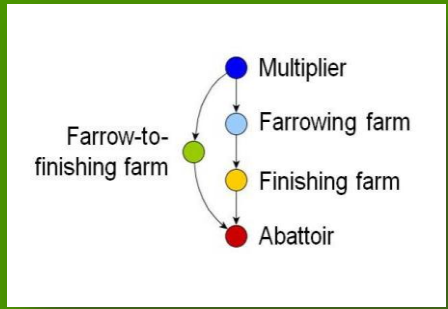
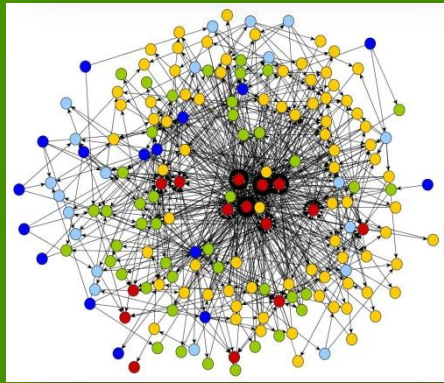
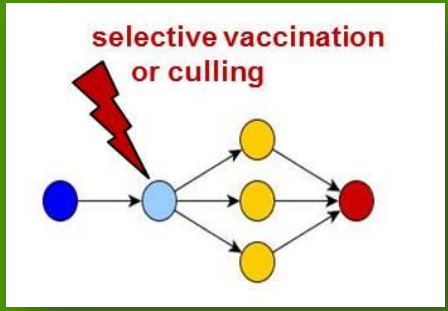
Faculty of Agricultural and Nutritional Science

Christian-Albrechts-University Kiel
Institute of Animal Breeding and Husbandry

Characterisation of the contact network in the pig supply chain







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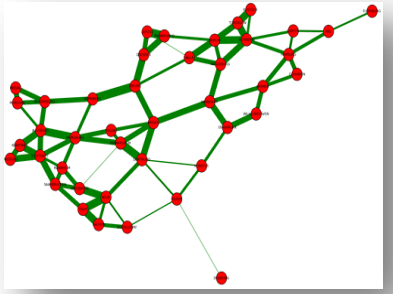
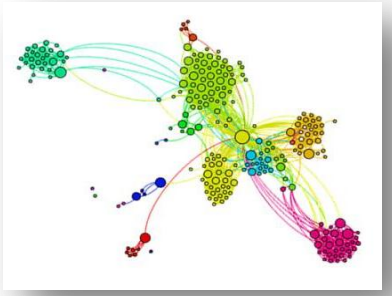
Introduction

- **Networks – parts of our everyday life**
  - Underground networks
  - Power grid
  - Social networks in the WWW

- **Network analysis**
  - Characterisation of network structures
  - Detection of central or important nodes



- **New approach to the control of animal diseases**
  - Cost aspects → extensive economic losses
  - Ethical aspects → preventive culling of healthy animals



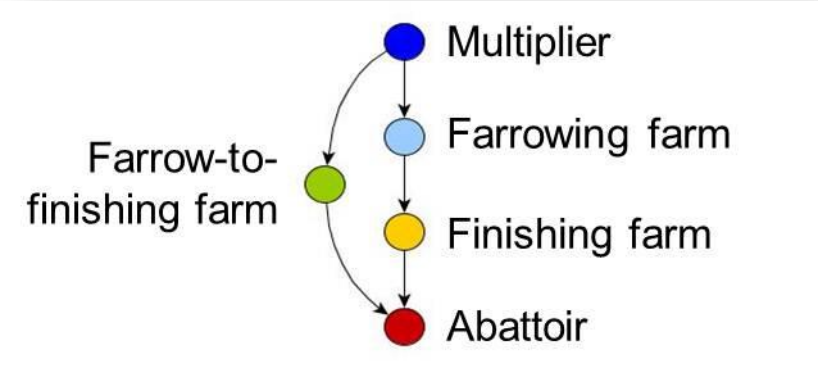
➢ **Project aims**
  - Characterisation of the network topology
  - Better prediction of disease transmission
  - Optimisation of control strategies

Data basis

- **Real network of the pork supply chain from a producer community in Northern Germany**
- **Observation period**

  → 01/06/2006 – 31/05/2009
- **Transported livestock**

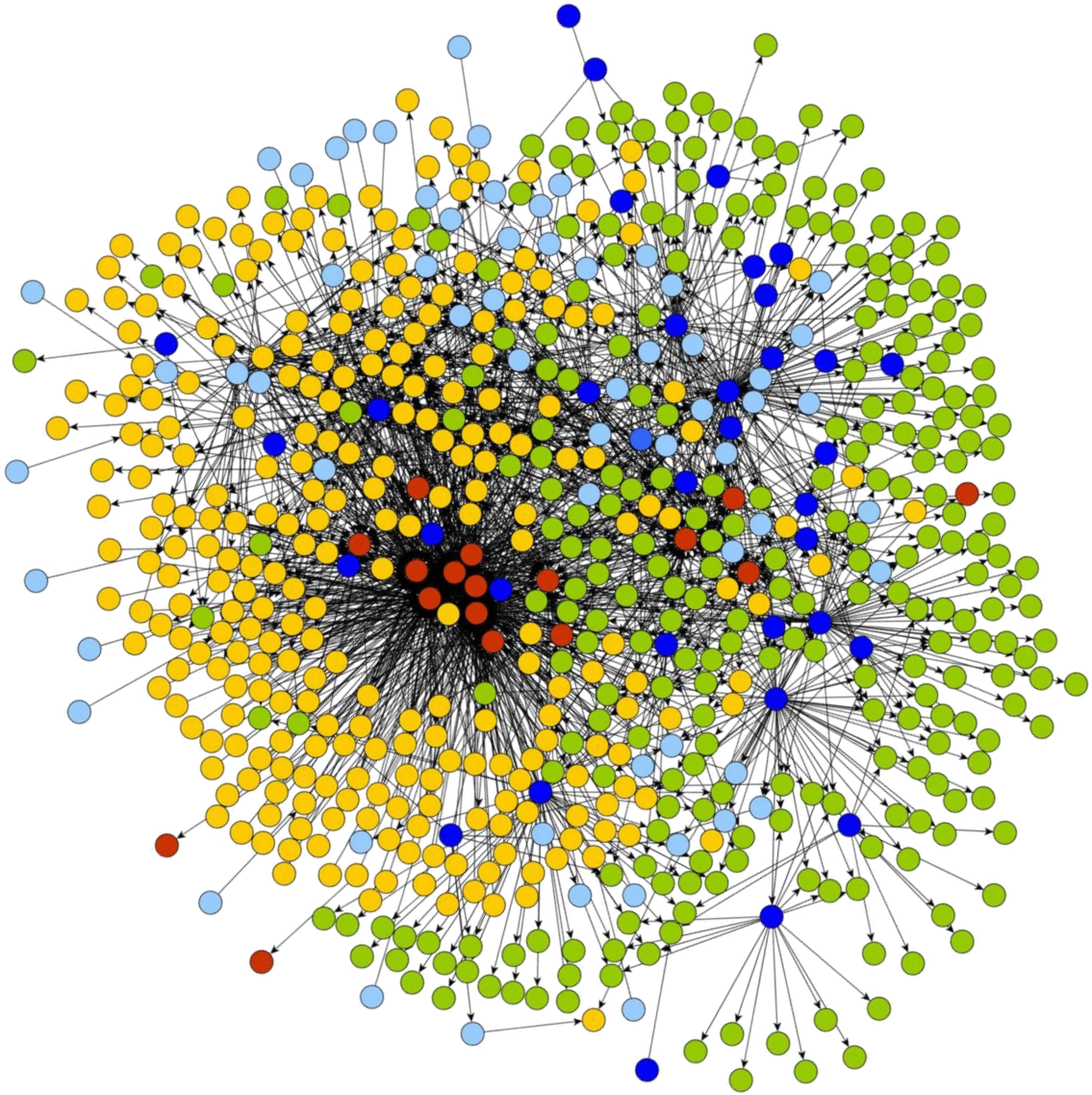
  → Piglets, fattening pigs, sows, boars



- **Static network analysis**

  → Aggregation of repeated trade connections to a single one

Data basis – Original network

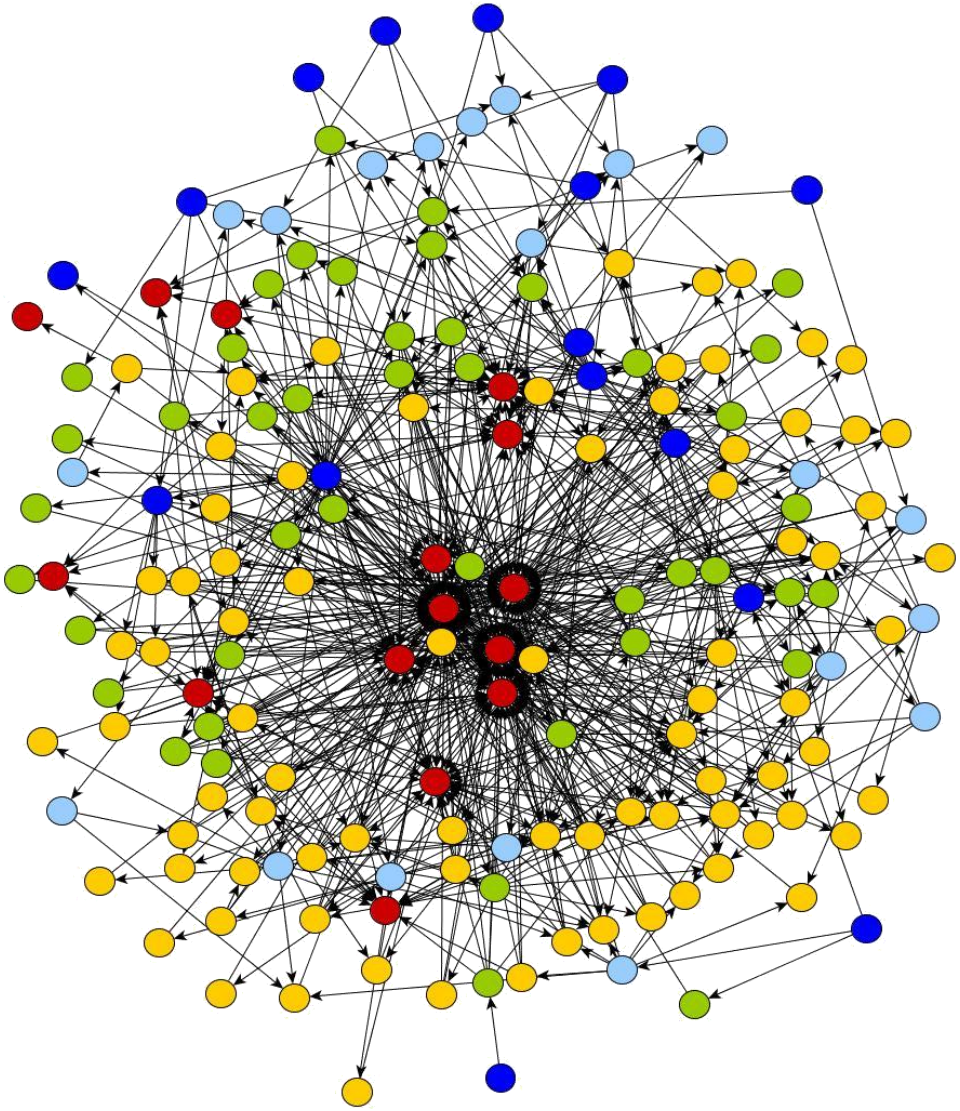


658 premises

35	Multipliers
62	Farrowing farms
271	Finishing farms
273	Farrow-to-finishing farms
17	Abattoirs

2,018 trade contacts

Data basis – Adapted network



176 premises

16	Multipliers
20	Farrowing farms
81	Finishing farms
44	Farrow-to-finishing farms
15	Abattoirs

793 trade contacts

Centrality measures

“Which are the most central or important nodes of a network?”

Degree centrality

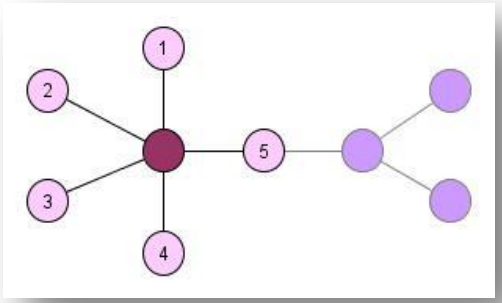
Betweenness centrality

Closeness centrality

Centrality measures – Degree centrality

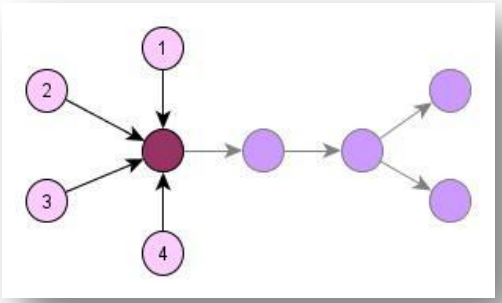
- **Definition**
  - The degree of a node is the number of connected edges
  - The in-degree of a node is the number of ingoing edges
  - The out-degree of a node is the number of outgoing edges

Degree



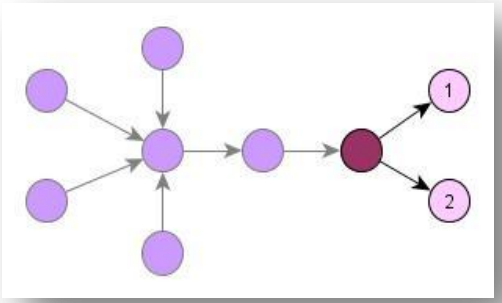
$$k_i = \sum_{j=1}^{n} A_{ij}$$

In-degree



$$k_i^{in} = \sum_{j=1}^{n} A_{ij}$$

Out-degree

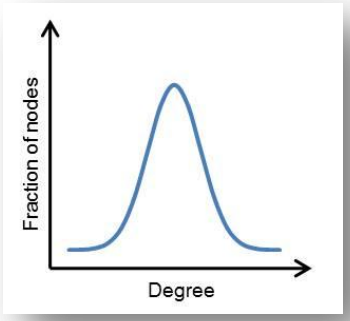


$$k_j^{out} = \sum_{i=1}^{n} A_{ij}$$

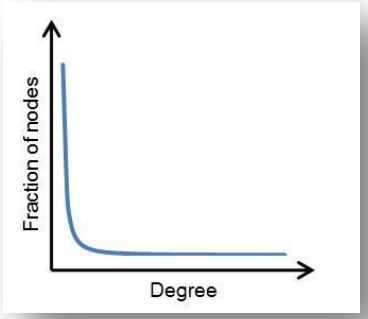
Centrality measures – Degree centrality

- **Degree Distribution**
  - $P(k)$ – **Probability that a randomly chosen node has degree k**

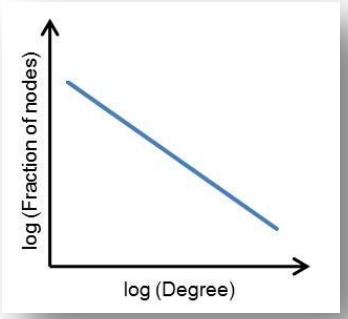
Random network



Scale-free network



Scale-free network (log-log-plot)

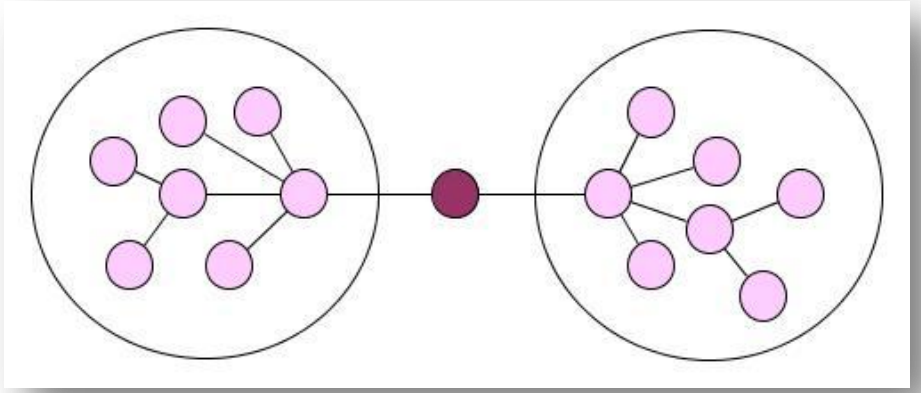


  - **Power-law degree distribution**
    - → $P(k) \sim k^{-\alpha}$
    - → Highly right-skewed
    - → A lot of premises with a low degree centrality
    - → Few premises with a high degree centrality

Centrality measures – Betweenness Centrality

- **Definition**
  - Betweenness centrality measures the extent to which a node lies on paths between other nodes
  - Number of geodesic or shortest paths a node lies on

$$B_i = \sum_{st} \frac{n_{st}^i}{g_{st}}$$

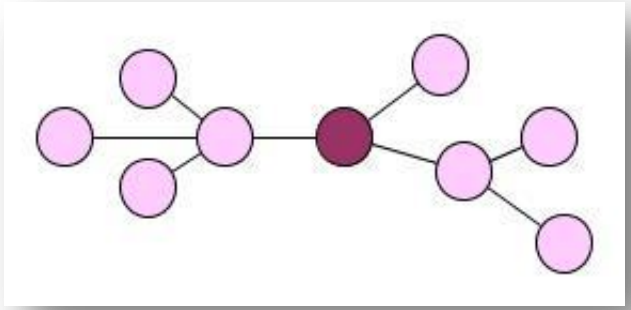


- **Betweenness centrality distribution**
  - Tendency to right-skewed distributions in most real networks
  - Power-law distribution

Centrality measures – Closeness centrality

- **Definition**
  - Closeness centrality measures the mean geodesic or shortest distance from a node to all other reachable nodes

$$C_i = \frac{\sum_j d_{ij}}{n}$$



- **Closeness centrality distribution**
  - Small dynamic range from largest to smallest value
  - No long tail to the distribution
  - Approximate normal distribution

Results – Degree centrality

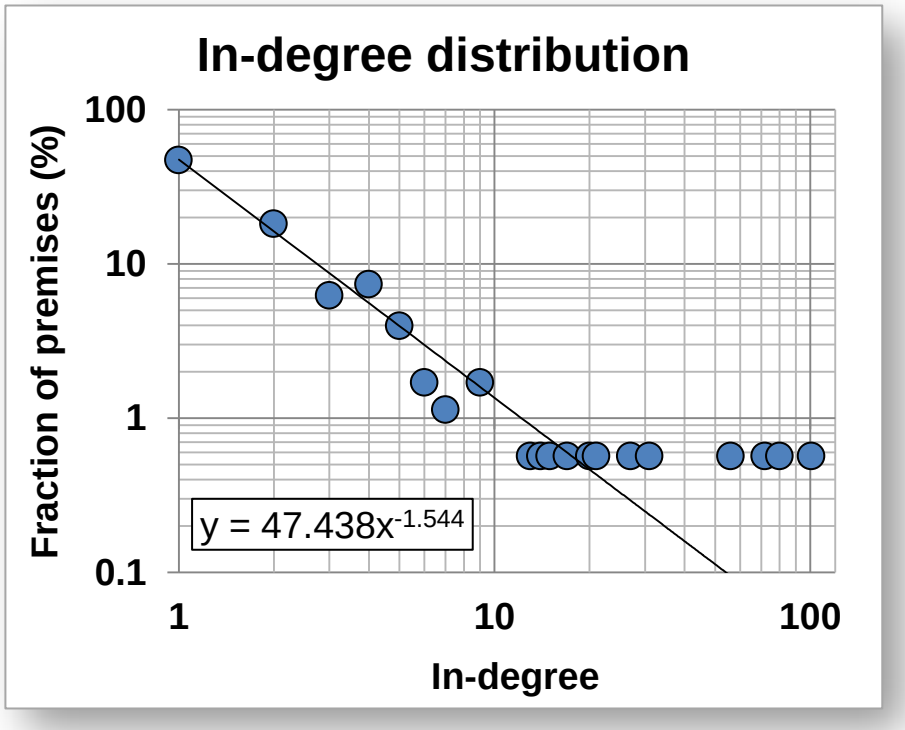
25th percentile, median and 75th percentile of the in-degree and the out-degree for the different farm types

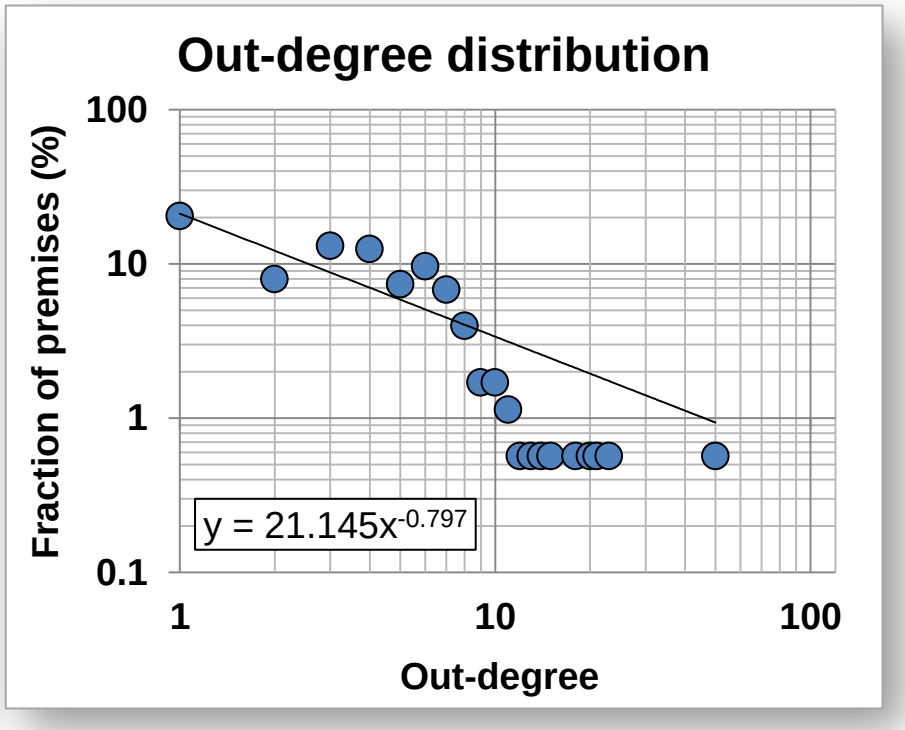
Premise type	n	In-degree			Out-degree		
		25th Pctl	Median	75th Pctl	25th Pctl	Median	75th Pctl
Multiplier	16	0	0	1	3	5	10
Farrowing farm	20	1	2	3	1	3	8
Finishing farm	81	1	2	3	2	3	5
Farrow-to-finishing farm	44	1	1	2	2	5	7
Abattoir	15	6	20	56	0	0	0
Total	**176**	**1**	**1**	**3**	**1**	**4**	**6**

→ **Different types of premises reveal different degrees due to their position in the network**

Results – Degree centrality

Distributions of the in-degree and the out-degree





→ **Approximate power-law degree distribution**

Results – Betweenness centrality

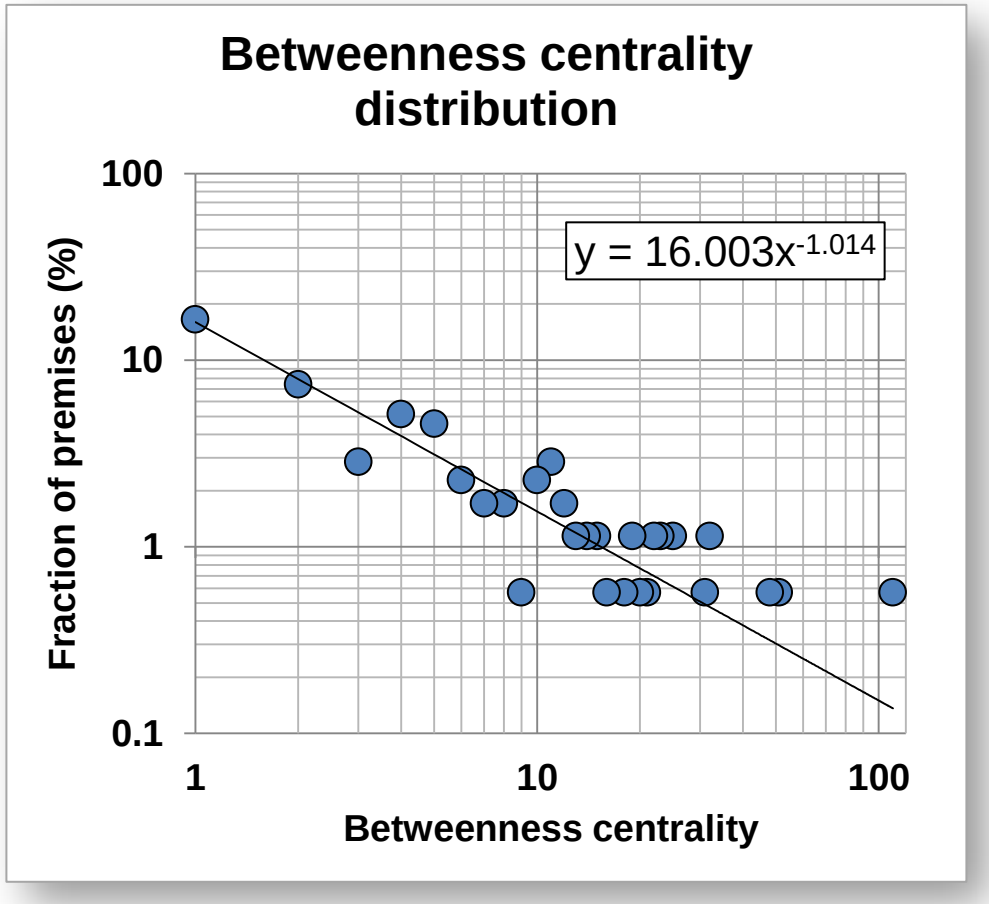
25th percentile, median, 75th percentile, minimum and maximum of the betweenness centrality for the different farm types

Premise type	n	Betweenness centrality				
		25th Pctl	Median	75th Pctl	Min	Max
Multiplier	16	0	0	24.2	0	110.2
Farrowing farm	20	3.6	6.2	12.8	0.2	50.7
Finishing farm	81	0.3	1.3	4.1	0	48.2
Farrow-to-finishing farm	44	0.2	2.3	10.9	0	25.4
Abattoir	15	0	0	0	0	0
Total	**176**	**0.1**	**1.2**	**6.4**	**0**	**110.2**

→ **Different types of premises reveal various betweenness centralities due to their position in the network**

Results – Betweenness centrality

Distribution of the betweenness centrality



- **Approximate power-law distribution**
  - A lot of premises with low betweenness centrality
  - Few premises with high betweenness centrality

Results – Closeness centrality

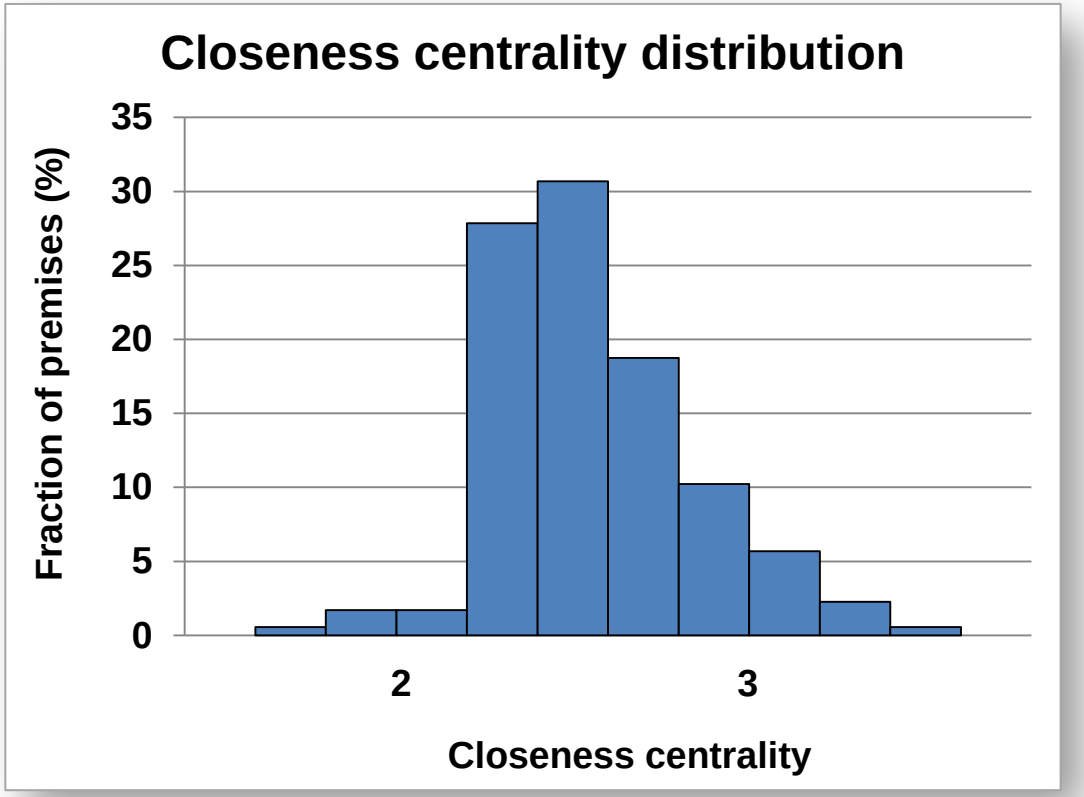
25th percentile, median, 75th percentile, minimum and maximum of the betweenness centrality for the different farm types

Premise type	n	Closeness centrality				
		25th Pctl	Median	75th Pctl	Min	Max
Multiplier	16	2.3	2.7	2.9	1.8	3.2
Farrowing farm	20	2.6	2.7	2.8	2.5	2.9
Finishing farm	81	2.2	2.3	2.4	2.0	3.2
Farrow-to-finishing farm	44	2.1	2.2	2.3	1.9	2.6
Abattoir	15	1.9	2.4	2.8	1.5	3.3
Total	**176**	**2.1**	**2.3**	**2.5**	**1.5**	**3.3**

→ **All farm types have nearly the same closeness centrality**

Results – Closeness centrality

Distribution of the closeness centrality



- **Small range**

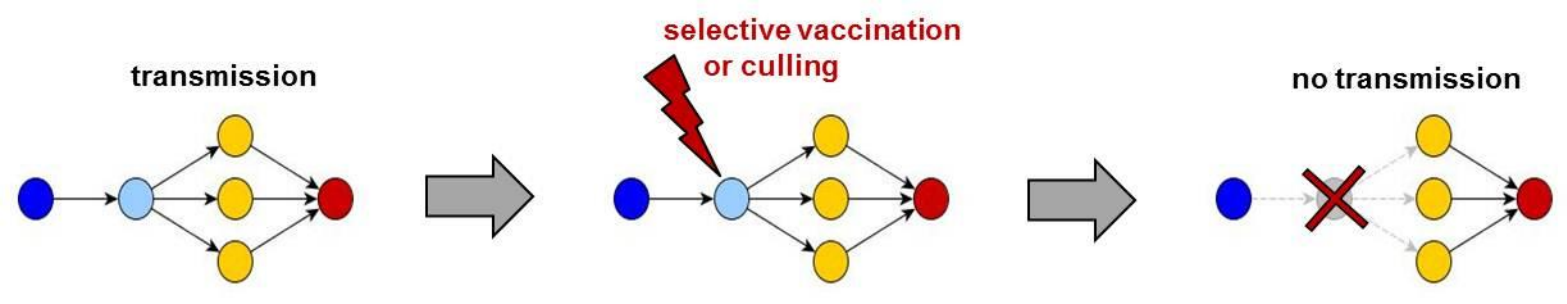
  $1.5 - 3.3$

- **Mean**

  2.3 ± 0.3

Outlook – Network resilience

- **Scale-free networks**
  - Highly resistant concerning the random removal of nodes
  - Highly vulnerable concerning the removal of the most central nodes of the network



- **Interruption of the chain of infection**
- **Prevention of further disease spread**

Conclusion

- Network analysis - Substantial tool for characterising contact structures
- Only a small range and low values of the closeness centrality
- Different types of premises reveal various degrees and betweenness centralities reflecting their position in the pig supply chain
- Degree and betweenness centrality distribution show scale-free characteristics

➢ **First step to interrupt the chain of infection and to prevent further disease spread**

Thank you for your attention!

Deutsche Forschungsgemeinschaft

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