



Research article

The impact of live sheep export trade on the South Africa economy

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Abstract: The study assesses the impact of the live sheep export trade on the South African economy. The study used a recent South African Social Accounting Matrix and a partial equilibrium model. The results are mixed. On a positive note, the higher the demand for live sheep exports, the higher the prices and the more significant the economic impact. On the other hand, South Africa loses value-adding opportunities such as output from abattoirs, including hides and skin, offal, head, and consumable internal organs, and employment when live lambs are exported and slaughtered in destination markets. These findings help policymakers to develop appropriate mitigation strategies to balance the advantages and disadvantages of live sheep export. A nationwide analysis may miss some of the local costs and benefits of live sheep exports. Future research can also be done in selected major areas that produce sheep in South Africa.

Keywords: live sheep; export; labour; income; value-added, South Africa

1. Introduction

Global commerce in live farm animals has doubled in the last 50 years [1]. Approximately 2 billion farm animals are loaded onto trucks or ships each year and transported to new countries on journeys that can last days or weeks. Every day, at least 5 million animals are transported. Revenue has increased as the trade has grown [1]. According to COMTRADE (United Nations Commodity Trade Statistics) figures, global commerce in all live animals was valued at \$342 million in 1988. Still, by 2017, it had increased to \$32 billion in real terms (the base year 2021) [2–3].

According to FAOSTAT [4], approximately 14 million live sheep were traded between countries in 2019. Seven of the ten largest sheep importers in 2019 were situated in the Middle East and North

Africa (MENA Region). The analysis period terminated in 2019, given that in 2020 and 2021, significant disruptions occurred due to COVID-19, pressure groups against the exportation of live sheep via the sea, and diseases that affected production. During this period, the reported data's reliability was questionable and deliberately excluded from the analysis. Of significant concern was the Eastern Cape Veterinary Services which advised against any live animal exportation to the Middle East from May to September 2020. The National Council of SPCAs (NSPCA) also disrupted live sheep exports between 2020 and 2021 by initiating law suites to prohibit it. Table 1 shows the top five importers and exporters of live sheep in 2019.

Table 1. The top five importers and exporters of live sheep in 2019 (head per year).

| Country | Value | Contribution (%) |
|------------------|-----------|------------------|
| Importers | | |
| Saudi Arabia | 4,734,471 | 59.08 |
| Libya | 1,037,103 | 12.94 |
| Qatar | 862,008 | 10.76 |
| Italy | 842,374 | 10.51 |
| Kuwait | 537,269 | 6.70 |
| Total | 8,013,225 | 100 |
| Exporters | | |
| Sudan | 3,467,522 | 36.69 |
| Romania | 2,892,141 | 30.60 |
| Spain | 1,429,288 | 15.12 |
| Australia | 1,069,731 | 11.32 |
| Hungary | 591,759 | 6.26 |
| Total | 9,450,441 | 100 |

Sources: Author's compilations from FAO.

The top five importers of live sheep in 2019 (head per year) were Saudi Arabia (59.1%), Libya (12.9%), Qatar (10.8%), Italy (10.5%), and Kuwait (6.7%). The five largest exporting countries in 2019 (head per year) were Sudan (36.7%), Romania (30.6%), Spain (15.1%), Australia (11.3%), and Hungary (6.3%).

South Africa was always a relatively large importer of live sheep and imported approximately 119,065 head in 2019, with most (112,688 head) imported from the major trading partner, Namibia [4]. South Africa is Namibia's main trading partner in livestock, meat, and meat products due to the two countries' economic integration in the Southern African Development Community (SADC) and Southern African Customs Union (SACU) geographic location. SACU is established as a customs union among five countries of Southern Africa: South Africa, Namibia, Botswana, Eswatini (formerly Swaziland), and Lesotho. This has led to an increase in trade over time. In terms of live sheep exports, before 2019, South Africa had historically never been a notable role player in the international market, with exports of less than 30,000 head per year.

In 2019, however, the annual number of live sheep exports from South Africa suddenly increased after the Kuwaiti company (Al Mawashi) started importing live sheep from South Africa. One mandate of Al Mawashi is to increase their purchase of sheep from smaller producers. According to Ally [5], the share of animals per shipment procured from small commercial aspired farmers rose from 8% (first shipment in 2019) to 22% (first shipment in 2020). Al Mawashi, Australia's largest buyer of live sheep,

began to look beyond Australia for new livestock suppliers [6]. This decision was made after the Australian Government and the Independent Live Export Regulator tightened restrictions on live sheep exports in 2018. The Australian Government decided to ban exports for three months of the year during the northern summer, causing supply disruption to the Gulf States and affecting the company's ability to source sheep from Australia for 12 months [6].

The Eastern Cape Development Corporation (ECDC) led an outbound mission to Kuwait in 2018. They met with Al Mawashi to discuss the export of live sheep and carcasses [6]. This was done to improve trading opportunities in international agro-processing markets. Al Mawashi soon started investing in infrastructure in South Africa, such as the construction of a feedlot near Berlin, Eastern Cape Province of South Africa, at the cost of R10.5 million, which created 58 jobs in the process and commenced with exporting both chilled carcasses and live animals [7]. According to Smith [6], Al Mawashi stated that the quality of sheep contributed to their decision to procure from South Africa. There is a demand for up to 600,000 head of live sheep to be imported from South Africa yearly [8]. This will only be realised if the necessary scale-up operations can be carried out in South Africa. The country's current infrastructure prevents shipping many sheep for export because only four shipments per year, totalling 280,000 animals, can be accommodated [9]. Long-term infrastructure development will assist in meeting the full demand [8].

Live animal trade between countries is a practice that has been done for decades. According to Norris et al. [10], before 1989, approximately 7 million sheep per year were exported from Australia to primarily Middle Eastern countries, generating nearly AU\$250 million in export income for the Australian economy. This is not to say that the industry is without challenges. In the past, live animal exports from various countries were halted primarily due to animal welfare concerns, including a lack of oversight of animals in transit and at their destination. Poor conditions during transportation and inhumane slaughter on arrival are two issues raised by animal charities calling for better regulation of the industry. This was also the case when South African exports began, and the National Council of Societies for the Prevention of Cruelty to Animals (NSPCA) obtained an interim court interdict prohibiting Al Mawashi from loading live sheep onto its vessels. However, Al Mawashi overturned the court interdicts and proceeded with the shipment. The company further won all subsequent cases, with costs, against the NSPCA [11,12].

South Africa's climate is ideally suited for stock farming, the most viable agricultural activity in large parts of the country. Almost 70% of the 12.3 million hectares of the land surface in South Africa is only suitable for raising livestock, particularly cattle, sheep, and goats, or for wildlife ranching [13]. Therefore, the sheep industry has proliferated since the first wool breeds were imported into the country in the late 1700s [14]. Since 1996, the national sheep flock has decreased from 29 million animals to 21.6 million in 2020 [15]. The decrease in sheep can be ascribed to many reasons, including the increased cost of labour, the negative influence of stock theft, predation, and a prolonged period of agricultural drought in many sheep-producing provinces in South Africa.

An essential aspect of the South African sheep industry, which is often overlooked, is that there is both a formal (fuelled mainly by commercial producers) and an informal (primarily fuelled by subsistence and small-scale producers) market. While the national flock numbers of DALRRD [15] include all the sheep in South Africa, the production and consumption statistics published by DALRRD [16] only include the formal market. When the total annual standard slaughter number (6.429 million) is compared with the national flock number (21.6 million), formal slaughtering represents only 29.7% of the national flock. These slaughter statistics also include the live sheep

imported from Namibia to be slaughtered in South Africa. As a rule of thumb, the commercial weaning percentage (the number of lambs weaned divided by the number of ewes mated) should be close to 100%, preferably above 80%. If the study assumes that the informal market producers have lower weaning percentages than the formal market producers, it should still not be much lower than 60%. Given the above, a very conservative assumption regarding the total (formal and informal) supply of the sheep market in South Africa will be that the informal market should at least supply the same number of animals as the formal market, which should bring the total offtake from the national herd to approximately 60%.

According to the formal sheep market statistics, South Africa is a net importer of mutton and lamb. Formal production is estimated at 177,100 tonnes, imports at 9400 tonnes, exports at 2500 tonnes, and domestic consumption at 184,000 tonnes [16]. Accepting the assumption that the informal market should at least be as large as the formal market will not change much about the net trade figures. Still, it increases domestic supply to 354,200 tonnes and domestic consumption to 361,100 tonnes.

Thus, approximately 177,000 tonnes of mutton and lamb, which are supposed to be high-value products in the formal market, are used yearly in the informal market. The sheep trade in the informal market is used at the subsistence or sold as live animals at lower prices than in formal markets for various uses such as funerals or weddings. According to Bahta and Bauer [17], some of the biggest challenges for small-scale farmers in South Africa is formal market access, with farmers indicating that they do not have access to price information, buyers, agents, or auctions due to the cost of transport. These are essential indicators that these farmers may not be able to participate in export markets, thus losing income in the process.

Although the welfare aspect of the live animal trade is an important issue and has been published widely, it is essential to focus on the impact of the live sheep export trade on the economy if done humanely [18,19]. There are few studies on the economic impact of live sheep exports. Previous studies focused on restricting live sheep exports and the economic effects of phased-out live sheep exports. These studies concentrated on the Australian live sheep export market [10, 18–20]. No studies have been done to assess the economic impact of live sheep export trade in general and South Africa, particularly in empirical evidence. Therefore, the study fills this gap in the literature by assessing the impact on the national net trade balance, GDP, national income, labour, household income level and makes a significant contribution to the body of knowledge by examining the possible macroeconomic impact of the live sheep trade on the South African economy.

This study assessed the impact of the live sheep export trade on the South African economy using a recent South African Social Accounting Matrix and a partial equilibrium model. This study's findings can assist policymakers in developing appropriate policies and mitigation methods to balance the advantages and disadvantages of live sheep export and prioritise strategies to enhance the economy of South Africa.

2. Materials and methods

2.1. Description of study context

Al Mawashi procured sheep from auctions and directly from producers by signing preferential offtake agreements with producers whose sheep do meet the required export standards [21]. The sheep are procured over approximately 45 days and kept in a feedlot, receiving the necessary feed rations

and medicaments. Once the required number of animals has been procured, a 30-day quarantine period starts before the animals can be shipped.

Although the article focuses on the live sheep trade, relative to the major exporters, South Africa did not actively participate in exporting live sheep in the past. The import of live sheep to South Africa mainly consists of live imports from Namibia destined for direct slaughter in South Africa. Further, South Africa also actively imports sheep meat. South Africa exported, on average, 390 tonnes of sheep meat per year over the last four years (2017–2020) while importing 6473 tonnes during the same period [22]. Although Al Mawashi mainly purchases weaned lambs, it also makes the largest share of the shipments, and they also procure older animals depending on market demand and supply. Since the composition of sheep (type and age) varies between shipments, the assumption is that all exported sheep are lambs.

One vessel can accommodate approximately 70,000 lambs. This equals 1400 tonnes of lamb carcasses if the average carcass weight is assumed to be 20 kg. The export of two vessels of live sheep per year will thus increase sheep meat exports from 390 tonnes per year (export price R21,840,000¹) to 2800 tonnes per year (export price R156,800,000) or an addition of R141,000,000 in export earnings per year. If five vessels (7000 tonnes of sheep meat) are exported per year, the export earnings of the sheep industry will increase by R370,160,000.

2.2. Procedures

This study used a 2015 Social Accounting Matrix (SAM) of South Africa as a database and a partial equilibrium model (Price and Leontief inverse matrix model) to assess the impact of the live sheep export trade on the South African economy. The 2015 SAM is the most recent matrix available for South Africa and the most suitable for this type of analysis. The SAM was constructed by Van Seventer and Davies [23] and was then converted to a Semi-Input-Output model to meet the needs of this study. The Semi-Input-Output model is a partial equilibrium econometric model that calculates the sectorial contribution to the South African economy in terms of inverse, open inverse, multipliers, and other variables relevant to this study to quantify the magnitude of various forms of multipliers. For a detailed explanation of a SAM, refer to the work done by Burfisher [24], King [25], Round [26], and Sen [27].

A SAM is an economy-wide data framework that usually represents the real economy of a single country [28]. More technically, a SAM is a square matrix in which single-entry bookkeeping is undertaken for a set of accounts that represent various economic agents such as productive activities, commodities, factors of production, and a range of institutions such as households, Government, and the rest of the world. A row and a matching column represent each account. Each cell shows payment from an account of the column to the account of its row – the incomes of an account appear along its row, its expenditures down the column. The same underlying principle of double-entry accounting is applied and, in the SAM, requires that for each account in the SAM, total revenue (row total) equals total expenditure (column total).

The SAM has become an essential economic database for strategic economic researchers and economic policymakers. According to King [25], SAM has two main goals: The first goal of SAM is data organisation, in which the accounts in the SAM represent economic actors related to financial

¹R = Rand—South African currency.

transactions. These transactions are recorded in SAM's relevant accounts. Therefore, SAM forms a complete database of all transactions among economic actors within a certain period that provides a "comprehensive picture" of the structure of an economy. The second goal of SAM is not only to provide input data but also to update experimental results from economic models [29].

The SAM flows are valued at producers' prices in the activity accounts and at market prices (including indirect commodity taxes and trade and transport margins) in the commodity accounts. The commodities are activity outputs, either exported or sold domestically, and imports. In the activity columns, payments are made to commodities (intermediate demand) and factors of production (value-added, comprising operating surplus and compensation of employees, the latter broken down by education attainment), as well as activity (production-based) tax. In the commodity columns, payments are made to domestic activities, various tax accounts (for domestic and import taxes), trade and transport margins, and the rest of the world. In the SAM, direct payments between the enterprises, households, and Government are reserved for transfers as reported in the national accounts. Finally, payments from the Government to factors (for labour services provided by public sector employees) are captured in a government services activity. Government consumption demand is a purchase of the output from this Government's services [23].

The SAM contains several factors of production, which earn incomes from their use in the production process and then pay their incomes to enterprises, households, the Government, and the rest of the world. Indirect capital earnings or enterprise profits are taxed according to average corporate tax rates, while some profits may be repatriated abroad. The remaining capital and labour earnings are paid to households [30].

The SAM does not provide extensive accounting for the sheep industry. The sheep industry was accounted for as part of the agriculture sector. To assess the impact of the live sheep export trade on the South African economy, the sheep industry was disaggregated from the agricultural sector account using different data sources, including the Department of Agriculture, Forestry and Fisheries (DAFF) [31], International Trade Centre [32], Statistics South Africa [33], and United Nations Commodity Trade Statistics [34]. The share of gross output to the total agricultural output used DAFF [31] data. The share of sheep's gross output (gross value of output) in 2015 was 3 % of total agricultural output. The percentage of export/import sheep products to total agricultural export/import and information on import tariffs were obtained from the International Trade Centre [32] and UN COMTRADE [34]. Information on household expenditure was sourced from the income and expenditure data of Stats SA [33]. To assess the impact of live sheep exports on labour, labour was also disaggregated based on information obtained from DAFF [31] and Stats SA [33]. Further, labour coefficients, or ratios of labour to the level of gross outputs, were derived from the base SAM in which wages and prices are conventionally set to one.

Data inconsistencies occurred due to the disaggregation of the sheep industry from the agricultural sector, and the SAM became unbalanced. The SAM must be balanced as a matter of principle to proceed with the analysis, using a code in GAMS software and a cross-entropy method to balance the SAM [35–38]. (A detailed cross-entropy method explanation is provided in the Appendix).

Due to the size of the data, the SAM of South Africa was aggregated into a standard form of nine activities and nine commodities for this study, as follows: agriculture, forestry, and fisheries; mining and quarrying; manufacturing; electricity and water; construction; wholesale and retail trade; transportation, storage, and communication; financial and business services; and community services. The interest of this study was live sheep; hence the sheep sub-sector was disaggregated from the

agriculture, forestry, and fisheries industry (a balanced aggregated SAM- Based input-output model is presented in Table S1, while Table S2 and Table S3 shows the nine activities and nine commodities in Supplementary).

Price and multiplier models, based on SAM, are fixed-price equilibrium models that can be used to examine the economic impact of live sheep exports on South Africa. According to Arndt et al. [39], SAM analysis is based on three assumptions. First, quantity decisions are established using value shares because prices are set. Second, in the SAM columns, functional relationships are considered linear. This means that Leontief production functions are applied in the activity columns. Still, imports and domestic production are not substituted in the commodity columns (Leontief production functions are characterised by constant returns to scale and the absence of substitution in factor and intermediate inputs). Third, multiplier models are driven by both price and demand.

Moreover, the critical assumptions of SAM-based IO model prices are that prices are determined by the cost of production, with the supplier shifting the burden to the consumer while consumers are price takers (cost-push effects and length of adjustment path ignored) [40].

The construction of input-output matrices from a SAM is used for economic analysis. The Leontief inverse matrix and the technical input coefficients are used to do this. The number of intermediate inputs required by one sector from another to produce each country's currency (South African Rand) is expressed as the following technical coefficient (Equation 1):

$$a_{ij} = \frac{X_{ij}}{X_j} \quad (i = 1 \dots n) \text{ and } (j = 1 \dots n) \quad (1)$$

Where " a_{ij} " is the quantity of product from sector "i" necessary to produce one unit of product from sector "j"; " X_{ij} " denotes the delivery of intermediate goods from sector "i" to sector "j", and " X_j " denotes total gross output (output of the different sectors). For specific elements in a transaction table, we have Equation 2:

$$a_{11} = \frac{X_{11}}{X_1}; a_{12} = \frac{X_{12}}{X_2}; X_{1n} = \frac{X_{1n}}{X_n} \quad (2)$$

The technical coefficients matrix, which is a collection of technical coefficients, is usually denoted by the capital letter "A" (Equation 3):

$$A_{ij} = \begin{bmatrix} a_{11} & \dots & a_{12} & \dots & \dots & a_{1n} \\ a_{21} & \dots & a_{22} & \dots & \dots & a_{2n} \\ & & \dots & \dots & & \\ & & \dots & \dots & & \\ & & \dots & \dots & & \\ a_{n1} & \dots & a_{n2} & \dots & \dots & a_{nn} \end{bmatrix} \quad (3)$$

Where $(i = 1 \dots n)$ and $(j = 1 \dots n)$ are integers.

The amount of input required to achieve a given level of gross output can be expressed as follows (Equation 4):

$$O = AX_n \quad (4)$$

Where "X" is a vector of an economy's activity levels (in value terms); "A" is a vector containing the intermediate demand for its output and the total final demand for its input at rates assumed to be

independent of the levels of activity in "X" (constant returns to scale); and "O" is a vector containing the intermediate demand for its output and the total final demand for its input. Total activity "X" satisfies endogenous ("AX") and exogenous ("D") uses. Assuming "A" is parametric, any change in "D" must be accompanied by a change in "X" (Equation 5):

$$X = AX + D \quad (5)$$

When solving for "X" the following is the relationship between "D" and the activity vector "X" (Equation 6):

$$AX + D = X; D = X - AX \quad (6)$$

Equation 6 is rearranged as (Equation 7), where "I" denoted as inverse matrix:

$$D = X(I - A) \quad (7)$$

As a result (Equation 8):

$$X = (I - A)^{-1}D \text{ or } DMa \quad (8)$$

The multiplier matrix or Leontief Inverse is represented by the expression " $(I - A)^{-1}$ " or " Ma ". Recall: general layout of the IO framework: $AX + D = X$ (introducing price in Equation 6). Read down the columns and introduce prices (Equation 9):

$$\begin{bmatrix} a_{11}X_1P_1 & a_{12}X_2P_1 & a_{13}X_3P_1 \\ a_{21}X_1P_2 & a_{22}X_2P_2 & a_{23}X_3P_2 \\ a_{31}X_1P_3 & a_{32}X_2P_3 & a_{33}X_3P_3 \\ + & + & + \\ W_1P_w & W_2P_w & W_3P_w \\ = & = & = \\ X_1P_1 & X_2P_2 & X_3P_3 \end{bmatrix} \quad (9)$$

In the base: Prices are assumed to be 1 and v_j is the value-added coefficient so that: $W_jP_w = v_jX_jP_w$

Next, substitute value added coefficient and divide by X (Equation 10):

$$\begin{bmatrix} a_{11}X_1P_1 & a_{12}X_2P_1 & a_{13}X_3P_1 \\ + & + & + \\ a_{21}X_1P_2 & a_{22}X_2P_2 & a_{23}X_3P_2 \\ + & + & + \\ a_{31}X_1P_3 & a_{32}X_2P_3 & a_{33}X_3P_3 \\ + & + & + \\ V_1X_1P_w & V_1X_2P_w & V_1X_3P_w \\ = & = & = \\ X_1P_1 & X_2P_2 & X_3P_3 \end{bmatrix} \quad (10)$$

Then, simplify (Equation 11):

$$\begin{array}{|c|}
 \hline
 \begin{array}{ccc}
 a_{11P1} & a_{12P1} & a_{13P1} \\
 + & + & + \\
 a_{21P2} & a_{22P2} & a_{23P2} \\
 + & + & + \\
 a_{31P3} & a_{32P3} & a_{33P3} \\
 + & + & + \\
 V_{1Pw} & V_{2Pw} & V_{3Pw} \\
 + & + & + \\
 P_1 & P_2 & P_3
 \end{array} \\
 \hline
 \end{array} \quad (11)$$

Where a_{ij} is now a "real" technical coefficient (Transpose A matrix and present in rows).

$$\begin{aligned}
 a_{11P1} + a_{21P2} + a_{31P3} + V_{1Pw} &= P_1 \\
 a_{12P1} + a_{22P2} + a_{32P3} + V_{2Pw} &= P_2 \\
 a_{13P1} + a_{23P2} + a_{33P3} + V_{3Pw} &= P_3
 \end{aligned}$$

Write in matrix algebra (Equations 12–15):

$$\begin{aligned}
 V_{1P2} &= P_1 \\
 V_{2Pw} &= P_2 = V' \\
 V_{3Pw} &= P_3
 \end{aligned} \quad (12)$$

$$A'P + V' = P \quad (13)$$

$$P = (I - A') - 1V'' \Rightarrow 1 = (I - A') - 1V' \quad (14)$$

$$\Delta P = (I - A')^{-1} \Delta V \quad (15)$$

3. Results and discussion

This section of the manuscript presents the research findings and the associated discussions. This shows how the authors interpreted the results and related them to existing knowledge on live sheep exports.

3.1. Impact on the gross domestic product (GDP) and trade balance

Exports are crucial for improving the trade balance of the sheep meat business [8]. The exports contribute to South Africa's overall trade balance by helping to offset the country's negative trade balance in ovine meat (sheep meat). Table 2 reveals the impact of live sheep exports.

According to Table 2, the result of shipping two vessels per year and increasing the sheep industry's exports from 390 tonnes per year to 2800 tonnes per year will improve the net trade balance by 0.076%, and an extra 0.001% will be contributed to the GDP of South Africa. Increasing live exports to five vessels per year (7000 tonnes) will increase the net trade balance by approximately 0.190%, while 0.003% will be added to the GDP of South Africa. These findings were in line with those of Hassall and Associates [41], who found that live sheep export contributed 10.3% to the rise of the Australian sheep meat industry's gross value. Islam [42] also found that live sheep exports contributed 0.040% to the trade balance.

Table 2. Impact of live sheep exports.

| Base: 390 | Tonne | |
|----------------------------------|-----------------|-----------------|
| | 2800 | 7000 |
| Net trade balance | 0.076% | 0.190% |
| Gross domestic product (GDP) | 0.001% | 0.003% |
| National income | R141,000,000.00 | R370,160,000.00 |
| Sheep slaughtered | -2.800% | -7.000% |
| Labour utilised for slaughtering | -0.500% | -1.200% |
| Local economy | -0.070% | -0.160% |
| Income of household | -0.210% | -0.510% |

Source: Author's calculation.

Furthermore, according to Villiers [8], the new market for live exports will increase demand, especially during the economic downturn first caused by COVID-19 and subsequently by the increased inflation and interest rates. It will help stabilise local lamb prices, as local demand for lamb is expected to decline as the economy slows. These lessons are essential for the South African sheep industry since they inform how the functions along the sheep value chain can be modified. Australia has a live sheep export market that accommodates small-scale and large-scale sheep farmers. This dual model is similar to the one currently used in South Africa.

3.2. Impact on labour and income

On the other hand, some value addition through the value chain in South Africa is lost when live lambs are exported. The value additions are products other than the main carcass that can also be processed and sold in markets. These include sheep carcasses, the sheep hides and skin, offal, head, and internal organs such as the heart, intestines, lungs, liver, and others which can also be consumed. All these cannot be harnessed if the sheep are sold live and slaughtered in the destination countries. Exporting two or five vessels of live sheep per year will increase the export earnings by R141,000,000 and R370,160,000, respectively. However, the number of sheep slaughtered in South Africa will decrease by 2.8% and 7%, respectively (Table 2).

With exporting two or five vessels of live sheep per year, the respective reductions in labour utilised for slaughter were 0.5% and 1.2%; income at the local economy level 0.07%, and 0.16%; and income at the household level 0.21% and 0.51% (Table 2). These findings are backed by Breusch [43] research, which found that if animals shipped live were slaughtered in Australia, sheep and lamb prices in Australia might drop by 18% to 35%. Breusch [43] appears to have arrived at these conclusions by presuming that sheep slaughter in Australia is the basis for setting the state's mutton and lamb export pricing rather than prices established in international markets.

Furthermore, the Department of Agriculture Australia [44] stated that if sheep planned for live export are processed in Australia, total employment in Australia will undoubtedly grow (locally). This is because meat processing is a labour-intensive business likely to employ more people than the live export industry [45]. In the three years leading up to 2016–2017, the Australian meat processing sector employed an average of 4 500 full-time workers yearly. Halting live exports might increase it with 350 full-time jobs in the meat processing industry [45].

4. Conclusions

The global trade in live farm animals has quadrupled over the last few decades. Yet, there is concern about the lack of control of animals in transit and at arrival due to uneven regulations. Globally and particularly in South Africa, without a well-performing livestock subsector, particularly the sheep subsector, achieving global and regional commitments to end poverty and hunger (SDGs 1 & 2) will be impossible. Because no meat preservation techniques are necessary, commerce in live animals has fewer infrastructure requirements than the trade in processed animal products. As a result, the live animal trade has become more accessible and prevalent. Live animal commerce offers the potential to quickly destock or refill livestock production systems in places experiencing long-term crises or reacting to climatic unpredictability. Therefore, this study assesses the impact of the live sheep export trade on the South African economy using a recent South African Social Accounting Matrix (SAM) and a partial equilibrium model.

The economic impact of the live sheep export trade on the South African economy has mixed results. On a positive note, the higher the demand for live sheep exports, the higher the prices and the more significant the economic impact. On the other hand, South Africa loses value-adding opportunities such as output from abattoirs, including hides and skin, offal, head, and consumable internal organs, and employment when live lambs are exported and slaughtered in destination markets.

The study recommends that the provincial government assist producers in becoming more involved in the live sheep export market by negotiating preferential offtake agreements between, especially, the small-scale farmers and the exporter. Involving producers who were previously supplying the informal market in the formal market through live exports should assist in balancing the advantages and disadvantages of live sheep export and prioritise strategies that will enhance the economy of South Africa. The findings of this study could help governments and policymakers develop appropriate policies and mitigation strategies.

The study is static and not dynamic. As a result, the study recommends that future research considers recent infrastructure development concerning the live sheep market using a dynamic Computable General Equilibrium Model.

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Conflict of interest

We declare that this work is original academic research carried out by the authors. We confirm that the manuscript has not been submitted elsewhere and is not under consideration by another journal. We declare no conflicts of interest.

Supplementary

Cross-entropy (CE) method

The cross-entropy (CE) method of balancing a SAM has become a typical procedure in most SAM-based models. The CE method, according to Robinson, Cattaneo, and El-Said [38], is based on Shannon's [46] information theory, which was applied to economics by Theil [47]. The key notion is that as indicated in equation (16), the expected information value of extra data may be expressed as a Kullback and Leibler [48], CE distance "I" between the prior "q" and posterior "p" probability distributions of a collection of "n" occurrences (Equation 16):

$$-I(p:q) = \sum_{i=0}^n P_i \ln \frac{P_i}{q_i} \quad (16)$$

The goal of the CE problem is to determine the set of "P_i" that minimizes Equation (16) utilizing previous data knowledge. The objective in SAM estimation or updating is to construct a new SAM coefficient matrix "A*" that minimizes the CE distance between itself and the prior (or initial and likely imbalanced) coefficient matrix "A". The minimization problem can be phrased as follows if "a*_{ij}" and "a_{ij}" are the respective elements of "A*" and "A" (Equation 17):

$$\text{Min} \left[\sum_i \sum_j a_{ij} \ln \frac{a^*_{ij}}{a_{ij}} \right] = \text{Subject to: } \sum_j a_{ij} y^*_j = y^*_i; \sum_j a_{ji} = 1 \text{ and } 0 \leq a_{ji} \leq 1 \quad (17)$$

After setting up the Lagrangian multiplier, the problem in Equation 17 does not have a closed-form solution and must be solved numerically. The ideal solution "a*_{ij}" may, however, be expressed as a function of both the Lagrange multipliers "I" associated with the row and column sums and the initial coefficient "a_{ij}" (Equation 18):

$$a^*_{ij} = \frac{a_{ij} \exp(\lambda_i y^*_j)}{\sum_{i,j} a_{ij} \exp(\lambda_i y^*_j)} \quad (18)$$

Robinson, Cattaneo, and El-Said [38], compare Equation 18 to Bayes's rule, which states that the posterior distribution equals the sum of the prior distribution and the likelihood function, divided by a normalization factor to convert relative probabilities to "absolute ones." As a result, Equation 18 can be viewed as an effective information processing rule that adheres to Zellner's information conservation principle [49]. It does not ignore any of the input data, and it also does not generate any misleading data. Robinson, Cattaneo, and El-Said [38] cite Golan et al. [50], in support of their claim that the CE estimator is consistent and possesses maximum likelihood features for some distributional assumptions.

Incorporating aggregation limitations and measurement errors into the fundamental minimization problem in Equation 17 enriches the problem. A typical aggregation constraint for k restrictions can be written as follows (Equation 19):

$$\sum_i \sum_j g_{ij}^{(k)} t_j = y^{(k)} \quad (19)$$

Where "g_{ij}" denotes an n-by-n aggregator matrix with ones for aggregate cells and zeros otherwise. Assume there are "k" aggregation constraints in total. Similarly, measurement mistakes are taken into

account in the following way (Equation 20):

$$y = x + e \quad (20)$$

Where "y" is a vector of row sums and "x" is a vector of known column sums measured with error "e." The error is calculated using a weighted average of known constants "v_{i,w}" as follows (Equation 21):

$$e_i = \sum_w w_{i,w} \cdot v_{i,w}$$

$$\sum_w w_{i,w} = 1 \text{ and } 0 \leq w_{i,w} \leq 1 \quad (21)$$

The weights are modeled as probabilities that are computed in conjunction with the matrix components "A*." The estimation method employed in this work is based on five symmetrical weights around zero. Equations 19–21, are used to solve the minimization issue (Equation 17).

Table S1.1. Aggregated SAM, R-million.

| Part 1 | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 |
|-----------|-----------|----------|---------|-----------|------------|-----------|-----------|-----------|-----------|------------|------------|
| A1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A4 | 0.00 | 0.00 | 0.00 | 6197.97 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| A11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C1 | 4119.21 | 581.54 | 145.38 | 18.18 | 104150.94 | 28.35 | 5.29 | 468.09 | 10.52 | 179.70 | 4368.09 |
| C2 | 581.54 | 82.10 | 20.52 | 2.57 | 14703.66 | 4.00 | 0.75 | 66.08 | 1.48 | 25.37 | 616.67 |
| C3 | 145.38 | 20.52 | 5.13 | 0.64 | 3675.92 | 1.00 | 0.19 | 16.52 | 0.37 | 6.34 | 154.17 |
| C4 | 3664.84 | 517.39 | 129.35 | 5157.26 | 211972.79 | 29842.40 | 16112.34 | 67.43 | 1743.42 | 0.00 | 12271.67 |
| C5 | 4731.17 | 667.93 | 166.98 | 16138.03 | 23036.00 | 9403.71 | 0.00 | 0.00 | 0.00 | 0.00 | 28.84 |
| C6 | 70196.24 | 9910.06 | 2477.51 | 112357.66 | 860410.52 | 25469.67 | 197826.32 | 167282.65 | 176326.24 | 126707.98 | 240440.19 |
| C7 | 47.88 | 6.76 | 1.69 | 422.47 | 1244.77 | 50.54 | 2090.78 | 157.98 | 1437.72 | 1874.21 | 611.46 |
| C8 | 181.44 | 25.61 | 6.40 | 571.92 | 4741.36 | 389.16 | 1303.92 | 5944.12 | 11022.23 | 19630.34 | 5282.12 |
| C9 | 12740.71 | 1798.69 | 449.67 | 73392.44 | 67291.10 | 27631.03 | 4792.17 | 35969.10 | 29472.84 | 36020.20 | 25571.63 |
| C10 | 11941.28 | 1685.83 | 421.46 | 35024.81 | 83295.00 | 5479.74 | 51001.16 | 146657.18 | 108235.27 | 385025.80 | 180812.21 |
| C11 | 6197.97 | 875.01 | 218.75 | 7980.04 | 76903.21 | 5553.99 | 12602.12 | 38840.87 | 38367.93 | 101881.78 | 167851.28 |
| TRNCSTDOM | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| FLAB | 22775.90 | 3215.42 | 803.86 | 132670.03 | 302228.47 | 38746.29 | 58249.19 | 218512.05 | 115314.03 | 304025.41 | 709511.36 |
| FCAP | 48278.94 | 6815.85 | 1703.96 | 146282.29 | 167309.68 | 98215.81 | 64060.46 | 204973.45 | 213887.40 | 363359.14 | 332503.00 |
| EN | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| HH | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| GOV | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ACTTAX | 369.27 | 52.13 | 13.03 | 3538.62 | 4616.23 | 7.21 | 1490.50 | 9982.42 | 5386.47 | 34683.17 | 12131.96 |
| YTAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| IMPTAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| STAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| S-I | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DSTK | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ROW | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 185971.76 | 26254.84 | 6563.71 | 539754.94 | 1925579.65 | 240822.91 | 409535.17 | 828937.96 | 701205.93 | 1373419.44 | 1692154.67 |

Table S1.2. Aggregated SAM, R-million.

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 |
|-----------|-----------|----------|---------|-----------|----------|------------|-----------|-----------|-----------|------------|------------|
| A1 | 155990.83 | 22022.24 | 5505.56 | 0.00 | 0.00 | 0.00 | 2346.03 | 0.00 | 0.00 | 107.10 | 0.00 |
| A2 | 22022.24 | 3109.02 | 777.26 | 0.00 | 0.00 | 0.00 | 331.20 | 0.00 | 0.00 | 15.12 | 0.00 |
| A3 | 5505.56 | 777.26 | 194.31 | 0.00 | 0.00 | 0.00 | 82.80 | 0.00 | 0.00 | 3.78 | 0.00 |
| A4 | 0.00 | 0.00 | 0.00 | 512285.37 | 14565.31 | 0.00 | 0.00 | 0.00 | 0.00 | 6706.29 | 0.00 |
| A5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1895532.20 | 0.00 | 0.00 | 0.00 | 29759.15 | 288.30 |
| A6 | 0.00 | 0.00 | 0.00 | 0.00 | 44031.65 | 0.00 | 0.00 | 0.00 | 196172.17 | 619.09 | 0.00 |
| A7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 291031.46 | 0.00 | 4840.40 | 113663.31 | 0.00 |
| A8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 768177.19 | 0.00 | 5369.38 | 55391.39 |
| A9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12212.71 | 0.00 | 0.00 | 504864.26 | 14747.21 | 169381.74 |
| A10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 322.40 | 0.00 | 0.00 | 1271531.20 | 101565.84 |
| A11 | 250.68 | 35.39 | 8.85 | 462.16 | 0.00 | 25649.65 | 65793.30 | 136271.09 | 54625.42 | 83543.31 | 1325514.82 |
| C1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| C11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TRNCSTDOM | 28566.35 | 4032.90 | 1008.22 | 29632.20 | 0.00 | 920769.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| FLAB | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| FCAP | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| EN | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| HH | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| GOV | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ACTTAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| YTAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| IMPTAX | 474.21 | 66.95 | 16.74 | 0.04 | 0.00 | 43750.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| STAX | 3077.86 | 434.52 | 108.63 | 1221.75 | 6.02 | 243854.78 | 1513.92 | 8295.93 | 22.44 | 39344.49 | 83518.65 |
| SI | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DSTK | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ROW | 15841.13 | 2236.40 | 559.10 | 145335.75 | 29.07 | 936056.52 | 1177.57 | 26949.34 | 41239.60 | 50896.36 | 53612.15 |
| Total | 231728.86 | 32714.66 | 8178.67 | 688937.27 | 58632.05 | 4077825.21 | 362598.69 | 939693.56 | 801764.29 | 1616305.81 | 1789272.88 |

Table S1.3. Aggregated SAM, R-million.

| | TRNCSTDOM | FLAB | FCAP | EN | HH | GOV | ACTTAX | YTAX | IMPTAX | STAX | SI | DSTK | ROW | Total |
|-----------|-----------|------------|------------|------------|------------|------------|----------|-----------|----------|-----------|-----------|----------|------------|------------|
| A1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 185971.76 |
| A2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 26254.84 |
| A3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6563.71 |
| A4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 539754.94 |
| A5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1925579.65 |
| A6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 240822.91 |
| A7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 409535.17 |
| A8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 828937.96 |
| A9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 701205.93 |
| A10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1373419.44 |
| A11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1692154.67 |
| C1 | 0.00 | 0.00 | 0.00 | 0.00 | 91764.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -327.18 | 26216.45 | 231728.86 |
| C2 | 0.00 | 0.00 | 0.00 | 0.00 | 12954.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -46.19 | 3701.15 | 32714.66 |
| C3 | 0.00 | 0.00 | 0.00 | 0.00 | 3238.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -11.55 | 925.29 | 8178.67 |
| C4 | 0.00 | 0.00 | 0.00 | 0.00 | 1930.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11067.78 | 394460.09 | 688937.27 |
| C5 | 0.00 | 0.00 | 0.00 | 0.00 | 992.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -138.96 | 3605.65 | 58632.05 |
| C6 | 0.00 | 0.00 | 0.00 | 0.00 | 1023766.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 414187.43 | 5557.13 | 644908.98 | 4077825.21 |
| C7 | 0.00 | 0.00 | 0.00 | 0.00 | 3520.66 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 350203.73 | -192.86 | 1120.91 | 362598.69 |
| C8 | 799256.96 | 0.00 | 0.00 | 0.00 | 75044.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -263.97 | 16557.61 | 939693.56 |
| C9 | 184751.99 | 0.00 | 0.00 | 0.00 | 267005.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -626.63 | 35503.73 | 801764.29 |
| C10 | 0.00 | 0.00 | 0.00 | 0.00 | 475031.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 63853.84 | 14862.90 | 52977.77 | 1616305.81 |
| C11 | 0.00 | 0.00 | 0.00 | 0.00 | 462021.03 | 828934.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -725.48 | 41770.37 | 1789272.88 |
| TRNCSTDOM | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 984008.95 |
| FLAB | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10488.00 | 1916540.00 |
| FCAP | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 87528.00 | 1734918.00 |
| EN | 0.00 | 0.00 | 939463.00 | 177258.00 | 337556.00 | 383518.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1837795.00 |
| HH | 0.00 | 1904048.00 | 520600.00 | 562077.00 | 0.00 | 427039.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 21129.00 | 3434893.00 |
| GOV | 0.00 | 0.00 | 88965.00 | 268266.00 | 248827.00 | 197935.00 | 72271.00 | 607552.00 | 44308.00 | 381399.00 | 0.00 | 0.00 | 3236.00 | 1912759.00 |
| ACTTAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 72271.00 |
| YTAX | 0.00 | 0.00 | 0.00 | 212908.00 | 394644.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 607552.00 |
| IMPTAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 44308.00 |
| STAX | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 381399.00 |
| SI | 0.00 | 0.00 | 0.00 | 617286.00 | 28223.00 | 25807.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 186084.00 | 857400.00 |
| DSTK | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 29155.00 | 0.00 | 0.00 | 29155.00 |
| ROW | 0.00 | 12492.00 | 185890.00 | 0.00 | 8372.00 | 49526.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1530213.00 |
| Total | 984008.95 | 1916540.00 | 1734918.00 | 1837795.00 | 3434893.00 | 1912759.00 | 72271.00 | 607552.00 | 44308.00 | 381399.00 | 857400.00 | 29155.00 | 1530213.00 | |

Where: A Activities-A1 (Agriculture, forestry & fishing); A2 (Cattle); A3 (sheep); A4 (Mining & quarrying); A5 (Manufacturing); A6 (Electricity & water); A7 (Construction); A8 Wholesale & retail trade); A9 (Transport, storage & communication); A10 (Financial & business services) and A11 (Community services). C Commodities-C1 (Agriculture, forestry & fishing); C2 (Cattle); C3 (sheep); C4 (Mining & quarrying); C5 (Manufacturing); C6 (Electricity & water); C7 (Construction); C8 (Wholesale & retail trade); C9 (Transport, storage & communication); C10 (Financial & business services) and C11 (Community services). TRNCSTDOM: Transaction cost/margin; Factors: FLAB (Factor labour) and FCAP (Factor capital); EN: Enterprises-Government and private enterprise; HH: Households; GOV: Government service; ACTTAX: Activity tax; YTAX: Income tax; IMPTAX: Import tax; STAX: Indirect tax; SI: Saving and investment; DSTK: Change in stock; and ROW: Rest of the world.

Table S2. Detailed components of activities.

| Activities | |
|---|--|
| Agriculture, Forestry & Fishing | A01 (Agriculture, forestry & fishing) |
| Cattle | |
| Live sheep | Disaggregated—variable interest for analysis |
| Mining of coal and lignite | A02 (Mining & quarrying) |
| Other mining and quarrying | |
| Food | A03 (Manufacturing) |
| Beverages and tobacco | |
| Spinning, weaving and finishing of textiles | |
| Knitted, crouched fabrics, wearing apparel, fur articles | |
| Tanning and dressing of leather | |
| Footwear | |
| Sawmilling, planing of wood, cork, straw | |
| Paper | |
| Publishing, printing, recorded media | |
| Coke oven, petroleum refineries | |
| Nuclear fuel, basic chemicals | |
| Other chemical products, man-made fibers | |
| Rubber | |
| Plastic | |
| Glass | |
| Non-metallic minerals | |
| Basic iron and steel, casting of metals | |
| Basic precious and non-ferrous metals | |
| Fabricated metal products | |
| Machinery and equipment | |
| Electrical machinery and apparatus | |
| Radio, television, communication equipment and apparatus | |
| Medical, precision, optical instruments, watches and clocks | |
| Motor vehicles, trailers, parts | |

Continued on the next page

| Activities | |
|--|--|
| Other transport equipment | |
| Furniture | |
| Manufacturing n.e.c, recycling | |
| Electricity, gas, steam and hot water supply | A04 (Electricity & water) |
| Collection, purification and distribution of water | |
| Construction | A05 (Construction) |
| Wholesale and retail trade (incl. repairs) | A06 (Wholesale and retail trade) |
| Hotels and restaurants | |
| Transport | A07 (Transport, storage & communication) |
| Post and telecommunication | |
| Financial intermediation | A9 (Financial & business services) |
| Insurance and pension funding | |
| Real estate activities | |
| Research and experimental development | |
| Renting of machinery and equipment | |
| Other business activities | |
| Government | A9(Community services) |
| Education | |
| Health and social work | |
| Other activities | |

Table S3. Detailed components of commodities.

| Commodities | |
|--|--|
| Agriculture, Forestry & Fishing and live animals | C01 (Agriculture, forestry & fishing) |
| Cattle | |
| Live sheep | Disaggregated—variable interest for analysis |
| Coal and lignite | C02 (Mining & quarrying) |
| Metal ores and other minerals | |
| Meat | C03 (Manufacturing) |
| Fish process product | |
| Vegetables, fruits and nuts | |
| Oils and fats | |
| Dairy products | |
| Grain mill products | |
| Starches products | |
| Animal feeding | |
| Bakery products | |
| Sugar | |
| Confectionary products | |
| Pasta products | |
| Food n.e.c. | |

Continued on the next page

Commodities

Alcohol, beverages, and tobacco products

Textile fabrics

Made-up textile, articles

Carpets

Textile n.e.c.

Knitting fabrics

Wearing apparel

Leather products

Footwear

Wood products

Paper products

Printing

Petroleum products

Basic chemicals

Fertilizers, pesticides

Paint, related products

Pharmaceutical products

Soap, cleaning, perfume

Chemical products, n.e.c.

Rubber tyres

Other rubber products

Plastic products

Glass products

Ceramics

Plaster, cement, and articles of concrete

Non-metallic products n.e.c.

Iron, steel products

Non-ferrous metals

Metal products

Engines, turbines

Pumps, compressors

Bearings, gears

Lifting equipment

General machinery

Special machinery

Domestic appliances

Office machinery

Electrical machinery

Radio, television

Medical appliances

Motor vehicles, parts

Ships and boats

Continued on the next page

| Commodities | |
|--|---|
| Railway and trams | |
| Aircrafts | |
| Other transport equipment | |
| Furniture | |
| Jewellery | |
| Manufactured products n.e.c. | |
| Wastes, scraps | C04 (Electricity & water) |
| Electricity distribution | |
| Water distribution | |
| Construction and related services | C05 (Construction) |
| Trade services | C06 (Wholesale and retail trade) |
| Accommodation and catering services | |
| Transport services | C07(Transport, storage & communication) |
| Telecommunications and postal services | |
| Financial services | C8(Financial & business services) |
| Insurance, pension | |
| Real estate services | |
| Research, development | |
| Legal, accounting | |
| Leasing, Rental services | |
| Other business services | |
| Public administration | C9 (Community services) |
| Education services | |
| Health, social services | |
| Other services n.e.c. | |

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