The Circulation of Bovine Animals in Maro Grosso do Dul State (Brazil) and its Potential Economic Implications in a Context of FMD Outbreaks

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(On going research)

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Outline

- Introduction
- Data and methodology
- Data analysis – the socieconomic networks
- Implications of the pattern of animal movement to an eventual FMD spread in MS
- Potential economic impacts of an eventual FMD outrbreak in MS state
- Final comments

1 – Introduction: objectives

- *This research aims simulating and analyzing the potential effects of a Foot-and-Mouth Disease outbreak in Brazil, in order to highlight the economic relevance of sanitary crises particularly taking into consideration its major role as a global beef and pork exporter.*

- **Simulation coverage** ➔ outbreak and dispersion in Mato Grosso do Sul state (Center-Western region)

- **Economic impacts**: based on the previous FMD outbreak in 2005 and 2006

- **Analytical tool**: socieconomic networks

1 - Introduction

- The Center-Western region: 33.5% of bovines and 37.5% of animal slaughtered. – Brazil, 2014

- Mato Grosso do Sul (MS) state → 30% of the regional herd; 9.9% and 11.6% of slaughtering in Brazil (2014)
  - It is the most important supplier of calves and unfinished cattle to other states (IBGE, 2017a).

- MS state borders with **Paraguai and Bolivia**, where cattle ranching is also a key economic activity; and borders with MT, GO, MG, SP and PR

- Availability of GTA data (oficial traffic of animals)

- Trial to combine epidemiological knowledge with economic modelling

2 – Data and Methodology

- **Methodology:** application of a socioeconomic network analysis to examine flows of cattle traffic in the state of MS and from there to other Brazilian states.
- A graph represents the network structure ➔ a set of vertices (or nodes) and a set of lines (links) and each line connects two vertices.
- **Node:** the smallest unit of a social network and it represents an actor of it => in this paper**:** **a municipality or a state.**
- **Link:** it represents the relation or the bonds between two actors – **given by animal transport between municipalities.**
  - Directed (arc) or undirected.
  - Arc: a pair of ordered vertices in which the first vertex is the sender (arc tail) and the second, the receiver (arc head)

Socioeconomic networks

- So, the network is defined by a graph and by additional information on its nodes links
- Additional information is irrelevant for the network framework (it is determined by the pattern of relations)
- **But:** it identifies which vertex represents a specific municipality for this study and provides conditions to associate the weight of each relation to the links (**given by the volume of animals moved between two municipalities)**

Socioeconomic network

- Scott (1988): this kind of analysis emerged from the sociology

- It allows evaluating relational data, as modelling structures resulted from the interaction between agents from a complex system, through measures and formal algorithms taken from the graph theory (JACKSON, 2010).

- Relations or links allows to examining behaviors, goods, information, epidemics etc.

- De Nooy et al. (205): network analysis provides an appropriate methodology to describe and explore socioeconomic links, detecting and interpreting patterns emerged from the social and economic interactions among agents in the network.

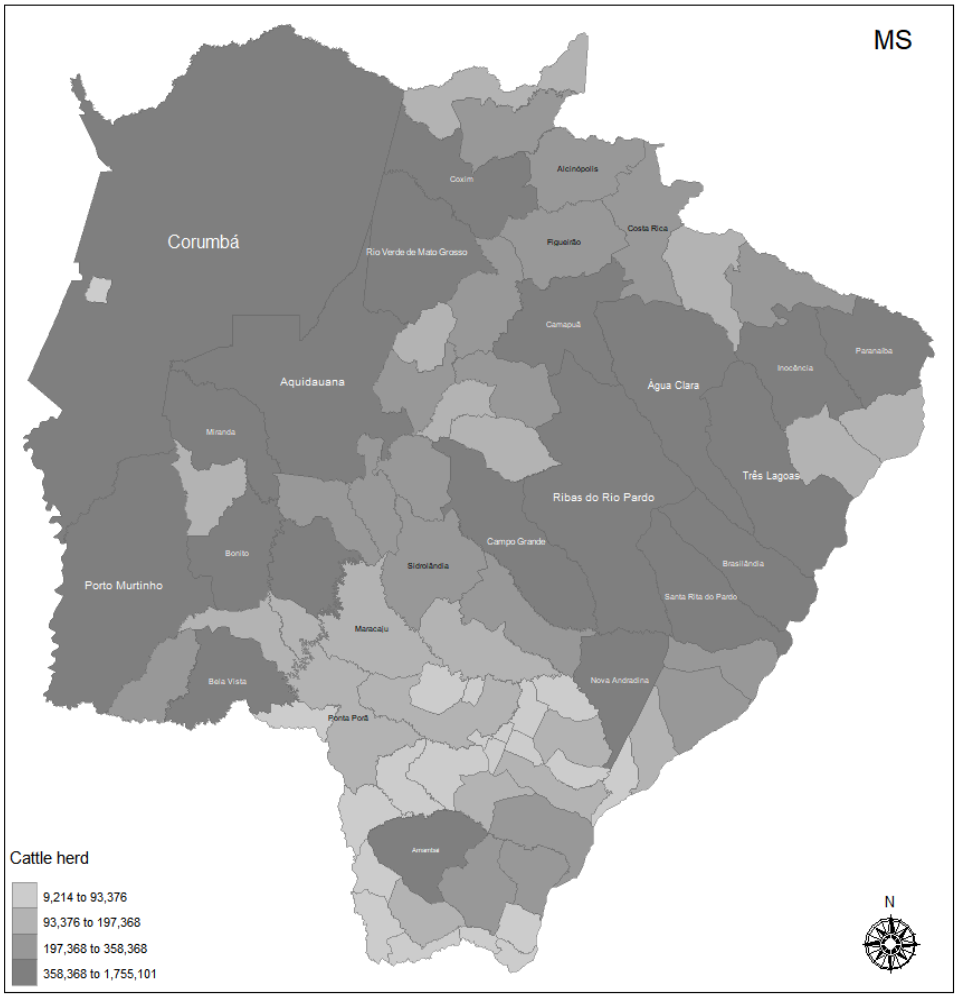
- Newman (2010): this application enables to include a structural dimension to analysis and the propagation effect, by considering the interdependence among agents of that framework

2.1 – Data

- GTA database. GTA means Guia de Trânsito Animal
- GTA: shows daily registers of animal movements in MS and provide the microregion and municipality of origin and destiny of the animals transported inside the state, the number of animals moved, the gender and age (0 to 12 months, 12-24 months, 24-36 months, and 36 months).
- Also information about the purpose of transporting animals, i.e: to slaugherhoses, fattening farms, breeding, sports, exhibitions, exporting and service.
- Base year: 2014

- Networks comprise 79 municipalities of MS and 432.457 GTA issued by the state
- No information about animals imported from other states or countries
- R software to compile the animal flows
- Software Pajek: to build the networks for the four quarters of 2014 and discriminate the purposes of issued GTA.

Cattle herd per municipality in Mato Grosso do Sul state, 2016



Source: IBGE (2017) database elaborated by authors with R software.

3 – Database analysis

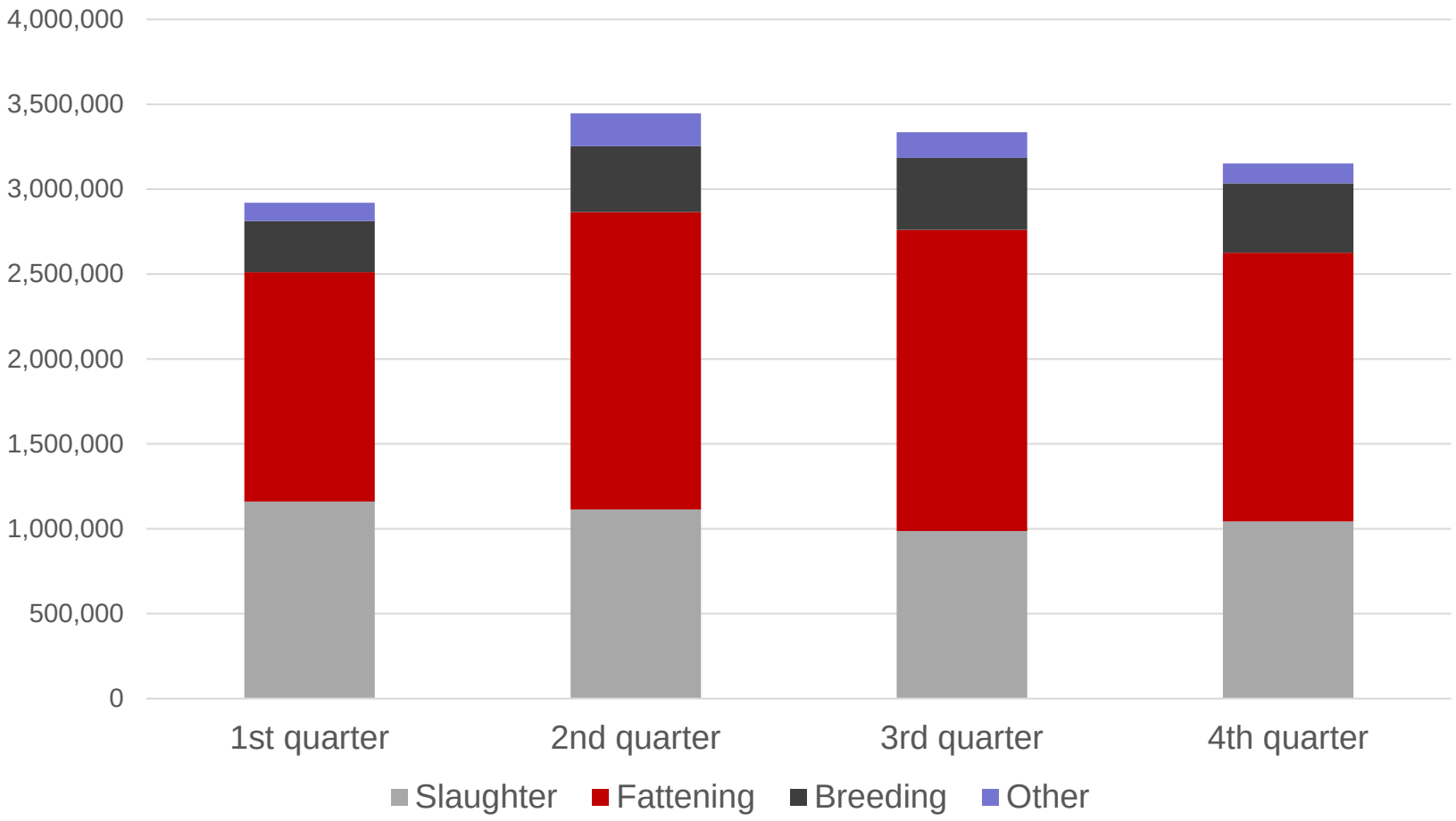
- In 2014, the MS state moved about 12.85 million animals, approximately 62% of its total bovine herd.

- Destination: 34% of animals to slaughtering, 50% to fattening farms, 12% for breeding purposes and 4%, to other purposes

- Differences along the year => seasonal patterns

- 494,346 heads were sent to other states (33.5% to slaughterhouses and 50.3% percent to fatting farms) ➔
- It highlights the relevance of the animal traffic in MS for evaluating the risk of FMD occurrence in Brazil.

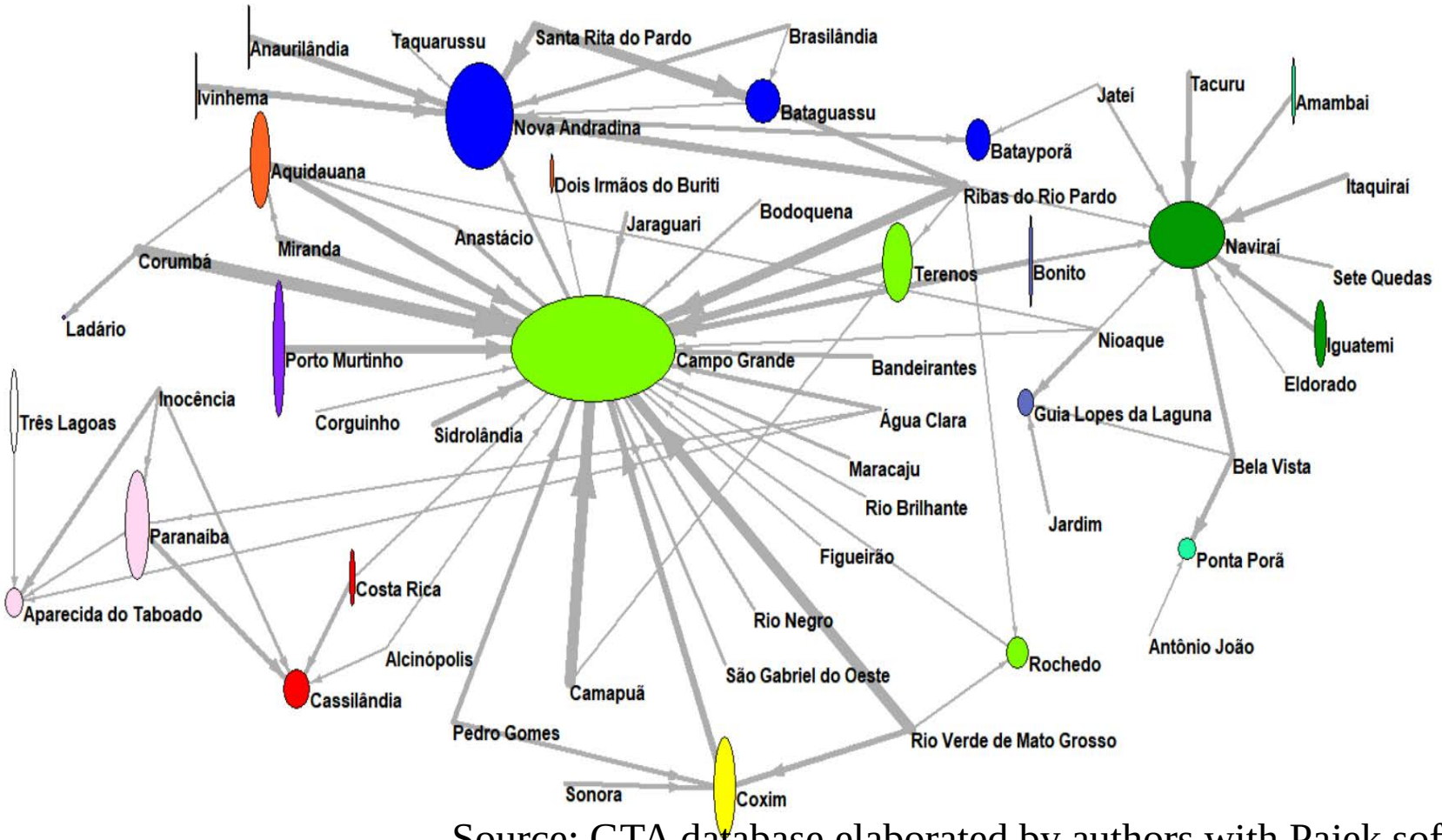
Number of animals moved quarterly by purpose: Mato Grosso do Sul, 2014



•Source: GTA database, elaborated by authors.

- Taking the 1st quarter/2014 to a more detailed exam:
  - the complete network of animals transported to slaughter has 79 nodes and 751 arcs.
  - Density = 0.12 (small once 12% of possible links indeed exist)
  - Average degree of 19.01 *links*.
  - In Network 1 → we modified the network to enhance visibility (excluding links representative of less than 3,000 heads, enhancing its visibility
- Size of node → refers to the combination of its *weighted indegree* and *weighted outdegree*.
- The length of node (the horizontal measure) shows its *weighted indegree*, i.e., the weight of arcs that arrives to this node (volume of animals received by that municipality/state)
- Size of node in vertical direction (the height of node) depicts its *weighted outdegree*, i.e., the weight of arcs that leave that node (volume of animals shipped from that municipality)

Network 1: Movement of animals to be slaughtered between municipalities in the MS state: 1st quarter 2014



Source: GTA database elaborated by authors with Pajek software.

Centrality Measures

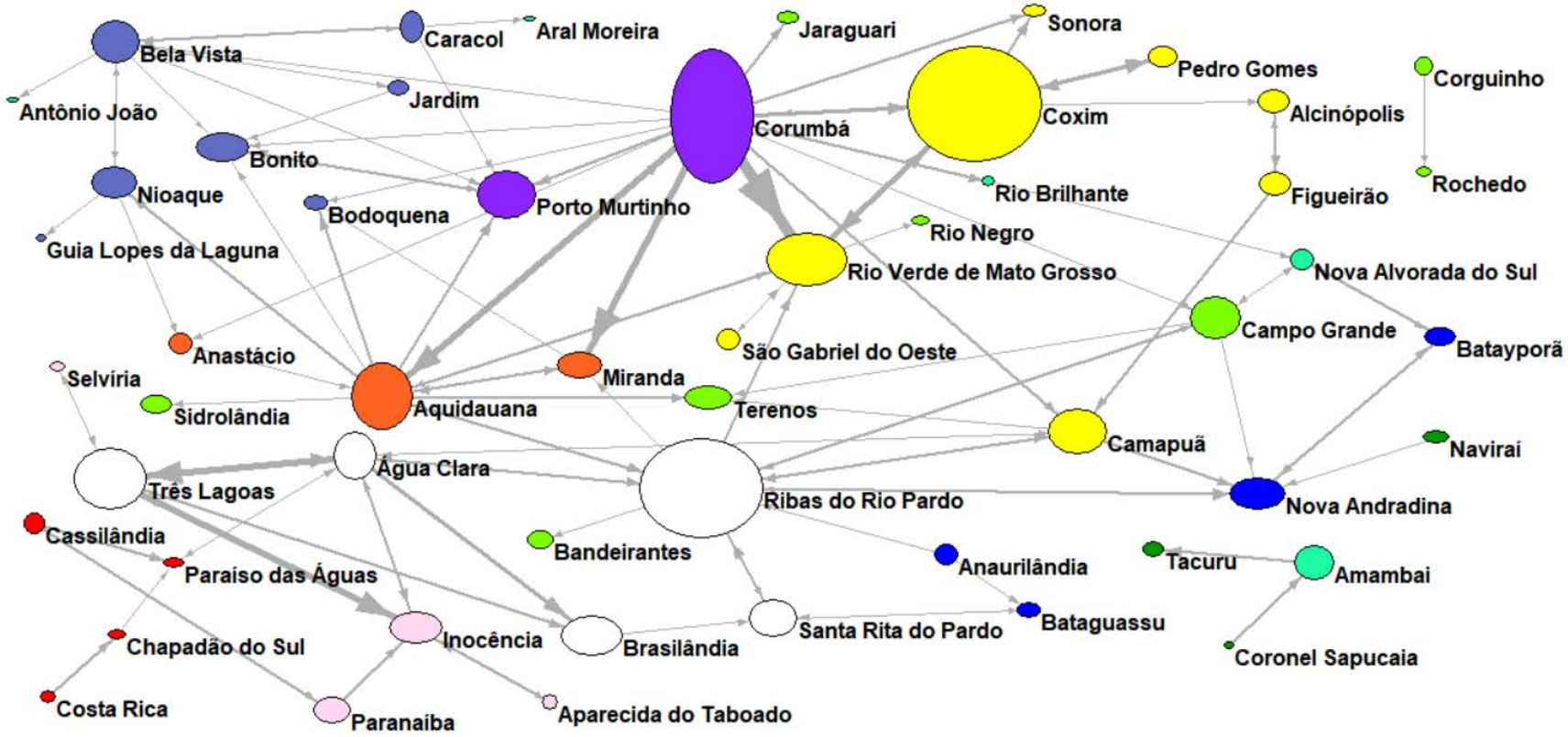
- The centrality degree measures how many direct neighbours a certain node has (how connected it is)
- For directed networks: measure the input degree (as a receiver) and the output degree (as a sender)
- **Closeness centrality**: how close a node is from others; it is the inverse of average distance from a vertix to others
  - Short distances among vertixes → higher closeness centrality
  - Hence ➔ the quicker will be the transmission by that vertix.
- **Betweenness centrality***:* evaluates the influence a vertix has over the speed of dissemination among the other vértices

Table 1 – Degree, closeness and betweenness centrality for major municipalities that transport animals to be slaughtered in MS state, 1st quarter 2014

Input Degree	%	Output Degree	%	Input Closeness	Result	Output Closeness	Result	Betweenness	Result
Campo Grande	7.99	Campo Grande	2.40	Campo Grande	0.804	Ribas do Rio Pardo	0.251	Campo Grande	0.112
Naviraí	7.59	Nioaque	2.13	Naviraí	0.780	Bandeirantes	0.246	Rochedo	0.028
Batayporã	7.19	Ribas do Rio Pardo	2.13	Nova Andradina	0.722	Campo Grande	0.243	Iguatemi	0.027
Nova Andradina	6.52	Bonito	2.00	Caarapó	0.703	Camapuã	0.242	Costa Rica	0.027
Caarapó	6.13	Maracaju	2.00	Bataguassu	0.690	Nioaque	0.242	Nova Andradina	0.026

Source: GTA database, elaborated by authors

Network 2: Movement of animals for fattening in the MS municipalities: 3rd quarter 2014



Source: Based on GTA database, elaborated with Pajek software.

Table 2 – Degree, closeness and betweenness centrality for major municipalities that send animals for fattening in the MS state, 3rd quarter 2014

Input Degree	%	Output Degree	%	Input Closeness	Result	Output Closeness	Result	Betweenness	Result
Ribas do Rio Pardo	2.90	Campo Grande	2.95	Ribas do Rio Pardo	0.780	Campo Grande	0.788	Campo Grande	0.052
Campo Grande	2.59	Ribas do Rio Pardo	2.49	Campo Grande	0.736	Ribas do Rio Pardo	0.722	Ribas do Rio Pardo	0.049
Corumbá	2.18	Corumbá	2.44	Corumbá	0.684	Corumbá	0.716	Corumbá	0.046
Nova Andradina	2.18	Camapuã	2.29	Nova Andradina	0.684	Camapuã	0.696	Camapuã	0.031
Camapuã	2.08	Dourados	2.24	Camapuã	0.672	Dourados	0.690	Nova Alvorada do Sul	0.028

Source: GTA database, elaborated by authors

Table 3 – Input weighted degree for major municipalities and main categories found in the GTA for MS state, 2014

Period	Slaughtering	%	Fattening	%	Breeding	%
1st quarter	Campo Grande	25.06	Corumbá	4.92	Paranaíba	4.00
	Naviraí	11.60	Ribas do Rio Pardo	4.87	Corumbá	3.78
	Nova Andradina	10.24	Camapuã	3.67	Camapuã	3.77
	Bataguassu	5.32	Coxim	3.40	Bela Vista	3.56
	Terenos	4.75	Três Lagoas	3.38	Ribas do Rio Pardo	3.34
2nd quarter	Campo Grande	25.66	Corumbá	6.71	Corumbá	7.26
	Naviraí	10.41	Ribas do Rio Pardo	4.66	Camapuã	4.14
	Nova Andradina	10.15	Três Lagoas	3.46	Bela Vista	3.54
	Bataguassu	6.31	Camapuã	2.94	Jardim	3.47
	Terenos	4.31	Água Clara	2.86	Coxim	3.30
3rd quarter	Campo Grande	24.68	Coxim	5.95	Corumbá	8.70
	Naviraí	11.38	Ribas do Rio Pardo	5.46	Brasilândia	5.35
	Nova Andradina	9.51	Corumbá	3.72	Aquidauana	4.59
	Bataguassu	7.70	Rio Verde de M.T.	3.52	Jardim	3.58
	Terenos	4.18	Três Lagoas	3.25	Ribas do Rio Pardo	3.20
4th quarter	Campo Grande	25.56	Corumbá	7.68	Bela Vista	6.67
	Naviraí	10.77	Ribas do Rio Pardo	4.87	Aquidauana	4.72
	Nova Andradina	9.52	Coxim	4.20	Corumbá	4.67
	Bataguassu	6.59	Rio Verde de M.T.	4.15	Camapuã	4.20
	Anastácio	3.94	Três Lagoas	3.09	Paranaíba	3.76

Source: GTA database, elaborated by authors

Table 4 – Output weighted degree for major municipalities and main categories found in the GTA for MS state, 2014

Period	Slaughtering	%	Fattening	%	Breeding	%
1st quarter	Ribas do Rio Pardo	5.06	Corumbá	7.44	Corumbá	6.65
	Porto Murtinho	3.49	Ribas do Rio Pardo	4.66	Paranaíba	4.82
	Camapuã	3.13	Três Lagoas	3.21	Bela Vista	4.32
	Corumbá	3.06	Coxim	3.17	Camapuã	3.53
	Rio Verde de M.T.	2.97	Camapuã	3.06	Aquidauana	3.42
2nd quarter	Ribas do Rio Pardo	4.74	Corumbá	12.70	Corumbá	10.23
	Porto Murtinho	3.35	Ribas do Rio Pardo	4.97	Camapuã	5.43
	Nova Andradina	3.23	Água Clara	3.94	Caracol	3.83
	Corumbá	3.21	Três Lagoas	3.03	Miranda	3.42
	Camapuã	3.16	Aquidauana	3.00	Paranaíba	3.29
3rd quarter	Ribas do Rio Pardo	4.49	Corumbá	7.57	Corumbá	9.44
	Camapuã	3.24	Coxim	6.52	Brasilândia	5.65
	Nova Andradina	3.11	Ribas do Rio Pardo	5.60	Aquidauana	5.38
	Porto Murtinho	3.09	Aquidauana	3.82	Jardim	4.05
	Santa Rita do Pardo	2.72	Três Lagoas	3.45	Camapuã	3.18
4th quarter	Ribas do Rio Pardo	5.01	Corumbá	11.38	Bela Vista	6.31
	Rio Verde de M.T.	3.46	Ribas do Rio Pardo	4.74	Aquidauana	5.97
	Camapuã	3.01	Coxim	4.49	Corumbá	5.07
	Nova Andradina	2.92	Aquidauana	3.50	Miranda	3.91
	Porto Murtinho	2.71	Rio Verde de M.T.	3.50	Paranaíba	3.68

Source: GTA database, elaborated by authors

Implications of the pattern of animal movement to an eventual FMD spread in MS

Literature review and previous experiences

- **International Literature:** Mahul and Durand (2000), Garner and Beckett (2005), Shankar et al. (2012) and Young et al. (2016).
- In the Brazilian literature on Agricultural Economics, however, there are not many studies addressing impacts of animal diseases using economic analysis and models.
- Some of them examine the last FMD occurrence (in MS, in 2005-06): Garcia et al. (2015)
- Economic and social impacts identified because of the FMD outbreaks: regional effects (job and income losses), and macroeconomic effects (export bans and damages to the Brazilian beef image in the international markets for several months after solved).

The Risk of FMD reintroduction

- The risk of the FMD reintroduction and the virus spread is one of the major concerns of governamental authorities and cattle farmers ➔ this disease causes major restrictions to international commercialization.
- The FMD crosses international frontiers through transit of infected animals and through importing animal products
- The high population density and the coexistence of susceptible species in farms turn the surveillance and control of the FMD very challenging (LYRA; SILVA, 2004).
- The Plan of Action for the FMD, established in 2009, by the Ministry of Agriculture, Livestock and Supply, highlights some preventive measures and prophylaxis against the FMD, such as the vaccination with inactive vírus

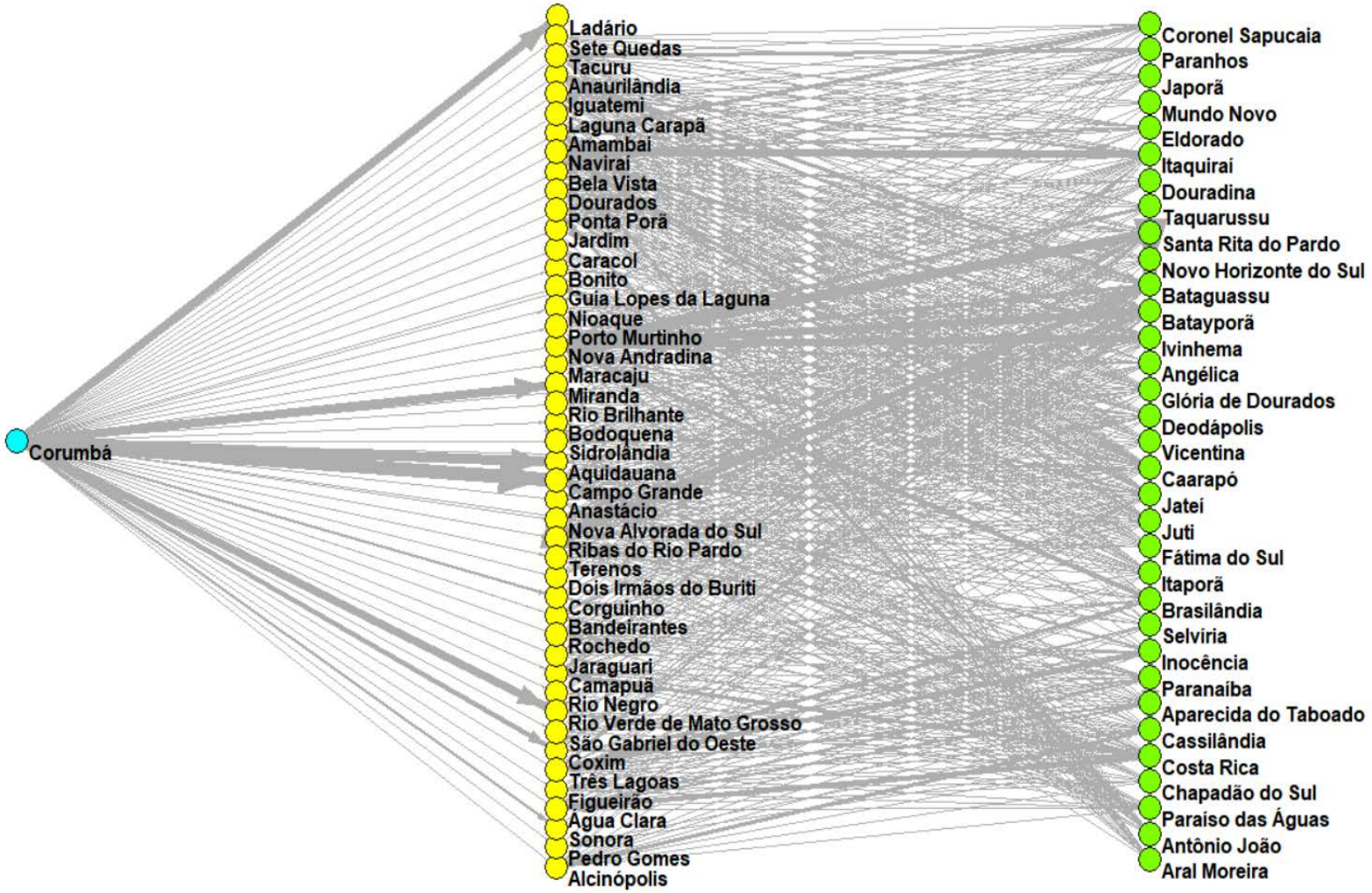
The Strategic Plan for the FMD Program 2017-2026

- March 2017: MAPA has launched the Strategic Plan for the National Program of FMD 2017-2026
- Main goal: to create and maintain sustainable conditions to guarantee the free FMD status and to amplify the disease free zones without vaccination in Brazil.
- Proposal: a 10 year schedule to eliminate the vaccination of FMD in the whole territory (MAPA, 2017a).
- So, it is compelling to conduct studies, targeting the identification of economic risk and building scenarios of potential effects for states and for Brazil.
  - MS state is a key-state in this analysis due to its border location, herd size and intense traffic of animals to inside and outside municipalities.
- **Here: considering the centrality measures, we chose Corumbá as a sender municipality to simulate a starting point on for a FMD outbreak and its spread in the state (See Network 3)**

Network 3:

- Network 3 exposes the framework of neighbours for Corumbá, for the first quarter of 2014 (similar for other quarters)
- As the goal is to examine the framework of the transmission network, it is imperative to consider the interdependence among municipalities, including indirect links as relevant factors to spreading the FMD.
- The node neighbourhood is evaluated: comprise all the nodes that can be reached by that node through a determined pathway
- **The shorter the pathway taken from one node to other, speeder the spread inside the network (DE NOOY et al., 2005).**
- It contains 79 vertices; Corumbá (stage zero) has direct link with 45 nodes (stage 1) and indirectly with others 33 (stage 2).
- In second stage, for MS, the infection reaches 100% of the network (in the state)

Network 3: Process of dissemination since Corumbá based on the animal traffic registered in 1st quarter of 2014



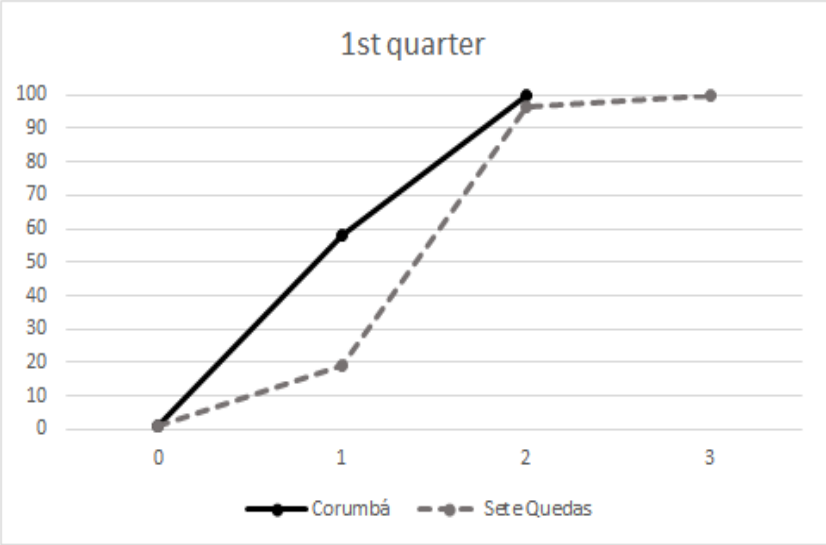
Source: GTA database, elaborated by authors

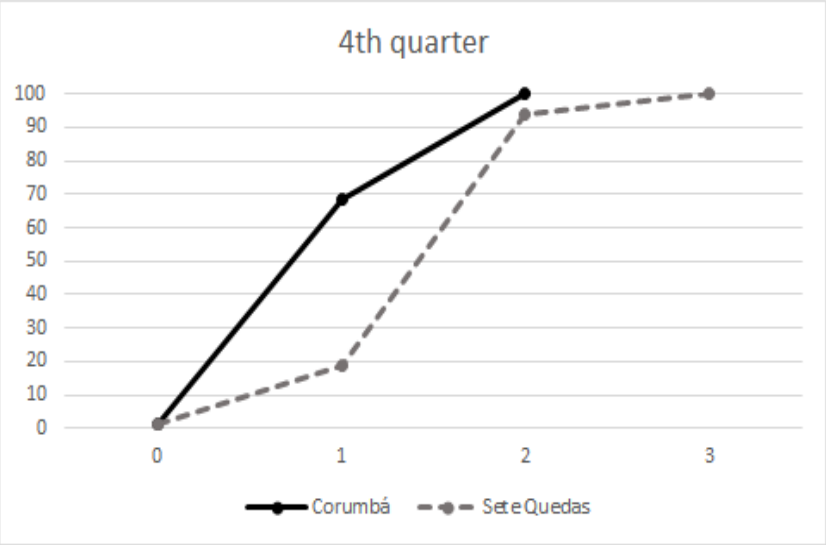
Hypotheses raised from this model about

1. in a dense network, the disease dissemination is easier and faster than in a spread network
2. in a disconnected network, the diffusion will be slower and less wider than in a connected network;
3. the larger the neighbourhood of a node, the faster it will be infected;
4. a central position increases the probability of infection; and
5. the diffusion from a central vertix is more rapidily than the diffusion from a peripheric node (DE NOOY et al., 2005).

These hypotheses underline the impact of the network frame in the process of the disease dissemination, and provide a scope to discuss about the employment of this knowledge to define strategies to prevent and control sanitary crises and to plan a sanitary services structure to manage risks.

Comparing the process of dissemination in Corumbá and Sete Quedas: 1st and 4th quarters 2014





The speed varies when a process originates from a central node or from a peripheric spread.

If the outbreak occurs in Corumbá, in both quarters, the state will be potentially 100% reached at the second stage

The curves do not show a "S" format (ending with logistic growth format) because the dissemination is very fast in this network

Source: GTA database, elaborated by authors

Potential economic impacts of an eventual FMD outrbreak in MS state

Economic and social impacts

- The negative impact of the FMD on the availability and distribution of animal products in the market causes direct effects over producers, rural entrepreneurs and rural families
- It reverberates negatively on the commercial activities of the agriculture and livestock sector, harming the consumer and the society in general, including the government.
- Taxes revenues, productivity, trade, foreign currency, jobs, devaluation of products, increasing costs for private and public agents and lack of confidence of stakeholders

6 – Final Comments

- Next steps: simulation of daily focus of disease for all municipalities of MS
- These simulation will allow identifying the herd and regions affected in each scenario, potentially affected if a FMD outbreak occurs.
- Considering the herd and area affected, the expenditures of governamental agencies and private agents with sacrifice and sanitary slaughtering will be calculated as well as the necessariy compensation payments to farmers
- Also considering the historical data of the last outbreak, we will estimate potential losses in exports, tax revenues and prices impacts, not only for the beef and pork production chain but also for other food chains affected because of trade restrictions in the affected region
- We can evaluate different moments of the disease occurrence → incubation time, notification delay,

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QUESTIONS?

COMMENTS?

SUGGESTIONS?