INPUT-OUTPUT ANALYSIS: THE CASE OF FOOT-AND-MOUTH DISEASE IN BRAZIL

MENEZES, Taís Cristina de; CUNHA, Marcelo Pereira da

Abstract: Brazil is an important supplier of meat on the international market, occupying the position of largest exporter of beef and fourth largest exporter of pork. As a result, the country increasingly needs to implement measures to ensure compliance with the health requirements imposed by the markets that import these products. A widely discussed issue, in this context, is foot-and-mouth disease (FMD), a highly contagious disease that affects animals with bipartite hooves and causes several restrictions on trade between countries. This paper aims to measure the economic impacts of an outbreak of FMD, from the closure of importing markets for beef and pork from Brazil, using an Input-Output model. The results show that the closing of the international market could cause a reduction in the value of Brazilian production between R$ 7.1 billion and R$ 8.1 billion, a drop in GDP between R$ 2.6 billion and R$ 3 billion, in addition to reducing the number of employed people by 60-70 thousand. These losses are approximately 30 times greater than the budget spent on agricultural defense by the Brazilian government. The results indicate that adverse events to animal health can cause significant socioeconomic losses, showing the importance of maintaining the health of herds in Brazil.

Keywords: foot-and-mouth disease; Brazil; input-output analysis; exports.

1. Introduction

Globalization has intensified the flow of animals, products and people between all countries in the world. Consequently, the risk of transmitting pathogens from one country to another has increased (FAO & OIE, 2012). The recent epidemic of African swine fever – which affected swine in Asia, Africa and Europe – and the coronavirus pandemic have highlighted how fast diseases can spread and their catastrophic potential on the affected countries economy. These events raised concerns about bioterrorism and biological threats and underlined the importance of studies that contribute to the elaboration of strategic plans and policies for the mitigation of health and economic risks related to human and animal diseases.

Among animal diseases, Shankar et al. (2012) state that foot-and-mouth disease (FMD) is the disease that has received the most attention in the long run, absorbing a significant proportion of animal disease control budgets and projects worldwide. FMD is highly transmissible, making it difficult to contain within specific areas. With the increasing extent and intensity of global interconnection, the management of this disease is increasingly challenging. This implies that FMD is not only a constant problem in endemically infected countries, but also a constant threat to free countries. Its control, therefore, generates an international public good. FMD is so important that it led to an initiative launched by the Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (OIE) for its global control (FAO & OIE, 2012).

In Brazil, the National Foot and Mouth Disease Prevention and Eradication Program (PNEFA[1]) was the first and largest consolidated animal health program created by the Ministry of Agriculture, Livestock and Supply (MAPA). Currently, Brazilian policies related to the

[1] PNEFA had some of its guidelines recently updated by Normative Instruction No. 48 of July 14, 2020 (MAPA, 2020b).

control and eradication of FMD are being modified in order to achieve a higher international health status - which may benefit exports of Brazilian animals and animal products, such as beef and pork. On April 29, 2020, Normative Instruction No. 36 was published, prohibiting the vaccination of animals against FMD in the states of Rio Grande do Sul, Acre, Rondônia, part of Amazonas and part of Mato Grosso (MAPA, 2020a). According to the Strategic Plan of PNEFA 2017-2026, all Brazilian states will suspend vaccination against FMD until the end of 2021 (MAPA, 2017).

Over the 2000s, cattle raising evolved at an accelerated rate in Brazil, which currently holds the largest commercial herd in the world, with 213.5 million head (IBGE, 2020). Brazilian pig raising has also evolved significantly in the past two decades, presenting the third largest pig herd in the world – just behind China and the European Union (USDA, 2020). This growth has made Brazil the largest producer and exporter of beef in the world, and the fourth largest producer and exporter of pork. However, despite presenting an increasing volume of exports of beef and pork, the livestock sector has shown a certain fragility in face of the demands imposed by large importing markets. Brazil faces several barriers to its exports. More specifically, Brazilian meats face tariff and non-tariff barriers that can jeopardize their commercialization in the international market (Gonçalves & Neto, 2010; Florindo et al., 2015; Ferreira et al., 2019).

During the rounds of multilateral negotiations under the General Agreement on Tariffs and Trade (GATT) of the World Trade Organization (WTO), there were reductions in tariff barriers and in the granting of subsidies - especially during the Uruguay Round (1986–1994). However, this process of countries' trade opening, determined by the mitigation of traditional protection measures, has been offset by the intensification of non-tariff mechanisms for trade protection. Non-tariff barriers consist of any restriction, expense or policy that is not a tariff, limiting access to imported products, in the form of quotas, licensing systems, health regulations and prohibitions (Carneiro, 2015). In this context, there are demands from the international market on the FMD status.

Once FMD is found in a previously free country, strict control measures are taken to eradicate it, including the slaughter of animals on infected properties and restriction of movement of animals, animal products, people and objects susceptible to contamination. Restrictions on international trade of animals and animal products are imposed on the country in crisis until it regains its FMD-free status. Outbreaks of FMD in the United Kingdom (2001), Japan (2010) and South Korea (2011) have shown that the disease can be reintroduced and spread in free countries even though they have sophisticated biosecurity systems.

The FMD virus is listed by OIE (2019) as one of the main animal infectious pathogens and is considered one of the greatest potential threats from bioterrorism (Casagrande, 2002; Breeze, 2004; Lee et al., 2012; Oladosu et al., 2013). Susceptible animals can spread this virus for several days without showing clinical signs of the disease (Buetre et al., 2013). Therefore, the costs of controlling and eradicating outbreaks are significant.

The great concern about this virus is due to the fact that it is highly contagious and can be transmitted (in addition to direct contact between animals) by contaminated animal products; by contact with secretions; by humans, non-susceptible animals, vehicles and equipment that have been in contact with infected animals; and it can also be transmitted by soil, air and water. The FMD virus can cross international borders by transporting infected animals and importing animal products.

Brazil has been internationally recognized as an FMD-free country since May 2018. The last outbreak in the country occurred between September 2005 and April 2006 in the state of Mato Grosso do Sul, an FMD-free zone with vaccination. This outbreak caused economic losses for livestock and related industries and the magnitude of these losses is still unknown. Among them, the most evident loss was the reduction in exports of beef and pork from Mato Grosso do Sul.

The costs of interruption in the agricultural chain caused by FMD are increased in countries where export markets are significant. Restrictions on access to the international market affect agriculture and the entire national economy, in addition to the region where the outbreak occurred (Lee et al., 2012; Oladosu et al., 2013).

In this sense, the present study aims to analyze the economic impacts of a FMD outbreak in Brazil, assuming a reduction in exports of beef and pork from Mato Grosso do Sul similar to that observed in 2006. Therefore, we use an Input-Output (I-O) model, based on the Brazilian input-output matrix for 2015, most recently published. The I-O model allows estimating which sectors would receive the side effects of reduced exports and what would be the extent of these effects.

It is known that the economic effects of FMD go beyond reductions in exports. However, it would be necessary to use an epidemiological model to estimate the size of an outbreak to estimate other types of impact, a model that does not yet exist for Brazil. The present study is limited to assessing the negative impacts of reduced exports on the Brazilian economy, although we recognize that the results will be underestimated because they do not take into account other impacts of the disease.

An understanding of the impacts of FMD is necessary to guide its control policy. In this context, the importance of promoting studies that assist in the formulation of strategies and policies for monitoring, controlling and eradicating outbreaks of animal diseases in Brazil is evident.

This paper is divided into three more sections, in addition to this introduction. The methodology and data used are detailed below. Subsequently, the results obtained from the proposed model are described and discussed. The last section presents the conclusion of the study.

2. Materials and methods

Several studies evaluate the potential economic impacts of FMD outbreaks in different countries. One of the most common approaches for this assessment are the I-O models (Ekboir, 1999; Mahul & Durand, 2000; Pendell et al., 2007; Rose et al., 2009; Cozzens et al., 2010; Lee et al., 2012; Kim, 2015; Hayama et al., 2017). I-O modeling reflects the structure of an economy and the interaction between its various productive sectors and consumers.

For Brazil, there are no studies that estimate the economic impacts of FMD using the I-O approach. This paper is based, then, on the instructions of Miller and Blair (2009) to build and analyze the I-O model for the Brazilian economy.

For the I-O model used in this study, the estimate structure for the economic impacts of a FMD outbreak is composed of an estimate of the direct, indirect and induced costs for

livestock and livestock-related industries from a reduction in beef and pork exports. In this context, economic impacts related to market instability, caused by the reaction of consumers or producers, are not considered.

The advantage of the I-O approach is that it allows estimating, in addition to the direct effects, which sectors receive side effects (spillover effects) and the size of these effects in case of an outbreak of FMD (RICH et al., 2005a; RICH et al., 2005b).

2.1 Data

The database for the analysis of the I-O model was given by the Input-Output Matrix for the year 2015, prepared from the Tables of Resources and Uses published by the Brazilian Institute of Geography and Statistics (IBGE, 2020). The data in this matrix provide a detailed view of the Brazilian productive structure, allowing to assess the degree of sectorial interconnection of the economy, as well as the impacts of variations in the final demand for products. The present study uses the matrix disaggregated into 67 activities and 127 products. However, for a better presentation of the results, the 67 sectors were aggregated into 23.

In addition, data on exports from Brazil and the state of Mato Grosso do Sul were used. More specifically, we selected data on exports of beef and pork, in US$ FOB, for the years 2005, 2006, 2014 and 2015. These data were obtained from the ComexStat database of the Ministry of Industry, Foreign Trade and Services (MDIC, 2020). The data were consulted according to the Mercosur Common Nomenclature codes presented in **Table 1**.

Table 1. Mercosur Common Nomenclature codes

Type	Code	Description
Beef	02.01.1000	Carcasses/half-carcasses of bovine fresh/chilled
	02.01.2010	Fresh/chilled forequarters of bovine with bone in
	02.01.2020	Fresh/chilled hindquarters of bovine with bone in
	02.01.2090	Other fresh/chilled cuts of bovine with bone in
	02.01.3000	Fresh or chilled bovine meat, boneless
	02.02.1000	Frozen bovine carcasses and half-carcasses
	02.02.2010	Frozen forequarters of bovines, with bone in, frozen
	02.02.2020	Frozen hindquarter of bovines, with bone in, frozen
	02.02.2090	Other frozen bovine cuts
	02.02.3000	Frozen bovine meat, boneless
	02.06.1000	Edible offal of bovine, fresh or chilled
	02.06.2100	Frozen edible bovine tongues
	02.06.2200	Frozen edible bovine livers
	02.06.2910	Frozen edible bovine tails
	02.06.2990	Other frozen edible bovine offal
	02.10.2000	Meat of bovine, salted/in brine/dried/smoked
	05.04.0011	Fresh/chilled/frozen/salted/smoked guts of bovine
Pork	02.03.1100	Fresh or chilled carcasses and half-carcasses of swine
	02.03.1200	Fresh/chilled hams/shoulders/cuts of swine with bone in
	02.03.1900	Other fresh or chilled meat of swine
	02.03.2100	Frozen carcasses and half-carcasses of swine

02.03.2200	Frozen hams, shoulders and cuts of swine
02.03.2900	Other swine meat, frozen
02.06.3000	Fresh or chilled edible offal of swine
02.06.4100	Frozen edible livers of swine
02.06.4900	Other edible offal of swine, frozen
02.10.1100	Hams, should. and cuts of swine, with bone in, salted, etc.
02.10.1200	Bellies and chest "streaky" of swine, salted, etc.
02.10.1900	Other meat of swine, salted, brine, dried, etc.
05.04.0013	Fresh/chilled/frozen/salted/smoked guts of swine

Source: Elaborated from MDIC (2020)

All export data in dollars (US$) were converted into reais (R$) by a real exchange rate for 2015, calculated from the annual exchange rate (IPEADATA, 2020), the General Price Index-Internal Availability (IGP-DI - IPEADATA, 2019) and the United States Consumer Price Index (CPI-USA - INFLATION EU, 2020). This conversion was necessary because the data in the Brazilian I-O matrix are in Reais (local currency) and, therefore, the shocks could not be in dollars.

2.2 Model closure

Given the objective of analyzing the impacts of a reduction in beef and pork exports on the Brazilian economy, the final demand for each product must be exogenous to the model, in order to allow shocks on the "beef" and "pork" products. Thus, the model closure is determined by the following equation:

$$(\boldsymbol{I} - \boldsymbol{B} \times \boldsymbol{D})^{-1} \times \boldsymbol{E} = \boldsymbol{Q} \quad (1)$$

where: $\boldsymbol{I}$ = identity matrix; $\boldsymbol{B}$ = matrix of technical coefficients of sectors in relation to products; $\boldsymbol{D}$ = market-share matrix; $\boldsymbol{E}$ = vector of final demand for products; $\boldsymbol{Q}$ = total demand for products.

With the necessary derivations (see Miller & Blair, 2009) we have:

$$\Delta \boldsymbol{X} = \boldsymbol{L} \times \Delta \boldsymbol{Y} \quad (2)$$

where: $\Delta \boldsymbol{X}$ = vector of variation in the production value of the sectors of the economy; $\mathbf{L}$ = Leontief inverse matrix; $\Delta \boldsymbol{Y}$ = vector of variation in the final demand of the economy.

From equation 2, it is possible to calculate the direct and indirect effects of shocks on the sectors final demand vector. Subsequently, in order to calculate the induced effects of this shock, families become endogenous to the model. To this end, a marginal propensity to consume of 80.5% was considered, estimated by Leite (2015) based on data from the Household Budget Survey (*Pesquisa de Orçamentos Familiares* - POF).

2.3 Exogenous shocks

To assess the impacts of an outbreak of FMD, considering a reduction in Brazilian beef and pork exports, we propose two shocks calculated in different ways.

Shock 1 consists of calculating the proportion in which exports of beef and pork from Mato Grosso do Sul fell between 2005 and 2006, in real values of 2015. This proportion is applied to the value of exports in 2014 (in real values of 2015), of these same products from Mato Grosso do Sul. The result indicates how much exports in 2014 would fall – similarly to 2005 – if a FMD outbreak had occurred in Brazil. This drop in exports in 2014 is subtracted from exports that actually happened in 2015, showing the magnitude of the negative shock to be applied to the I-O model for 2015. We consider that the behavior of exports would be the same as that observed in the last outbreak.

$$[\left(\frac{X_{i06}}{X_{i05}}\right) - 1] \times 100 = \Delta X_i \quad (3)$$

$$X_{i14} - (\Delta X_i \times X_{i14}) = X^*_{i15} \quad (4)$$

$$X^*_{i15} - X_{i15} = S_{1i} \quad (5)$$

where: i = product ("beef", "pork"); X_{i05}= exports of product i in 2005, at 2015 values; X_{i06}= exports of product i in 2006, at 2015 values; ΔX_i= percentage change in exports of product i; X_{i14}= exports of product i in 2014, at 2015 values; X_{i15}= exports of product i in 2015, at 2015 values; X^*_{i15}= exports of product i in 2015, if a FMD outbreak had happened; S_{1i}= shock 1 in exports of product i.

Shock 2, in turn, considers the specific closure of the markets that imported beef and pork from Mato Grosso do Sul between 2005 and 2006. Most of these markets returned to buying products from the state after overcoming the health crisis. Thus, we calculated the proportion in which each of these markets closed for products exported by Mato Grosso do Sul in 2006. This percentage reduction was applied to exports from the state to the same countries in 2014, showing what would be the drop in exports in the event of an outbreak of FMD that year. Again, this reduction in exports is subtracted from the exports that actually took place in 2015. We then obtain a shock approximately 13% less than shock 1.

It is considered that the behavior of the importing markets for beef and pork from Mato Grosso do Sul would be similar to that observed in 2006. It was not considered the closing of markets conquered after 2006, nor the closing of markets that remained buying animal products from the state even with the occurrence of FMD in 2006.

$$[\left(\frac{X_{ij06}}{X_{ij05}}\right) - 1] \times 100 = \Delta X_{ij} \quad (6)$$

$$X_{ij14} - \left(\Delta X_{ij} \times X_{ij14}\right) = X^*_{ij15} \quad (7)$$

$$\sum_j X^*_{ij15} - \sum_j X_{ij15} = S_{2i} \quad (8)$$

where: i = product ("beef", "pork"); j = importing country; X_{ij05}= exports of product i to country j in 2005, at 2015 values; X_{ij06}= exports of product i to country j in 2006, at 2015 values; ΔX_{ij}= percentage change in exports of product i to country j; X_{ij14}= exports of product i to country j in 2014, at 2015 values; X_{ij15}= exports of product i to country j in 2015, at 2015 values; X^*_{ij15}= exports of product i to country j in 2015, if a FMD outbreak had happened; S_{2i}= shock 2 in exports of product i.

In the absence of an input-output model disaggregated at the state level for Brazil, shocks on product exports, in the vector of final demand, were made assuming that aggregate exports from Brazil are nothing more than the sum of exports of each state that makes up the country and that, therefore, a reduction in exports from Mato Grosso do Sul would lead to a fall in aggregate national exports.

3. Results and discussion

Table 2 shows the results of shock 1, which consisted of a negative shock of R$ 1,336.01 million in exports of the product "beef" and R$ 100.28 million (also negative) in exports of product "pork", totaling a fall of R$ 1.436 billion in the vector of final demand for products (mentioned in Equation 1).

Making the transformations to obtain an equivalent shock in the sectors, the results showed that the final demand in the slaughter and other livestock products sector suffered the greatest negative impact (- R$ 1.4 billion), followed by the sector of other food products (- R$ 12.7 million), trade (- R$ 10.6 million) and livestock (- R$ 4.4 million).

The value of national production, in this case, decreased by approximately R$ 8.1 billion (see equation 2). The sectors that suffered the greatest impact on production value are slaughter, trade and livestock. Families had a total income loss of R$ 1.91 billion.

In addition, shock 1 had a negative impact on the Gross Domestic Product (GDP) of R$ 2.977 billion, equivalent to 0.05% of the GDP in 2015 (calculated from the input-output matrix of the same year). Such negative variation is explained in 51.8% by the induced effect present among the sectors of the economy. The sector with the greatest reduction in GDP was trade.

Tax revenues, in turn, presented a negative variation of R$ 247.2 million, explained by 44.6% due to induced effects. The number of employed people, given the shock of R$ 1.436 billion in the final demand of the economy, decreased by 68.3 thousand - which corresponds to 0.67% of the total employed people in 2015, according to the input-output matrix. The livestock sector represented 37% of this reduction in occupations, and the trade sector, 16%.

Sectors	ΔY (R$ million)	ΔX (R$ million)	Participation of the induced effect in ΔX	ΔGDP (R$ million)	Δtax revenues (R$ million)	Δemployment (number of people)
Agriculture	-1.3	-186.7	40.3%	-116.9	-1.3	-3,605.1
Livestock	-4.4	-559.7	7.8%	-332.9	-25.4	-25,329.2
Other agricultural products	-0.1	-27.4	40.2%	-21.9	-0.6	-815.6
Extractive industries	0.0	-75,3	51.6%	-43.8	-3.3	-68.9
Slaughter and other livestock products	-1,403.7	-1,627.0	5.6%	-334.2	-51.9	-4,698.6
Other food products	-12.7	-288.1	31.7%	-78.1	-8.7	-1,407.1
Manufacture of footwear and other leather goods	-2.5	-16.7	80.0%	-7.4	-0.7	-202.9
Manufacture of organic and inorganic chemicals	-0.6	-81.0	37.4%	-38.4	-3.6	-56.3
Manufacture of cleaning products and cosmetics	-0.3	-18.4	81.5%	-7.1	-0.9	-63.5
Trade	-10.6	-645.6	60.4%	-440.5	-24.3	-11,069.0
Ground transportation	0.0	-249.3	43.6%	-128.7	-10.5	-2,831.0
Manufacturing industries	-0.1	-804.8	60.4%	-325.6	-48.4	-3,222.1
Electricity and gas	0.0	-153.6	59.3%	-69.0	-5.3	-90.3
Water, sewage and waste management	0.0	-23.0	80.4%	-15.6	-1.0	-192.1
Construction	0.0	-13.4	67.3%	-7.7	-0.9	-183.7
Transport, storage and mail	0.0	-200.2	74.0%	-120.4	-12.0	-2,833.3
Information and communication	0.0	-136.8	73.3%	-77.3	-8.6	-441.0
Financial and insurance activities	0.0	-384.3	65.7%	-267.6	-16.7	-1,550.8
Real estate activities	0.0	-264.6	94.4%	-246.4	-3.7	-202.1
Other service activities	0.0	-269.7	68.5%	-184.9	-11.8	-7,029.1
Health	0.0	-85.9	99.9%	-58.2	-4.8	-1,120.1
Education	0.0	-54.0	94.8%	-41.0	-2.5	-1,197.6
Administration, defense and social security	0.0	-18.7	59.8%	-13.9	-0.3	-132.6
HOUSEHOLDS	0.0	-1,914.7	100.0%	-	-	-
TOTAL	**-1,436.3**	**-8,099.0**	**32.1%**	**-2,977.6**	**-247.2**	**-68,342.2**

Table 2. Economic impacts of shock 1 (in Reais, R$ of 2015)

Source: Model results

The economic impacts resulting from shock 2 are shown in **Table 3**. The second shock was formed by a reduction of R$ 1,188.68 million in exports of the product "beef" and of R$ 62.92 million (also negative) in exports of the product "pork". In total, therefore, a negative shock of R$ 1.251 billion was applied to the vector of final demand for products from the Brazilian economy in 2015.

The participation of the induced effect remains in all variables analyzed. What changes in relation to shock 1 are the values at the level of each sector, due to a negative shock 13% less than the previous one. All results are 13% lower than the results of shock 1 due to the linearity of the I-O model.

With shock 2, families had a total income loss of approximately R$ 1.67 billion. The GDP decreased by approximately R$ 2.595 billion, equivalent to 0.04% of the 2015 GDP. Tax revenues fell by R$ 215 million and the number of employed people had a reduction close to 59.6 thousand - which is equivalent to 0.58% of the employment in 2015.

From the results of both shocks, it is possible to observe that losses in the value of production are equivalent to approximately 5.6 times the value of shocks in the final demand of the economy. In other words, the direct shocks to beef and pork exports caused by an outbreak of FMD could have a negative effect 5.6 times greater on the Brazilian economy. This multiplier effect can be explained by several factors determined by the existing relations between the sectors of the Brazilian economy.

A possible cause of this effect can be determined by the high Hirschman-Rasmussen connection rates of the sectors most significantly affected by shocks in final demand. This is because the linkages between sectors promote impeller effects on the economy. Some sectors, due to their connectedness with others, are able to drive growth (positive or negative) in other sectors, based on their growth (positive or negative).

The backward chaining effects, given by the Hirschman-Rasmussen backward linkage index, occur from the increase/decrease in demand for inputs from other sectors, which should increase/decrease their production to meet this change in demand. The effects of forward chaining, given by the Hirschman-Rasmussen forward linkage index, are observed when the increase/decrease in demand in one sector causes an increase/decrease in production in another sector (TOSTA et al., 2005; SANTOS et al., 2009; MILLER & BLAIR, 2009).

Sectors	ΔY (R$ million)	ΔX (R$ million)	Participation of the induced effect in ΔX	ΔGDP (R$ million)	Δtax revenues (R$ million)	Δemployment (number of people)
Agriculture	-1.1	-162.6	40.3%	-101.8	-1.1	-3,138.7
Livestock	-3.8	-487.8	7.8%	-290.2	-22.2	-22,077.5
Other agricultural products	0.0	-23.9	40.2%	-19.1	-0.5	-710.8
Extractive industries	0.0	-65.6	51.6%	-38.2	-2.9	-60.0
Slaughter and other livestock products	-1,223.5	-1,418.2	5.6%	-291.3	-45.3	-4,095.6
Other food products	-10.5	-250.4	31.7%	-67.9	-7.5	-1,223.2
Manufacture of footwear and other leather goods	-2.3	-14.6	80.0%	-6.5	-0.6	-177.5
Manufacture of organic and inorganic chemicals	-0.5	-70.6	37.4%	-33.4	-3.1	-49.0
Manufacture of cleaning products and cosmetics	-0.3	-16.0	81.5%	-6.2	-0.8	-55.4
Trade	-9.4	-562.8	60.4%	-384.0	-21.2	-9,648.9
Ground transportation	0.0	-217.2	43.6%	-112.1	-9.1	-2,466.7
Manufacturing industries	-0.1	-701.2	60.4%	-283.8	-42.2	-2,807.8
Electricity and gas	0.0	-133.9	59.3%	-60.2	-4.6	-78.7
Water, sewage and waste management	0.0	-20.1	80.4%	-13.6	-0.9	-167.4
Construction	0.0	-11.7	67.3%	-6.7	-0.8	-160.1
Transport, storage and mail	0.0	-174.5	74.0%	-104.9	-10.4	-2,469.1
Information and communication	0.0	-119.2	73.3%	-67.4	-7.5	-384.3
Financial and insurance activities	0.0	-334.9	65.7%	-233.2	-14.5	-1,351.3
Real estate activities	0.0	-230.6	94.4%	-214.7	-3.2	-176.1
Other service activities	0.0	-235.0	68.5%	-161.1	-10.3	-6,125.4
Health	0.0	-74.9	99.9%	-50.8	-4.2	-976.1
Education	0.0	-47.0	94.8%	-35.7	-2.2	-1,043.6
Administration, defense and social security	0.0	-16.3	59.8%	-12.2	-0.3	-115.5
HOUSEHOLDS	0.0	-1,668.5	100.0%	-	-	-
TOTAL	**-1,251.5**	**-7,057.5**	**32.1%**	**-2,594.7**	**-215.4**	**-59,558.7**

Table 3. Economic impacts of shock 2 (in Reais, R$ of 2015)
Source: Model results

In this sense, **Table 4** presents the forward and backward linkage indexes of the sectors most affected by the shocks in final demand proposed in the present study. We observe that, with the exception of livestock, all sectors have a strong connectedness with the rest of the economy.

Agriculture, chemical manufacturing and trade are highly demanded sectors by other sectors, with a forward linkage index greater than one. In other words, these sectors are demanded by other sectors above the economy average. The slaughter sector (sector most affected by shocks), other food products, footwear manufacturing, chemical manufacturing and manufacture of cleaning products have a backward linkage index greater than one, indicating that they demand inputs above the average of the rest of the economy.

The sector of manufacture of organic and inorganic chemicals is a key sector in the Brazilian economy, according to this metric, with rates of connection backward and forward higher than the unit. This may indicate that, when affected by positive or negative shocks, the sector tends to strongly affect other sectors of the economy.

Among the sectors in **Table 4**, the sector of slaughter and other livestock products stands out for its high rate of backward connection, which may also indicate that, in the event of a shock, this sector significantly affects the sectors from which it demands inputs.

Table 4. Hirschman-Rasmussen linkage indexes (selected sectors)

Sector	Backward Linkage	Forward Linkage
Agriculture	0.951	**1.895**
Livestock	0.991	0.903
Slaughter and other livestock products	**1.386**	0.796
Other food products	**1.300**	0.991
Manufacture of footwear and other leather goods	**1.158**	0.646
Manufacture of organic and inorganic chemicals	**1.112**	**1.824**
Manufacture of cleaning products and cosmetics	**1.206**	0.641
Trade	0.849	**3.842**

Source: Model results

Although the calculated impacts are an aggregate estimate, it is possible to have an idea of the size of the chains that a reduction in beef and pork exports would have on the Brazilian economy.

The reduction in GDP caused by these shocks seems small compared to the greatness of Brazil's economy. However, by making a comparison with the budget executed for Agricultural Defense by the Ministry of Agriculture, Livestock and Supply (MAPA), in 2015, it is possible to more fully assess the dimension of the shocks proposed in the present study.

In 2015 (the same year as the database used), MAPA spent R$ 91,858,393.69 on activities related to Agricultural Defense, according to the Transparency Portal (BRASIL, 2020). The variation in GDP caused by shock 1 (-0.05%) is 32 times greater than this budget, and the variation given by shock 2 (-0.04%), 28 times.

That is, considering only the impacts of a FMD outbreak on exports, the losses to the Brazilian economy would be significantly greater than the annual expenses with the prevention of animal diseases. This value could be even higher if all other losses caused by FMD were considered, such as animal slaughter and costs of controlling and eradicating outbreaks.

Although it is not possible to directly compare the results of the present study with other studies, they are consistent with the results found by Countryman and Hagerman (2017) for the evaluation of the impacts of FMD outbreaks in South America in 2001.

These results show, therefore, the importance of promoting investments in agricultural defense, in order to prevent the entry and spread of animal diseases in Brazil. Ensuring a health status free of several animal diseases is essential for Brazil to guarantee access to the international market and maintain its position as an important meat exporter to the rest of the world.

4. Conclusions

Based on an I-O model, the present study sought to analyze the losses caused by a reduction in Brazilian beef and pork exports in 2015, due to a FMD outbreak. The study considered a reduction in exports similar to that observed in 2006, when the state of Mato Grosso do Sul suffered an outbreak - which led to the closure of several import markets for animal products.

Some reservations should be made regarding the limitations of the proposed model. In the absence of an input-output matrix at the state level adequately disaggregated for the problem studied, it was decided to use the matrix at the national level. It was considered, then, that national exports are nothing more than the sum of exports from all states. Therefore, making a shock taking into account a reduction in monetary value - equivalent to the loss of a specific state - would not cause great damage to the analysis.

The proposed shocks may have overestimated export losses, since it was considered a behavior similar to that observed in the past. Furthermore, the shocks did not consider new import markets conquered after 2006. However, there is no way to predict the behavior of countries in the event of an outbreak of FMD or any other disease and, therefore, it was considered reasonable to apply a shock based on past experience.

In addition, the I-O model at the national level does not allow the analysis of the substitution effects existing between different types of meat and between Brazilian states (there could be substitution in the supply of meat to the international market between states). The I-O approach also leaves out crucial price-related adjustments that may be important in determining the economic impacts of shocks, in addition to being a linear approach. This could be solved using a regional general equilibrium model.

It is also noteworthy that an outbreak of FMD causes several negative economic impacts and the closing of export markets is just one of them. However, this is the clearest and most visible impact when an outbreak occurs and, therefore, we chose to use it in calculating shocks - given the absence of an epidemiological model that would allow us to assess other types of impact.

The results of the study show that adverse events to animal health can cause significant socioeconomic losses, reducing not only the value of production, GDP and revenue, but also the number of jobs and household income. They show, therefore, the importance of maintaining the health of herds, especially when considering Brazil's position as one of the main meat suppliers in the international market.

Due to FMD economic impacts, caused by its unfavorable effects on production, productivity, livestock profitability and foreign trade, this disease should remain the focus of actions that guarantee the health of the Brazilian herd - mainly with the current proposal to suspend vaccination throughout Brazil. However, health programs for other animal diseases should also not be abandoned. Agricultural defense, in general, should always be seen as a strategy for maintaining the development and growth of the Brazilian livestock, allowing the continuity of trade of agricultural products in the face of economic and sanitary barriers in the world market.

There is still much to be done in the economic modeling of the losses caused by the occurrence of FMD, especially in Brazil, where there are few studies on this topic. One can try to estimate shocks in exports with greater precision, analyzing the historical behavior of importing countries in relation to health crises in the countries of origin of the products. It is also essential to calculate other types of shocks resulting from the incidence of the disease. These advances can be implemented in future work.

References

BRASIL. **Portal da Transparência**. 2020. Available in: <http://www.portaltransparencia.gov.br/funcoes/20-agricultura?ano=2015>.

BREEZE, R. Agroterrorism: betting far more than the farm. **Biosecurity and Bioterrism**, v. 2, n. 4, 2004.

BUETRE, B.; WICKS, S.; KRUGER, H.; MILLIST, N.; YAIINSHET, A.; GARNER, G.; DUNCAN, A.; ABDALLA, A.; TRESTRAIL, C.; HATT, M.; THOMPSON, L.J.; SYMES, M. Potential socioeconomic impacts of an outbreak of foot-and-mouth disease in Australia. **Australian Bureau of Agricultural and Resource Economics and Sciences**, Research report 13.11, 2013.

CARNEIRO, F. L. **Medidas não tarifárias como instrumento de política comercial: o conceito, sua importância e as evidências recentes de seu uso no Brasil**. Texto para discussão n. 2.135. Ipea. Brasília, 2015.

CASAGRANDE, R. Biological warfare targeted at livestock. **BioScience**, v. 52, 2002.

COUNTRYMAN, A.M.; HAGERMAN, A.D. Retrospective Economic Analysis of Foot and Mouth Disease Eradication in the Latin American Beef Sector. **Agribusiness**, v.33, n. 2, 2017.

COZZENS, T.; GABHARDT, K.; SHWIFF, S.; LUTMAN, M.; PEDERSEN, K. Modeling the economic impact of feral swine-transmitted foot-and-mouth disease: a case study from Missouri. **USDA National Wildlife Research Center**. Paper 1262, 2010.

EKBOIR, J.M. Potential impact of foot-and-mouth disease in California: the role and contribution of animal health surveillance and monitoring services. **Agricultural Issues Center**. University of California, Davis, 1999.

FERREIRA, M.D.P.; VIEIRA FILHO, J.E.R. **Inserção no mercado internacional e a produção de carnes no Brasil**. Texto para discussão nº 2479. Ipea. Rio de Janeiro, 2019.

FLORINDO, T.J.; MEDEIROS, G.I.B.; COSTA, J.S.; RUVIARO, C.F. Competitividade dos principais países exportadores de carne bovina no período de 2002 a 2013. **Revista de Economia e Agronegócio**, v. 12, n. 1, 2015.

FOOD AND ABRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO); WORLD ORGANISATION FOR ANIMAL HEALTH (OIE). **The global foot and mouth disease control strategy: strengthening animal health systems through**. 2012. Available in: <https://www.oie.int/doc/ged/D11886.PDF>.

GONÇALVES, J.R.; NETO, N.K.L. Desafios para as exportações brasileiras de carne bovina. **Informações Econômicas**. São Paulo, v. 40, n. 10, 2010.

HAYAMA, Y.; OSADA, Y.; OUSHIKI, D.; TSUTSUI, T. An economic assessment of foot and mouth disease in Japan. **Revue Scientifique et Technique**, v. 36, n. 1, 2017.

INFLATION EU. **Worldwide inflation data**. 2020. Available in: <https://www.inflation.eu/>.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Matriz de Insumo-Produto 2015**. 2020. Available in: <https://www.ibge.gov.br/estatisticas/economicas/contas-nacionais/9085-matriz-de-insumo-produto.html?=&t=o-que-e>.

IPEADATA. **IGP-DI e taxa de câmbio**. 2020. Available in: <http://www.ipeadata.gov.br/Default.aspx>.

KIM, M. Supply driven input-output analysis: case of 2010-2011 foot-and-mouth disease in Korea. **Journal of Rural Development**, v. 38, n. 2, 2015.

LEE, B.; PARK, J.; GORDON, P.; MOORE, J.E.; RICHARDSON, H.W. Estimating the state-by-state economic impacts of a foot-and-mouth disease attack. **International Regional Science Review**, v. 35, n.1, 2012.

LEITE, F.P. Como o grau de desigualdade afeta a propensão marginal a consumir? Distribuição de renda e consumo das famílias no Brasil a partir dos dados da POF 2002-2003 e 2008-2009. **Economia e Sociedade**, v. 24, n. 33, 2015.

MAHUL, O.; DURAND, B. Simulated economic consequences of foot-and-mouth disease epidemics and their public control in France. **Preventive Veterinary Medicine**, v. 41, n. 1, 2000.

MAPA. Ministério da Agricultura, Pecuária e Abastecimento. **Instrução Normativa Nº 36, de 29 de abril de 2020**. Brasília, Diário Oficial da União, ed. 82, seção 1, p. 5, 2020a.

MAPA. Ministério da Agricultura, Pecuária e Abastecimento. **Instrução Normativa Nº 48, de 14 de julho de 2020**. Brasília, Diário Oficial da União, ed. 134, seção 1, p. 2, 2020b.

MAPA. Ministério da Agricultura, Pecuária e Abastecimento. **Plano Estratégico do Programa Nacional de Febre Aftosa 2017-2026.** Brasília, 2017.

MILLER, R.E.; BLAIR, P.D. Input-Output Analysis: foundations and extensions. 2ª Edição. Cambridge University Press. Cambridge, 2009.

MINISTÉRIO DA INDÚSTRIA, COMÉRCIO EXTERIOR E SERVIÇOS (MDIC). **ComexStat**. 2020. Available in: <http://comexstat.mdic.gov.br/pt/home>.

OIE. World Organisation for Animal Health. **Terrestrial Animal Health Code.** Paris, 2019. Available in: <https://www.oie.int/en/standard-setting/terrestrial-code/access-online/>.

OLADOSU, G.; ROSE, A.; LEE, B. Economic impacts of potential foot and mouth disease agroterrorism in the USA: a general equilibrium analysis. **Journal of Bioterrorism and Biodefense**, S12:001, 2013.

PENDELL, D.L.; LEATHERMAN, J.; SCHROEDER, T.C.; ALWARD, G.S. The economic impacts of a foot-and-mouth disease outbreak: a regional analysis. **Western Agricultural Economics Association Annual Meeting**. Portland, 2007.

RICH K.M.; MILLER G.Y.; WINTER-NELSON A. A review of economic tools for the assessment of animal disease outbreaks. **Revue Scientifique et Technique**, v.24, n. 3, 2005a.

RICH K.M.; WINTER-NELSON A.; MILLER G.Y. Enhancing economic models for the analysis of animal disease. **Revue Scientifique et Technique**, v. 24, n. 3, 2005b.

ROSE, A. A framework for analyzing and estimating the total economic impacts of a terrorist attack and national disasters. **Journal of Homeland Security and Emergency Management**, v. 6, n. 9, 2009.

SANTOS, V.E.; GOMES, M.F.M.; BRAGA, M.J.; SILVEIRA, S.F.R. Análise do setor de produção e processamento de café em Minas Gerais: uma abordagem matriz insumo-produto. **Revista de Economia e Sociologia Rural**, v. 47, n. 2, 2009.

SHANKAR, B.; MORZARIA, S.; FIORUCCI, A.; HAK, M. Animal disease and livestock-keeper livelihoods in Southern Cambodia. **International Development Planning Review**, v. 34, n. 1, p. 39-64, 2012.

SILVA, S.Z.; TRICHES, D.; MALAFAIA, G. Análise das barreiras não tarifárias à exportação na cadeia da carne bovina brasileira. **Revista de Política Agrícola**, n. 2, 2011.

TOSTA, M.C.R.; GOMES, M.F.M.; LIRIO, V.S.; SILVEIRA, S.F.R. Importância e encadeamento dos setores de produção e abate e processamento da cadeia suinícola em Minas Gerais. **Revista de Economia e Sociologia Rural**, v. 43, n. 2, 2005.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA). **Livestock and Poultry: world markets and trade**. 2020. Available in: <https://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.pdf >.