static models assume fixed economic structures and parameters, overlooking dynamic processes such as capital accumulation, technological change, and behavioural adaptation. This limits their ability to capture

critical adjustments and external shocks—such as global trade disruptions—which are especially relevant for export-dependent and environmentally vulnerable sectors like livestock.

For example, Frija et al. (2020) used a static CGE model to assess livestock interventions in Africa, assuming constant production technologies and employment elasticities. This approach fails to reflect how farmers adapt to shocks like feed price spikes or droughts—challenges common in LMICs. These limitations are particularly significant for women, who play key roles in small-scale livestock systems but are often excluded from model assumptions. As Baltenweck et al. (2022) note, women face unique constraints such as limited access to credit and markets, which static models fail to capture. Similarly, Brooks et al. (2010) highlight how static models underestimate the impact of trade volatility on women, who often lack the resources to buffer against price shocks—leading to policies that overlook the need for trade stability and market access for women.

Climate change further compounds these challenges. Livestock systems in developing countries face increasing risks from droughts, heat stress, and fodder shortages—impacts that disproportionately affect women reliant on small ruminants and poultry for income (FAO, 2009). Yet, most models inadequately integrate climate risks. For instance, Frija et al. (2020) used a simplified climate scenario assuming uniform productivity impacts across Africa, ignoring localised vulnerabilities such as recurrent droughts in pastoral areas. While Bakker et al. (2018) included stochastic weather shocks, their model did not account for long-term climate effects like shifting rainfall patterns, soil degradation, or pest outbreaks—factors that heavily impact small-scale, women-led livestock operations.

The limited integration of climate change, global price volatility, and political instability restricts the models' ability to inform policies that enhance resilience—especially for women in livestock systems.

While these models offer powerful tools for simulating policy impacts, their limitations in representing informal economies, reliance on static assumptions, and narrow use of gender-disaggregated indicators reflect a deeper disconnect from lived gender realities. Predominantly dependent on formal market data and aggregate household structures, they often fail to capture the complex, context-specific roles that women occupy in livestock-related livelihoods, roles that are central to rural economies yet rarely reflected in formal datasets. This exclusion, from a gender empowerment perspective, undermines the ability of models to reflect women's control over resources and contributions to household resilience. Moreover, while participatory development theory underscores the importance of designing policies informed by the voices and experiences of those most affected (Cornwall, 2008; Rahman, 1993), quantitative modelling approaches frequently abstract away from these realities, reducing gender to a labour input rather than conceptualising it as a dynamic social construct shaped by norms, power relations, and intra-household negotiations.

Nevertheless, several promising approaches are emerging. Dynamic CGE models linked with microsimulation techniques (e.g. Ahmed and O'Donoghue (2007)) provide a pathway to estimate how macro-level shocks translate to household-level gender outcomes. By systematically linking macroeconomic shocks to micro-level empowerment outcomes and validating these linkages through participatory methods, hybrid models can move beyond predictive analysis to co-creation. This approach aligns with empowerment frameworks that emphasise resources, agency, and achievements, and supports the design of livestock and agricultural policies that are both analytically rigorous and socially responsive, ensuring that policy design reflects both structural economic processes and lived gender realities. Another key development is the incorporation of gender-specific indicators—such as the Women's Empowerment in Agriculture Index (WEAI) or Women's Empowerment in Livestock Index (WELI)—into simulation models. These composite indices capture multidimensional empowerment across domains like access to resources, decision-making, and time use, offering a structured approach to gender analysis.

Moreover, participatory modelling approaches and agent-based simulations offer innovative ways to incorporate social norms and decision-making dynamics. These models can simulate intra-household negotiations and responses to interventions, making them well-suited to reflect gender roles and constraints in livestock systems. Yet, they remain underutilized in ex-ante impact assessments and livestock sector foresight.

Overall, while no single modelling framework fully captures the complex gender dynamics in livestock systems, combining models—e.g. CGE for macro trends, MS for household-level effects, and gender indices for empowerment outcomes—holds significant potential. A modular modelling strategy, drawing on

interdisciplinary methods and updated data, is urgently needed to ensure more accurate and gender-responsive foresight assessments in LMICs.

5. Conclusion

This paper reviewed how gender roles and impacts have been addressed in economic models of agricultural and livestock sector interventions. Through a synthesis of modelling studies employing CGE, PE, and MS techniques, the paper assessed the extent to which these approaches have captured gender-differentiated outcomes, including labour allocation, income, consumption, and empowerment indicators. Findings reveal that while current models provide useful insights into sectoral and macroeconomic impacts, they often fail to account for gender-specific dynamics, particularly those relevant to women's roles in informal livestock economies. The review underscores the limitations of static frameworks, outdated data, and oversimplified assumptions that fail to reflect adaptive behaviours, social norms, or intra-household decision-making—factors critical for understanding how interventions affect men and women differently.

Our study has a few implications for policy. First, the study suggests that no single model is sufficient in adequately capturing the multidimensional nature of gendered impacts. Therefore, a mixed methods modelling strategy is recommended, combining the strengths of different approaches to capture multi-level and multidimensional gender impacts. This strategy can support the design of more inclusive livestock policies and investments, particularly in LMICs where the livestock sector is central to rural livelihoods and women's economic participation. Secondly, the analysis identified promising directions for future model development. These include the integration of gender-sensitive indicators such as WEAI and WELI, dynamic microsimulation frameworks linked to CGE models, and participatory and agent-based approaches that incorporate social norms and local knowledge. Such advances enable better reflection of gendered constraints and opportunities in livestock systems and improve the relevance of policy recommendations. Third, women play a critical role in informal livestock-related activities, including small-scale poultry production and home-based milk processing. These contributions, while central to rural livelihoods and household food security, are frequently excluded from economic analyses. Policy frameworks must therefore explicitly acknowledge and incorporate such informal activities to ensure that interventions capture the full spectrum of women's economic participation and support more gender-responsive and inclusive development outcomes.

This paper highlights the potential for economic modelling to become a more powerful tool in supporting gender-responsive development. By embedding gender analysis more deeply in foresight assessments and policy simulations, development actors can better identify which interventions are most likely to enhance women's autonomy, reduce poverty, and contribute to resilient and inclusive livestock systems.

Finally, hybrid modelling, when systematically grounded in gender-sensitive indicators and subjected to participatory validation, constitutes a robust methodological pathway for advancing the analysis of agricultural and livestock systems in LMICs. Such an approach ensures that women's agency, contributions, and constraints are explicitly incorporated into policy design processes. In doing so, economic models are repositioned from abstract, theoretical simulations toward empirically informed and contextually relevant instruments that can guide inclusive development strategies and strengthen the resilience of food systems.

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Abbreviations

CGE	Computable General Equilibrium
LMICs	Low-and-middle income countries
MS	Micro-simulation
PE	Partial Equilibrium
SAM	Social Accounting Matrix
WELI	Women Empowerment in Livestock Index
WEAI	Women Empowerment in Agriculture Index
WISE	Wellbeing, Inclusion, and Sustainability dimensions

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Appendices to Quantifying Gender Dimensions of Agricultural and Livestock Sector Interventions

Appendix 1: Theoretical Background

Computable General Equilibrium (CGE) Models.

Approaches to CGE modelling generally follow four basic conventions: Walrasian models, applied general equilibrium (AGE) models, standard country models - which apply traditional neo-classical or structuralist CGE methodologies as popularised by institutions such as the International Food Policy Research Institute (IFPRI) and the World Bank - and CGE frameworks based on econometric approaches (Ahmed & O'Donoghue, 2007).

Theoretically, these models are grounded in general equilibrium theory, which assumes that markets for goods, services, and factors of production clear simultaneously through price adjustments (Burfisher, 2011). CGE models represent the economy using a system of equations that describe production, consumption, and market clearing conditions. These equations are calibrated using a SAM which captures the flow of economic transactions across different sectors and agents in the economy.

A central assumption of CGE models is that economic agents—households, firms, and others - maximise utility or profit, with prices adjusting to ensure market equilibrium across all markets.

In a typical CGE model, sectoral output is represented through a production function which defines how inputs are combined to produce goods or services:

$$Y_j = A_j \cdot F(L_j, K_j, M_j) \quad (1)$$

where Y_j = output of sector (j);
 L_j , K_j , M_j = Labour, capital, and intermediate inputs, respectively, of j.
 A_j = Total factor productivity of j.
 F = Functional form (e.g. Cobb-Douglas: $Y_j = A_j L_j^\alpha K_j^\beta M_j^{1-\alpha-\beta}$).
 The Household Utility Function is represented as:

$$U_h = U(C_h, S_h) \quad (2)$$

where C_h = Consumption of goods by household (h).
 S_h = Savings of h.
 Utility is maximised subject to a budget constraint:

$$\sum P_i C_{hi} + S_h = Y_h \quad (3)$$

And,
 The Market Clearing equation is represented as:

$$\sum D_{ij} = \sum S_{ij} \quad (4)$$

where D_{ij} and S_{ij} are demand and supply of good (i) in sector (j).

Partial Equilibrium (PE) Models.

Theoretically, PE models focus on a single sector or market, treating all other sectors as exogenous. This approach allows for detailed analysis of sector-specific interventions (Kretschmer & Peterson, 2010). PE models are grounded in microeconomic theory of demand and supply, assuming partial market clearing, and use elasticities to capture behavioural responses to policy or market changes.

These models analyse supply and demand dynamics within a specific market, such as crops or livestock, and are particularly useful for evaluating targeted policies, including input subsidies, price supports, or trade measures.

In PE models, the supply function is typically represented as follows:

$$Q_s = \beta_0 + \beta_1 P + \beta_2 W + \beta_3 Z + \varepsilon \quad (5)$$

where Q_s = Quantity supplied of good (s).
 P = Price of the good.
 W = Input prices (e.g. wages, capital costs).
 Z = Exogenous factors (e.g. technology, policy).
 ε = Error term.

The demand function is typically represented as follows:

$$Q_d = \gamma_0 + \gamma_1 P + \gamma_2 Y + \gamma_3 X + \varepsilon \quad (6)$$

where Q_d = Quantity demanded.
 Y = Income.
 X = Other factors (e.g. prices of substitutes).
 ε = Error term.

The Equilibrium Condition is represented as the following equation which indicated that supply equals to demand in equilibrium.

$$Q_s = Q_d \quad (7)$$

Microsimulation (MS) Models.

Microsimulation models are grounded in microeconomic theory and behavioural analysis, using individual or household-level data to simulate the impacts of policies on specific population groups, (Bourguignon & Spadaro, 2006). Their ability to model labour supply, consumption, and income dynamics at the individual level makes them well-suited for capturing heterogeneity, including gender differences.

MS models can be either static (non-behavioural) or dynamic (behavioural) and are often linked with CGE models to incorporate macroeconomic effects. Their theoretical foundation combines microeconomic theory, statistics, and computational modelling. Behavioural responses to policy changes are typically incorporated using elasticities derived from econometric estimates.

In these models, individuals are treated as agents whose behaviours are simulated iteratively through equations or rule-based systems. The emphasis on heterogeneity is achieved by drawing on detailed, individual-level data—most commonly from household surveys.

The econometric estimation of behavioural responses -such as labour supply - featured in MS models is typically represented as follows:

$$H_i = \alpha_0 + \alpha_1 W_i + \alpha_2 Y_i + \alpha_3 X_i + \varepsilon \quad (8)$$

where H_i = Hours worked by individual (i).

W_i = Wage rate.

Y_i = Non-labour income.

X_i = Demographic or policy variables.

ε = Error term.

Consumption or Welfare Impact equation is represented as:

$$C_i = \beta_0 + \beta_1 P + \beta_2 Y_i + \beta_3 Z_i + \varepsilon \quad (9)$$

where C_i = Consumption by individual/household (i).

P = Prices.

Y = Income.

Z_i = Policy or environmental variables.

Appendix 2: Summary of articles reviewed

Author/Year	Objective/Gender-based Objectives	Modelling Type	Variables Evaluated	Sector	Intervention	Impact
Al-haboby et al. (2016)	Analyses the extent to which productivity-driven growth in agricultural subsectors contribute to accelerating economy wide growth, raising household incomes, and affecting household income distribution. Gender-themed Question: To what extent does productivity-driven growth in agricultural subsectors impact on the income levels of female headed households and different skill levels of females across rural and urban locations?	CGE	1. Per capita income growth 2. Agriculture productivity 3. Labour	Agriculture	Productivity increases	Income
Arndt and Tarp (2000)	Analyses the interactions between agric. Technological improvement, risk, and gender roles. Gender-themed Questions: 1.What is the effect of technological change on male and females in a household? 2.What is the level of agricultural labour undertaken by men and women under different risk levels?	CGE	1. Agriculture labour 2.Non-agricultural labour 3. Productivity (Risk-constrained agricultural activities and non-agricultural activities)	Agriculture	Agricultural technology improvements	Marketing efficiency
Arndt et al. (2011)	Assess the macro and micro level implications of biofuels expansion in a low-income, land-abundant setting. Gender-themed Question: How does biofuel expansion increase the participation of women and benefits in biofuel production?	Dynamic CGE	1. Labour 2. Production 3. Poverty 4. Employment	Agriculture	Productivity increase	1. Poverty reduction 2. Employment 3. Economic growth
Bakker et al. (2018)	Assesses how the Food Distributed Extendable Complementarity (Food-DECO) model can estimate the effects of seasonality and regional distribution networks on human nutrition. Gender-themed Questions: 1. What effect does seasonality and regional distribution networks have on human	PE	Consumption	Agriculture including livestock.	Technology increase	1. Food security 2. Nutrition 3. Income

Author/Year	Objective/Gender-based Objectives	Modelling Type	Variables Evaluated	Sector	Intervention	Impact
Breisinger and Ecker (2014)	nutrition in terms of gender and per capita income? 2. What is the impact of a regional crop failure and the possible effectiveness of commonly proposed food security interventions Estimates changes in a country's food and nutrition security subject to economic growth and related income distribution over time Gender-themed Question: How does the household calorie consumption change for households with higher proportion of women?	CGE	1. Consumption 2. Sectoral GDP growth	Agriculture including the livestock	Economic growth	1. Food security 2. Nutrition 3. Income 4. Welfare
Cockburn et al. (2008)	Assess the direct and growth effects of trade liberalisation on gender. Gender-themed Question: How does trade liberalisation impact on the wage gap and employment status of men and women with different skill sets?	Dynamic CGE	1. Income 2. Production 3. Labour	Agriculture	Trade liberalisation	1. Productivity 2. Poverty 3. Welfare 4. Economic growth
Corong (2014)	Analyses the economic, gender, poverty, and distributional effects of global and unilateral tariff elimination policies in the Philippines. Gender-themed Questions: 1. What is the combined effect of trade liberalisation on gender and poverty? 2. Would existing inequality between men and women be moderated or exacerbated by trade liberalisation? 3. To what extent do tariff elimination policies affect male relative to female employment? 4. Can trade be expanded while at the same time reducing poverty and gender inequality?	Recursive dynamic PHILGEM Model (A SAM-based General Equilibrium Model)	1. Household labour income earnings 2. Aggregate labour demand 3. Capital income shares	Agriculture including livestock	Trade policies	Income
de Souza and Domingues (2015)	Analyses the importance of women's labour for the Brazilian economy for the period 2006-2013 Gender-themed Question: The effect of women's work in terms of income, consumption, and well-being.	CGE	Labour and Income	Agriculture but not livestock	Educational qualification	1. Income 2. Consumption 3. Well-being
Filipski et al. (2011)	Analyse the impacts of the Dominican Republic-Central American Free Trade Agreement (DR-CAFTA) on rural incomes and welfare in the Dominican Republic. Gender-themed Question: How does the elimination of agricultural import tariffs hurt women in both agricultural and non-agricultural households?	CGE	1. Income 2. Production 3. Reproduction and leisure	Agriculture	Trade liberalisation	1. Wage income 2. Welfare
Filipski et al. (2017)	Evaluate the impact of saffron price volatility and production technologies on producers and the economy. Gender-themed Question: How does price boom and bust	LEWIE model (an applied GE Model)	1. Income 2. Production 3. Labour	Agriculture, including livestock	Productivity increases due to investment in technologies	1. Income 2. Productivity 3. Employment

Author/Year	Objective/Gender-based Objectives	Modelling Type	Variables Evaluated	Sector	Intervention	Impact
Fofana et al. (2005)	affect both men and women in saffron production? Analyses the effects of trade liberalisation on male and female work and Leisure in Nepal. Gender-themed Question: What are the implications of tariff elimination on imported goods in Nepal and the benefits on income distribution and leisure among women?	CGE	1. Income distribution 2. Market and domestic works 3. Consumer price changes 4. Consumption 5. Welfare 6. Time and resource allocation	Agriculture and other non-agriculture and public sectors	Trade liberalisation	1. Income 2. Welfare 3. Time allocation 4. Resource allocation
Fontana and Wood (2004)	Assesses how well a gendered social accounting matrix (SAM) and computable general equilibrium (CGE) model can capture trade effects. Gender-themed Question: How does differences in resource endowments, labour market characteristics and socio-cultural norms shape the way in which trade expansion affects gender inequalities?	CGE	1. Wage rate 2. Female Employment 3. Female market participation 4. Gender wage gap	Agriculture including livestock	Trade expansion	1. Wage rate 2. Employment
Frija et al. (2020)	Assesses the medium and long-term effects of alternative agricultural research and development investment scenarios on male and female employment in 14 African countries. Gender-themed Question: What is the impact of investments in agriculture on overall employment and gender disparities in labour participation?	Combines CGE with PE	1. Employment 2. Labour productivity	Agriculture but not livestock	1. Agricultural Research 2. Investment	Employment
Harttgen et al. (2016)	Analyses the impact of changes in prices of specific food groups, such as maize prices or prices for staple foods, as well as the negative short-term household level income shocks on the entitlements to calorie consumption of individuals and how these changes affect overall food poverty. Gender-themed Question: How does price and income shocks affect the calorie consumption and overall poverty of women?	MS	1. Consumption 2. Poverty 3. Food security	Agriculture	Price liberalisation	1. Consumption 2. Poverty
Hendy and Zaki (2013)	Identifies the effects of trade liberalisation policy measures on income redistribution. Gender-themed Question: To what extent does macroeconomic policies affect, on the microeconomic level, female's poverty, wages, and employment opportunities?	Combines CGE and MS	1. Labour income 2. Capital income	Agriculture including livestock	Trade liberalisation Policy	Income
Kinyondo and Mabugu (2009)	Examines the effects of economy wide and partial productivity increases on the economy, gender employment, wages, income, and welfare in South Africa. Gender-themed Questions:	CGE	1. Total factor productivity (TFP) 2. Factor income earning 3. Economy-wide productivity	Agriculture including livestock	Partial productivity increases	1. Employment 2. Wages 3. Income 4. Welfare

Author/Year	Objective/Gender-based Objectives	Modelling Type	Variables Evaluated	Sector	Intervention	Impact
Latorre (2016)	1.What effect does productivity have on gender employment and on all skills possessed by men and women mostly in labour-intensive sectors? 2.How does productivity improve the welfare of men and women due to reduced commodity prices and improved earnings? 3.Would there be a difference to women employment if there was to be policy to deliberately target women or men-intensive sectors only and what is the outcome related to gender rigidities in sectors? Assesses how foreign trade and the entry of new firms affect female and male employment, allocation and incomes. Gender-themed Question: How does Foreign Direct Investment and Tariff Reform impact on the wages of women?	CGE	1. Wages 2. Production	Agriculture including livestock	Trade intervention	1. Employment 2. Factor re-allocation 3. Incomes 4. Welfare
Liyanaarachchi et al. (2016)	Analyses the effects of trade liberalisation on income distribution and poverty in the urban, rural and estate sectors in Sri Lanka Gender-themed Question: How do gender status affect the probability of being employed?	Combines MS with CGE	1. Income 2. GDP growth 3. Wage earnings	Agriculture	Trade liberalisation	1. Economic growth 2. Poverty reduction 3. Wages 2. Gross operating surpluses 4. Employment
Sinha and Khan (2008)	Examines the incorporation of gender and the informal sector within a general equilibrium framework for India Gender-themed Questions: What is the impact of economic variables on household accounts such as income, consumption expenditures and resource generating and absorbing capacity of women?	CGE	1. Income 2. Consumption 3. Resource generation	Informal sector including agriculture	Policy intervention	1. Poverty reduction
Smith & Chavas, (1997)	Investigates the effect of agricultural commercialisation on the balance of women's dual roles in non-income pooling West African Households Gender-themed Questions: 1. What is the effect of agricultural commercialisation on the balance of women's dual roles? 2. What are the impacts of the price changes on the control of women's time and income?	MS	1. Time control 2. Income control	Agriculture	Price liberalisation policy	1. Income 2. Well-being 3. Decision-making power