Economic Impacts of Peste des Petits Ruminants (PPR) in Ethiopia

Abstract
The livestock sector is one of the key contributors to the Ethiopian economy. However, animal health has been a major challenge for the livestock sector of Ethiopia. Peste des Petits Ruminants (PPR) is regarded as one of the most important diseases for small ruminants in Ethiopia. In this study, we identify the macroeconomic impacts of PPR on GDP for the Ethiopian economy. We employ the GTAP model and database in tandem with epidemiological modeling results to simulate the effects of PPR in Ethiopia and observe its impact on various sectors of the economy as well as regional and domestic trade effects. Results show that, if negative externality of PPR is eradicated from Ethiopia, the country's gain in welfare, measured by equivalent variation (EV), is USD 59.37 million as well as a GDP increase by USD 14 million. We also find that the rest of the world also gains from a PPR free small ruminant sector of Ethiopia.

1. Introduction

The livestock sector is one of the key contributors to the Ethiopian economy, contributing 20% and 40% to the GDP and agricultural GDP respectively (Dessie, 2022). However, animal health has been a major challenge for the livestock sector of Ethiopia due to its dry climate and tropical weather (Ayele et al., 2021; Hooper, 2016). The Ethiopia Livestock Master Plan (ELMP), 2015 has ranked livestock diseases in Ethiopia based on the impact on household density, market, and intensification of livestock production. Based on these factors, Peste des Petits Ruminants (PPR) is regarded as one of the most important diseases for small ruminants in Ethiopia.

Ethiopia is a top producer of small ruminants with 40 million sheep and 51 million goats. PPR is one of the most economically significant diseases for small ruminants in Ethiopia. Due to its high morbidity and mortality of up to 90%, people depending on livestock for their livelihood are severely affected by the disease (Kotchofa et al., 2021). Reported economic losses of PPR in

Ethiopia are equivalent to 14% of annual household income, dramatically affecting the livelihoods of affected flock owners (Jemburu, 2022).

Existing studies focused on the investigation of the potential costs of the disease as well as the benefits of eradicating the disease. Lhermie et al., (2021) used a bioeconomic household production model to estimate income loss at the household level in sub-Saharan Africa, which ranged from 2 to 40% depending on the livestock income share of total annual household income. Jones et al. (2016) adopted a benefit-cost analysis and suggested strong economic returns from the global eradication of PPR with a benefit-cost ratio of 33.8 and an internal rate of return of 199%.

In this study, we identify the macroeconomic impacts of PPR on GDP for the Ethiopian economy. We employ epidemiological model outputs from Global Burden of Animal Diseases) GABDs[1] into a computable general equilibrium (CGE) model to simulate the economic impact of PPR. This study is different than the existing literature in several aspects. First, this study considers the fact that livestock life span is dictated by market forces and thus losses and costs arise in both the productivity and trade of animals and animal products along the value chain (Hennessy & Marsh, 2021). Losses and costs estimated with a fixed price, e.g., Jemburu et al. (2022), do not consider these market price dynamics. Kotchofa et al. (2021) use a macroeconomic model to determine the economic impact of PPR in Ethiopia and Burkina Faso with a hypothetical shock on the value of small ruminants. This study uses outputs from an epidemiological model to calculate shocks in live animal production and observe its impact on various sectors of the economy as well as regional and domestic trade effects.

[1] https://animalhealthmetrics.org

To our knowledge, no studies have employed epidemiological model outputs in an economic framework to evaluate the economic impact of PPR in Ethiopia. Some regional studies mentioned previously attempted to capture the market dynamics of PPR. For example, Lhermie et al. (2021) captured the price effects of PPR by employing a bioeconomic model in sub-Saharan Africa. Jones et al. (2016) used a social accounting matrix (SAM) to compute downstream impacts of PPR in related and unrelated sectors. Our model differs from previous work as we employ output from an independent epidemiological model based on national-level data from Ethiopia in tandem with an economic model. Additionally, the global CGE model used in this study allows us to analyze the disease impact of PPR across various directly and indirectly related sectors, on trade flows, and the world economy.

2. Methods

2.1. CGE Model

We employ the standard Global Trade Analysis Project (GTAP) model and GTAP database (Hertel, 1997; Aguiar et al., 2019) in tandem with epidemiological modeling results to simulate the effects of PPR in Ethiopia. For this study, we use the GTAP model version 7 (Corong et al., 2017) and the GTAP database version 11 with a 2017 base year. This database includes 160 regions and 65 sectors of economic activity. Since the Ethiopian economy witnessed significant growth during this time, we update the database to 2022 by implementing exogenous macroeconomic shocks similar to Beckman and Countryman (2021). Since this study is for the national-level impact of PPR in Ethiopia, we include Ethiopia as a single region and aggregate remaining countries into four other regions: sub-Saharan Africa (SSA), North America, Middle East and North Africa, and the Rest of the world. For sectoral aggregation, we treat ruminant live animal and ruminant meat sectors separately, and account for non-ruminant livestock and feed sectors separately to analyze the supply chain behavior between these industries. We aggregate all remaining agricultural commodities as a single combined sector. We also evaluate the impact of PPR disease on the pharmaceutical industry by accounting for a dedicated health sector. Regional and sectoral aggregation are shown in Appendix table A1 and A2, respectively.

2.2. Counterfactuals

In GBADs' dynamic population model, the negative externality of PPR in the small ruminant livestock sector of Ethiopia is identified by comparing two counterfactual scenarios. In the first counterfactual scenario, small ruminants are assumed to be disease free (Gilbert et al., 2024). Consequently, small ruminants in this scenario is assumed to have better fertility rate, zero mortality rate, and better liveweight conversion than current status quo. It is also assumed in the model that the farm producers get higher prices for the live animals than the current state and incur zero health related costs in this scenario. In the second counterfactual scenario, only the PPR disease impacts the health (i.e., mortality and morbidity) of small ruminants of Ethiopia. Therefore, although the fertility and livestock conversion are similar to the disease-free state, mortality exists in the PPR state. Similar to the disease-free state, farm producers are assumed to get higher prices for the live animals. However, contrary to the disease-free state, they incur health related costs such as medicines and veterinary care due to the prevalence of PPR.

2.3. Shock Calculation

We used the epidemiological model outputs of GBADs to calculate PPR-induced shocks for small ruminant production. We calculated the percentage change in output in Ethiopia due to PPR based on the difference between the counterfactual scenarios described in section 2.2, an ideal disease-free scenario and when PPR is present as the only prevalent disease. This percentage change indicates the impact of PPR on the production of small ruminants in Ethiopia. Since the GTAP database includes a combined cattle and small ruminant sector, we adopt a sector share-weighted method to introduce shocks in the live animal sector for small ruminants following Countryman et al., (2023). Therefore, to simulate the impact of PPR within the entire livestock sector, we calculate the small ruminant industry share of total live animals from the Food and Agricultural Organization (FAO) database[2]. We then apply this weighted shock in the live ruminant sector for Ethiopia to simulate the economic effects of PPR on small ruminants.

3. Results

The live ruminant sector is directly impacted by PPR with indirect effects on the ruminant meat industry as well as non-ruminant livestock industries. Preliminary results show that a PPR disease free small ruminant sector of Ethiopia increases its live animal supply by 0.33% and meat supply by 0.06% (Table 1). In the meat sector, output increase by 0.06% with a price decrease by 0.02%. It is interesting to note that, the increase in meat output corresponds to relatively minor changes in meat price.

Table 1: Changes in Output and Domestic Market Prices in Ethiopia

Sectors	**Output (% change)**	**Price (% change)**
Ruminant Live Animal	0.33	-1.98
Meat of Ruminant	0.06	-0.02
Other Livestock	0.07	-0.05
Feed	0.06	-0.02
Other Agriculture	0.11	-0.03
Health	0.03	0.01
Other Industries	0.03	0.02

[2] https://www.fao.org/faostat/en/#data

Table 2 illustrates the impact on trade due to the shift. Due to the increase in the domestic live animal supply, exports increase by 4.46% as well as a 3.56% drop in imports in this industry. In meat sector, exports increase by 0.1% and imports decrease by 0.03%.

Table 2. Changes in Imports and Exports in Ethiopia

Sectors	**Changes in Exports (%)**	**Changes in Imports (%)**
Ruminant Live Animal	4.46	-3.56
Meat of Ruminant	0.10	-0.03
Other Livestock	0.28	-0.08
Feed	0.11	0.02
Other Agriculture	0.24	-0.06
Health	0.01	0.05
Other Industries	-0.04	0.08

Table 3 shows the regional impact of the live animal supply shift. We can see that, due to this shift, the equivalent variation (EV) of Ethiopia increased by USD 59.37 million and the GDP increased by USD 14 million. Total world EV increased by USD 60.33 million.

Table 3. Changes in GDP and Welfare Measured by Equivalent Variation

Regions	**EV (Million USD)**	**GDP (Million USD)**
Ethiopia	59.37	14
North America	0.06	-2
MENA	0.65	2
SSA	0.05	0
Rest of the World	0.20	1

Table 4 breaks down welfare into various components that contribute to the overall welfare effects. We find that technological change is the key driver for overall welfare effects in Ethiopia since the shift was imposed as a productivity change in the live ruminant animal sector in the model. For the world economy, we observe that the regional terms of trade and the change in savings cancel each other and the positive change in welfare is attributed to the gain in allocative efficiency and technological change.

Table 4. Decomposition of Welfare Changes (Equivalent Variation, US$ Million)

Regions	Allocative Efficiency	Technological Change	Terms of Trade	Savings and Investment	Total
Ethiopia	8.06	52.3	-0.312	-0.656	59.4
North America	0.257	0	-0.292	0.095	0.059
MENA	-0.019	0	0.675	-0.007	0.65
SSA	-0.005	0	0.054	0.002	0.05
Rest of the World	-0.24	0	-0.125	0.566	0.201
Total	8.06	52.3	0	0	60.3

4. Discussion

PPR is marked as one of the major diseases in the livestock sector of Ethiopia. During an outbreak period from September 2017 to the end of January 2018 in northwest Ethiopia, losses for per affected animal were USD 13.4 for sheep and USD 12.9 for goat (Jemburu et al., 2022). Dynamic population model of GBADs estimates an approximate USD 50 million loss in morbidity and mortality due to PPR in the small ruminant livestock sector of Ethiopia. In this study, we employ a computable general equilibrium modeling framework to show that the economy wide welfare gain of PPR free small ruminant sector of Ethiopia is about USD 59 million. This contributes USD 14 million to the GDP of Ethiopia, which is 1.51% of the per capita GDP of Ethiopia at the year 2021[3].

We would like to point out limitations of the study. We used a regional modeling framework, GTAP, for this analysis focusing on a single country. A more detailed sectoral breakdown might be useful for a more specific identification of the counterfactual scenarios. For example, GTAP live ruminant sector includes both cattle and small ruminants. Since, we are focusing on the small ruminant subsector only, we weight the shock according to the cost share of small ruminant in the live ruminant sector.

[3] https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=ET

This study is intended to offer policymakers a baseline metric for the economy-wide effects of PPR to justify and prioritize resource allocation. Optimal allocation is especially important in a limited resource economy such as Ethiopia where total public expenditures averaged 13.11% of GDP (Shakil et al, 2023). Positive allocative efficiency effects may justify further allocation of resources in this sector to mitigate PPR disease impacts. The small ruminant sector of Ethiopia minus the PPR disease is also beneficial for the SSA economy as well. We simulate an increase in small ruminant exports from Ethiopia that benefits the SSA region following the increase in output resulting from eliminating PPR. Overall, in a world where there is no PPR in Ethiopia, global welfare is simulated to increase by USD 60.30 million. These results highlight the potential positive effects of combating animal diseases such as PPR that may be achieved through regional and international collaborations regarding animal health.

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Appendix

Table A1. GTAP Sectoral Aggregation

Aggregation	Sectors
Agricultural Commodity	Paddy rice; Wheat; Vegetables, fruit, nuts; Oil seeds; Sugar cane, sugar beet; Plant-based fibers; Vegetable oils and fats; Processed rice.
Live Ruminant	Bovine cattle, sheep and goats.
Ruminant Meat	Bovine meat products.
Other Livestock	Animal products nec; Raw milk; Wool, silk-worm cocoons; Meat products nec; Dairy products.
Feed	Cereal grains nec; Crops nec; Food products nec.
Health	Basic pharmaceutical products.
Other Industry	Forestry; Fishing; Coal; Oil; Gas; Minerals nec; Sugar; Beverages and tobacco products; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Petroleum, coal products; Chemical products; Rubber and plastic products; Mineral products nec; Ferrous metals; Metals nec; Metal products; Computer, electronic and optic; Electrical equipment; Machinery and equipment nec; Motor vehicles and parts; Transport equipment nec; Manufactures nec; Electricity; Gas manufacture, distribution; Water; Construction; Trade; Accommodation, Food and servic; Transport nec; Water transport; Air transport; Warehousing and support activi; Communication; Financial services nec; Insurance; Real estate activities; Business services nec; Recreational and other service; Public Administration and defe; Education; Human health and social work a; Dwellings.

Table A2. GTAP Regional Aggregation

Regions	Countries
Ethiopia	Ethiopia.
North America	Canada; United States of America; Mexico; Rest of North America.
Middle East and North Africa	Bahrain; Iran Islamic Republic of; Israel; Jordan; Kuwait; Oman; Qatar; Saudi Arabia; Turkey; United Arab Emirates; Rest of Western Asia; Egypt; Morocco; Tunisia; Rest of North Africa.
Sub-Saharan Africa	Benin; Burkina Faso; Cameroon; Cote d'Ivoire; Ghana; Guinea; Nigeria; Senegal; Togo; Rest of Western Africa; Central Africa; South Central Africa; Kenya; Madagascar; Malawi; Mauritius; Mozambique; Rwanda; Tanzania; Uganda; Zambia; Zimbabwe; Rest of Eastern Africa; Botswana; Namibia; South Africa; Rest of South African Customs.
Rest of World	Australia; New Zealand; Rest of Oceania; China; Hong Kong; Japan; Korea; Mongolia; Taiwan; Rest of East Asia; Brunei Darussalam; Cambodia; Indonesia; Lao People's Democratic Republ; Malaysia; Philippines; Singapore; Thailand; Viet Nam; Rest of Southeast Asia; Bangladesh; India; Nepal; Pakistan; Sri Lanka; Rest of South Asia; Argentina; Bolivia; Brazil; Chile; Colombia; Ecuador; Paraguay; Peru; Uruguay; Venezuela; Rest of South America; Costa Rica; Guatemala; Honduras; Nicaragua; Panama; El Salvador; Rest of Central America; Dominican Republic; Jamaica; Puerto Rico; Trinidad and Tobago; Caribbean; Austria; Belgium; Bulgaria; Croatia; Cyprus;

	Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; Netherlands; Poland; Portugal; Romania; Slovakia; Slovenia; Spain; Sweden; United Kingdom; Switzerland; Norway; Rest of EFTA; Albania; Belarus; Russian Federation; Ukraine; Rest of Eastern Europe; Rest of Europe; Kazakhstan; Kyrgyzstan; Tajikistan; Rest of Former Soviet Union; Armenia; Azerbaijan; Georgia; Rest of the World.