PigSustain

Predicting the Impacts of Intensification and Future Changes on UK Pig Industry Resilience

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Project Aims

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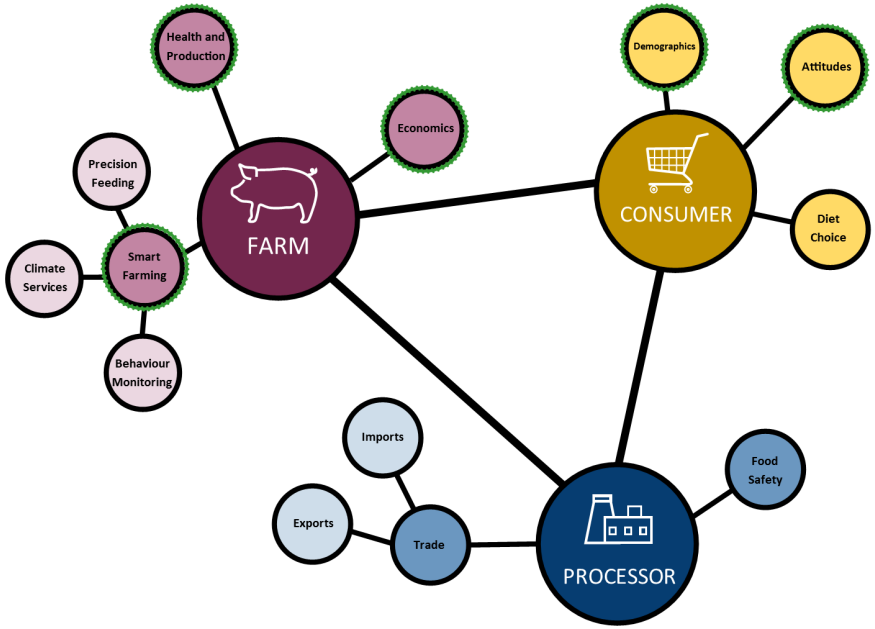

Use a multi-disciplinary, integrated systems approach to model and assess the resilience of the UK pig industry to 2030.

Develop models to assess how the industry would likely be affected by shocks and trends such as changes in consumer demand, trade, environment and climate change and emerging animal diseases.

Why pigs?

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- UK pork industry is a key contributor to the UK meat industry. It currently employs 75,000 employees and is worth £1.25 billion *(Source: DEFRA 2019)*

- International supply chains
- Human health vs dietary choice
- Environmental impacts
- Animal health & disease
- Work force

- Impacts of Brexit and trade
- Impacts of Covid

Human health and consumption

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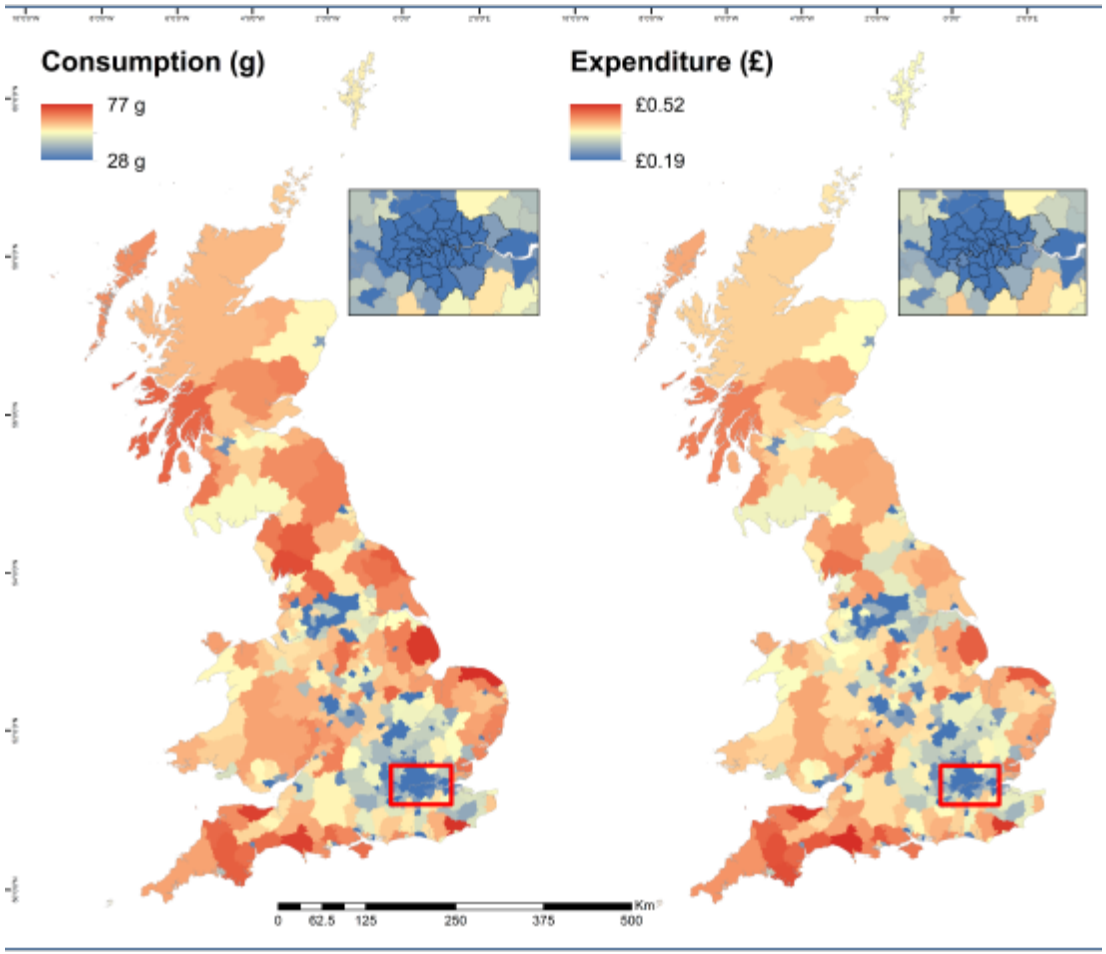

Linking socio-demographic foundations with detailed datasets on expenditure, consumption, lifestyle, diet, attitudes and environmental values to demand and stability

Local authority district level estimates of consumption and expenditure of bacon and ham (for household consumption) for 2014. Values are per person, per week.

Data: Living Cost & Food Survey, ONS.

James WHM; Lomax N; Birkin M; and **Collins LM.** 2020. Geodemographic Patterns of Meat Expenditure in Great Britain. Applied Spatial Analysis and Policy https://doi.org/10.1007/s12061-020-09344-5

Red meat consumption & targeted policy intervention

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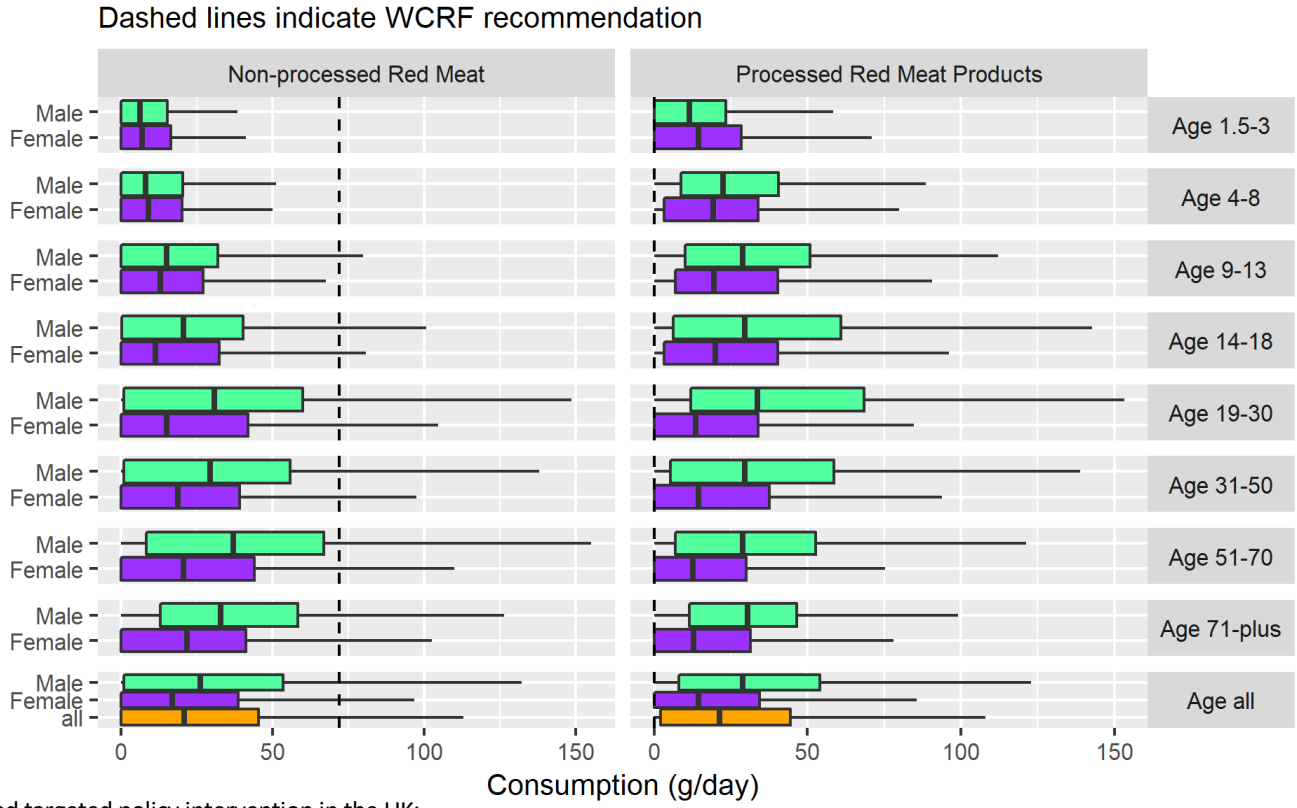
- Health – environment – industry nexus
- Colorectal (bowel) cancer is the third most common cancer worldwide with approximately 1.8 million new cases recorded each year (Bray et al., 2018).
- A comprehensive meta-analysis concluded that "consumption of processed red meat is a convincing cause of colorectal cancer" (WCRF, 2018)

Data: National Diet and Nutrition Survey (NDNS) data on the types and quantities of foods consumed by individuals across the UK.

Average red and processed meat consumption for different demographic groups.



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Red meat consumption forecasting

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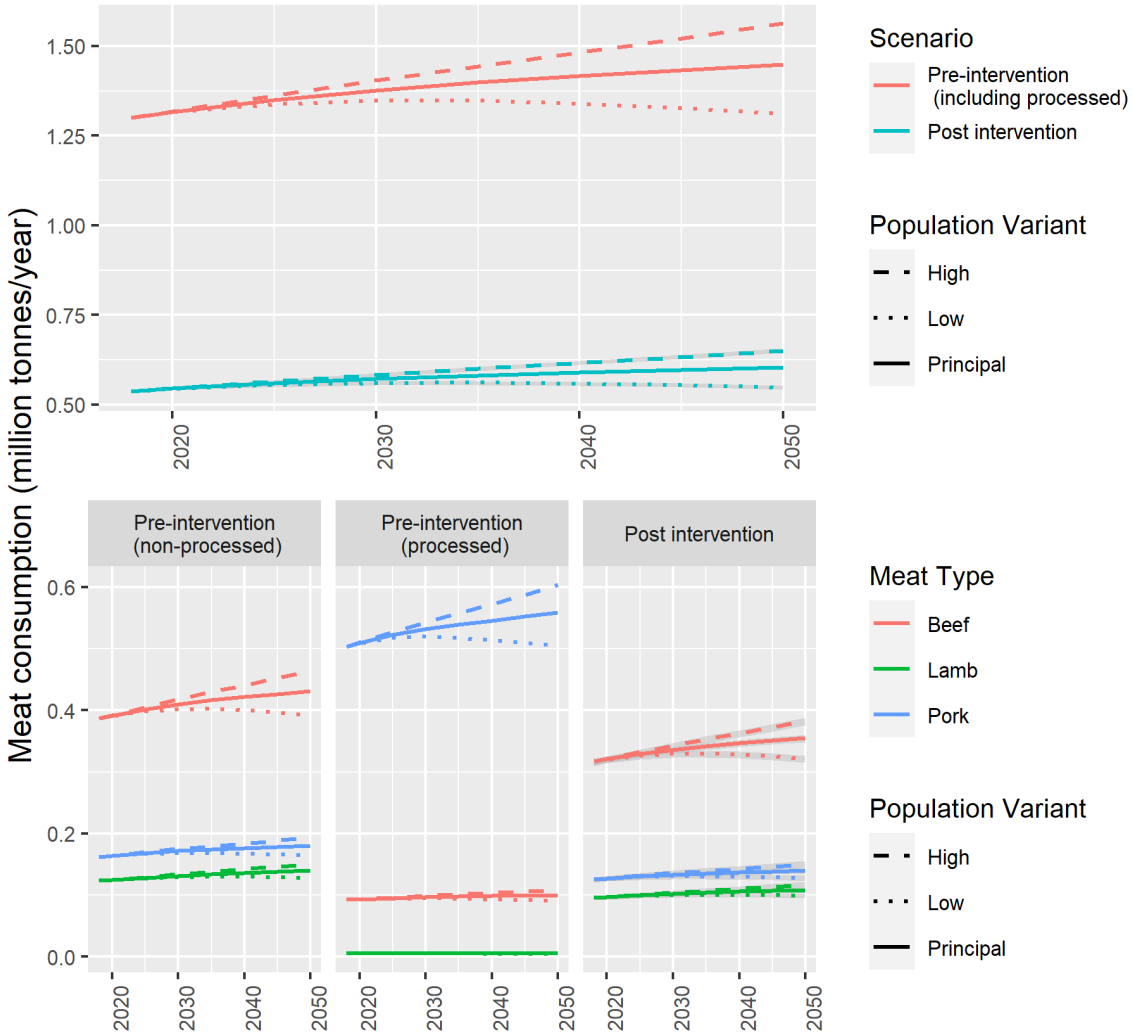
- Total consumption (2018) for all processed and processed red meat was 1.30 m tonnes per year.
- Assuming no intervention, by the year 2050 this is projected to increase to 1.45 million tonnes (+11.5%)
- Aligning to WCRF guidelines results in greater decrease in pork consumption compared to other meats.
    - Pork consumption from 0.66 to 0.13m tonnes (-81.4%).
    - Beef from 0.49 to 0.32m tonnes (-34.9%)
    - Lamb 0.14 to 0.10m tonnes(-31.9%).



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Projected environmental impacts

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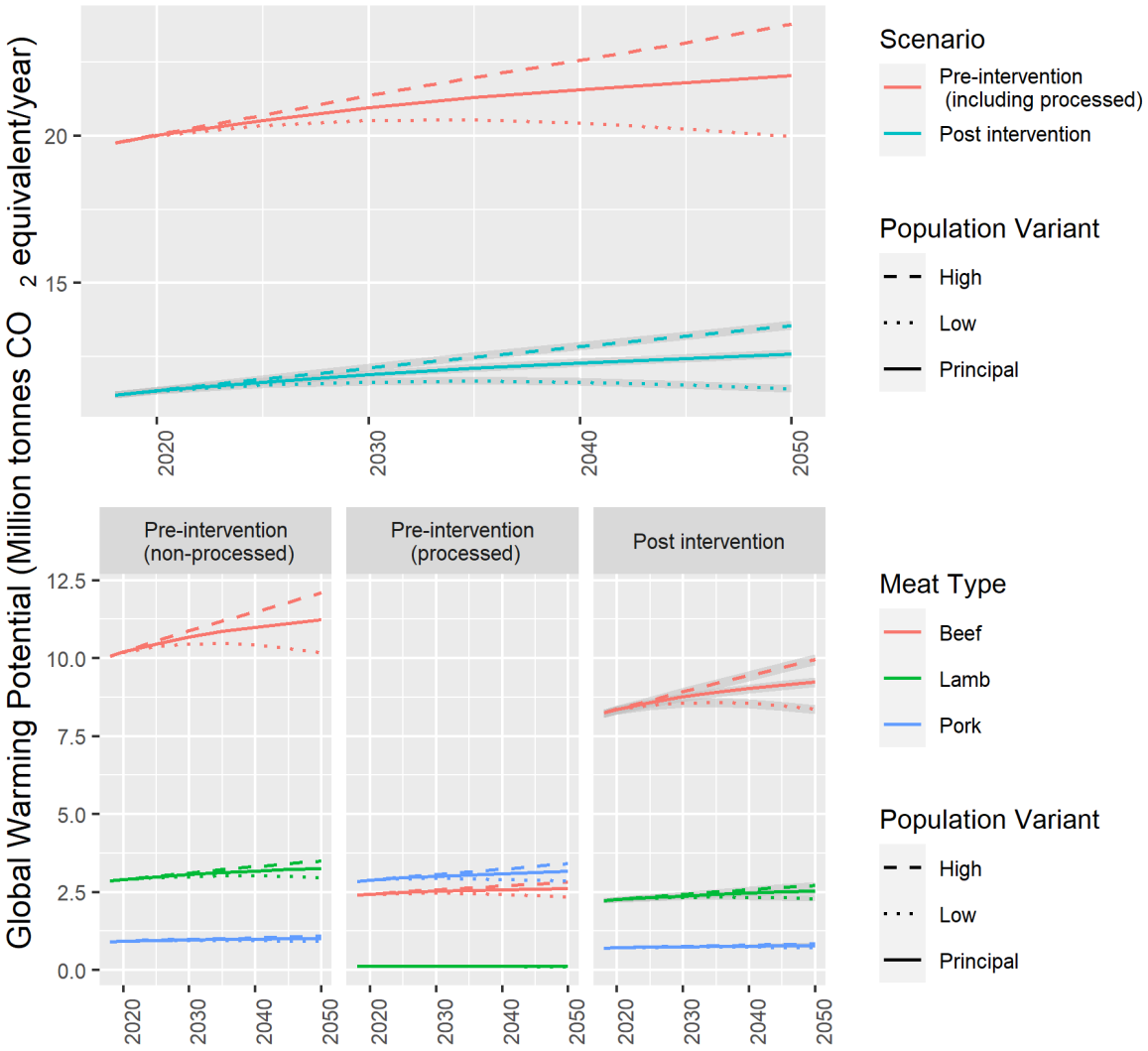
- Total contemporary Global Warming Potential (2018) for all processed and processed red meat estimated at 19.77m tonnes CO^2 eq per year. Without intervention, projected to increase to 22.06m tonnes CO2 eq by 2050 (+11.6%).
- Alignment to WCRF guidelines reduced GWP by 43.4%.
- Beef accounts for greatest GWP, pork the least.
- Alignment with WCRF results in much larger decrease in pork GWP (-81.1%)
- However, the industry is investing in innovation to reduce the GWP of production so this figure may be lower in practice.



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Animal health

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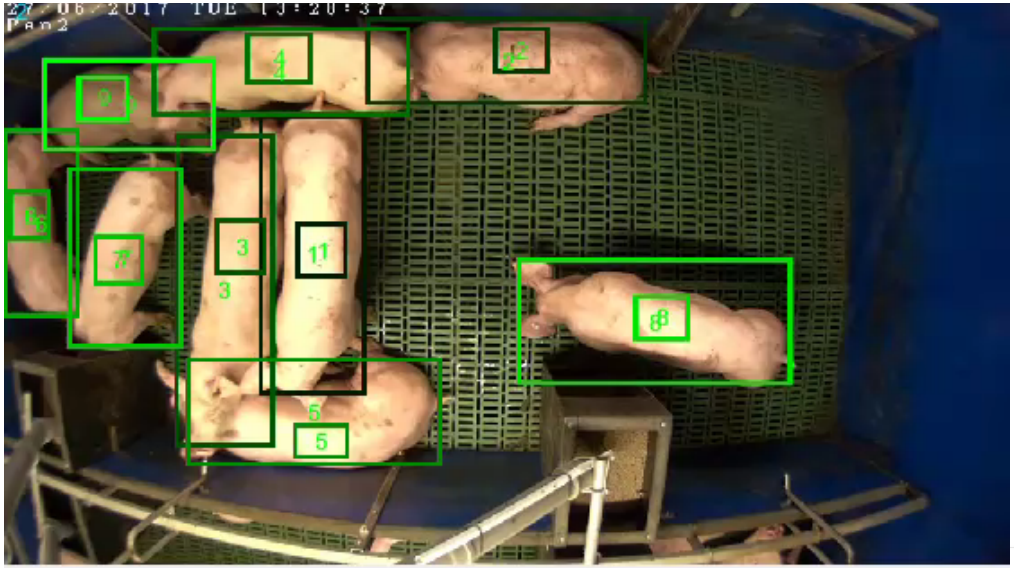
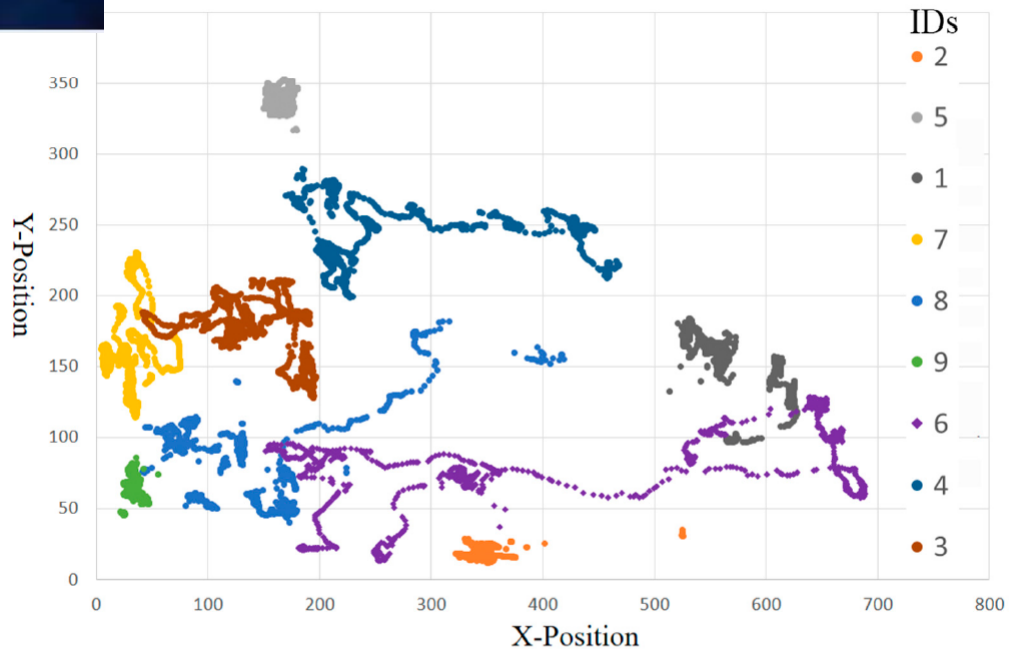


97.44% detection precision

95.2% tracking accuracy



Zhang L, Gray H, Ye X, **Collins LM** & Allinson N. 2019. Automatic Individual Pig Detection and Tracking in Pig Farms. Sensors 19:1188.

Lee H; Perkins C; Gray H; Hajat,S; Friel M; Smith RP; Williamson S; Edwards P; and **Collins LM.** 2020. Influence of temperature on prevalence of health and welfare conditions in pigs: time-series analysis of pig abattoir inspection data in England and Wales. Epidemiology & Infection 148: e30

Economic models of disease risks on farm

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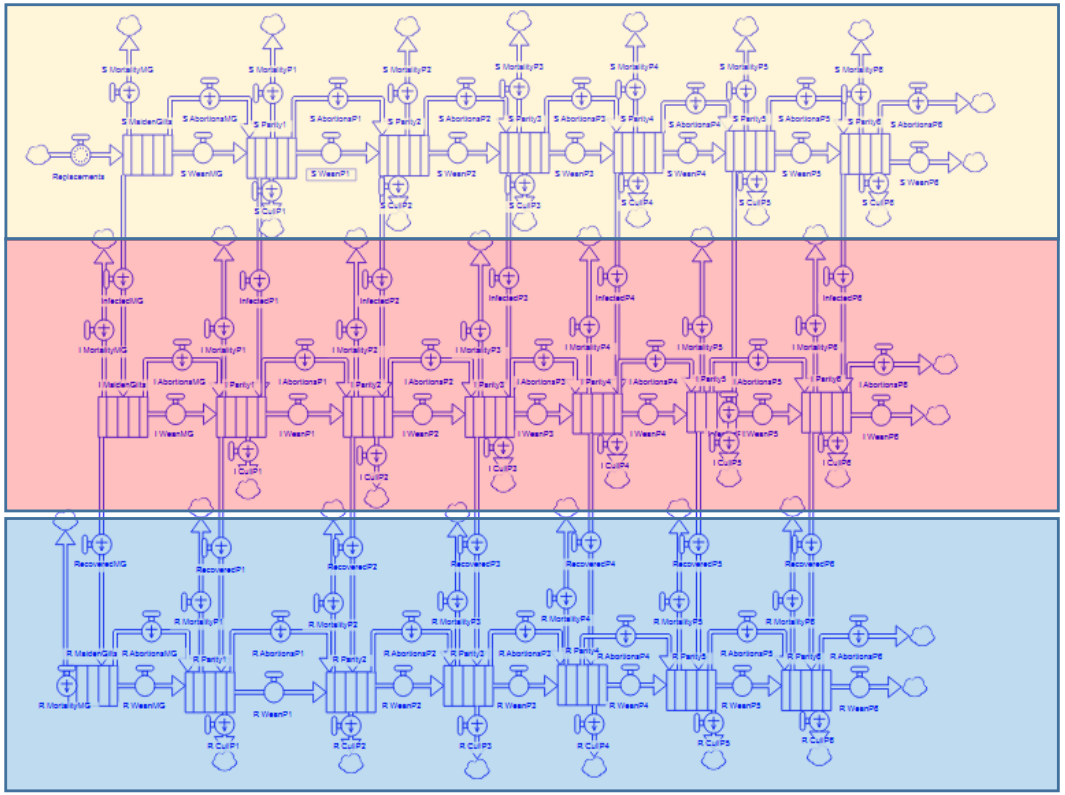
- Model adapted to run different scenarios – disease, prices, changes in management e.g. cull rate
- FBS data, WP1 and 3 data

- Main levels:
  - Volume of output from physical modules
  - Prices for output
  - Variable costs (value or price and volume) and gross margin
  - Fixed costs and income at enterprise and farm level



Breeding module physical flows

Yellow: healthy sows, Red: infected sows, Blue: recovered sows

Developing a national-level food system model

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- Global food system faces numerous endogenous and exogenous, biotic and abiotic risk factors
- Quantitative models help us understand food systems' expected responses to shocks and stresses.
- We developed a mathematical model of national-level food system, incorporating:
    - Domestic supply of a commodity
    - International trade
    - Consumer demand
    - Food commodity price
- Using Bayesian estimation, we applied the dynamic food systems model to infer sustainability of the UK pig industry

Can pigs tell us anything about the wider food system?

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- Historically, pig industries have been of much interest to economists and agronomists as one of the first investigations into business or 'pork' cycles (e.g. Haldane 1934; Ezekiel 1938; Sterman 2000).

- Business cycles reflect the oscillations between commodity prices and supply, which have been posited to be the result of both endogeneous and exogeneous mechanisms.

- **The pig industry is an interesting model to consider concepts of food system resilience more generally**

System model structure

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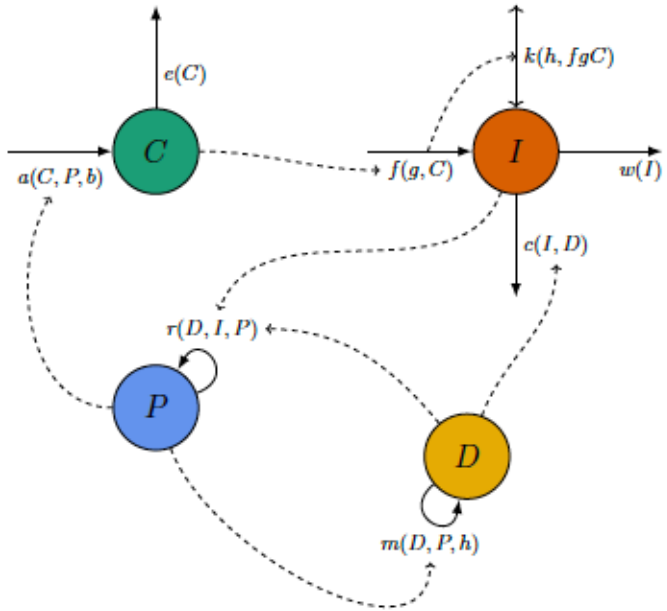
- Capital (raw material - gauge of viability; e.g. number of breeding animals, or number paddy fields in rice supply chains)
- Inventory (stock of processed commodity)
- Consumer demand (amount of inventory demanded over specified time period)
- Commodity price (price received by producers per commodity unit)



The general structure of the theoretical complex food system model. Blue circles denote the the four state variables (capital, inventory, demand and price). Solid arrows indicate the different flows into and out of each state variable comprising their rate of change, and the arrow labels display generic functions of the model state variables and parameters (see Table 1 for the specific definitions used in this model). Dashed arrows show dependencies between different state variables and flows.

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Data sources

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Variable	Data	Details
T - TIME	Time set to monthly intervals 2015-2019	Price data only available for this time period
C - CAPITAL	Number female pigs in breeding herd (June & Dec surveys – DEFRA 2020)	Breeding herd represents main capital of meat industries
I - INVENTORY	Amount (kg) new pork available for consumption (DEFRA 2020; AHDB 2020)	Calculated as UK production plus imports minus exports
P - PRICE	All pig price (kg/deadweight) (DEFRA 2020)	Price producers receive assumed to be proportional to retail price
D – CONSUMER DEMAND	No data available	Latent variable

Food system model dynamics

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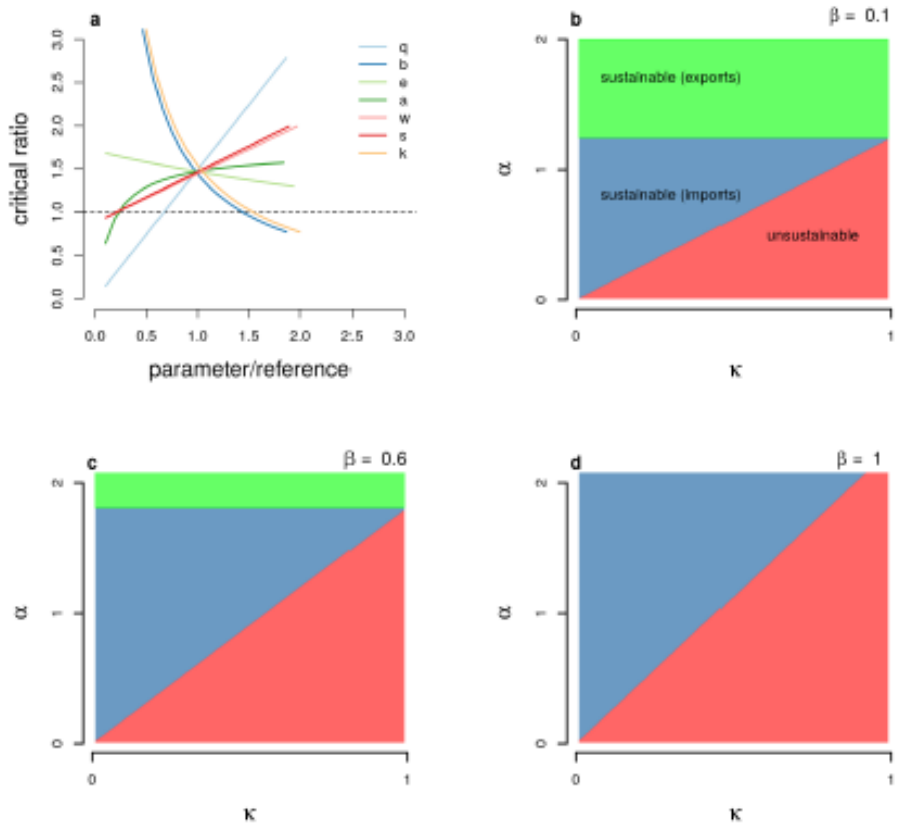
- Sustainability of the domestic industry depends on a compound of:
  - Profitability (price to cost of production ratio)(α)
  - Ability to produce new capital (growth & depreciation rates)(β)
  - Strength of international trade (κ)

- Below κ = 1, international trade outcompetes domestic industry and model enters unsustainable regime characterised by total reliance on imports.



Panel a shows the sensitivity of the model to key parameters. Panels b-d show stable behaviour with unsustainable (red), sustainable with imports (blue) and sustainable with exports (green).

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Fitting the food systems model to the UK pig industry data

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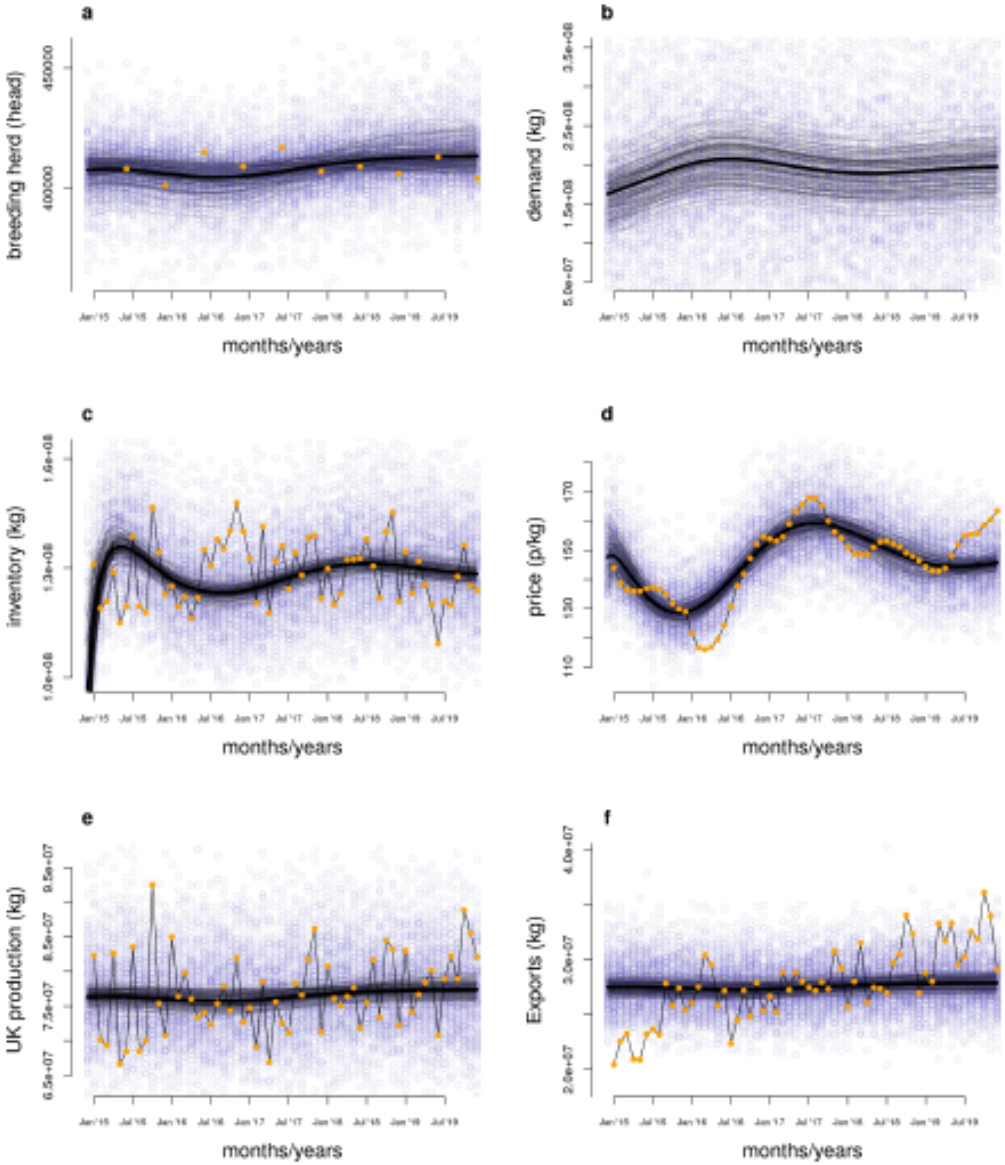

Orange filled circles show the raw monthly data (some data is missing), thin black lines display 200 random samples from the posterior distribution, the thick black lines indicate the mean posterior trajectory, and open blue circles display 200 random samples from the posterior predictive distribution (i.e. predictions incorporating random noise).

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Food system model take homes

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- Unsustainable food system regime results in higher commodity prices, lower inventory and lower consumer demand than when domestic supply is sustainable.

- Systems that must supplement domestic supply with imports to meet demand are more vulnerable to collapse.

- Systems that produce a surplus of domestic commodity benefit from exporting more.

- Supports literature on diversification of commodity sources to ensure food system resilience. However, also suggests that complete self-sufficiency is potentially harmful where the food system is reliant on few supply chains.

Is the UK pig industry sustainable?

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- From the 2015-19 data, UK pig industry is in the sustainable regime.
- Whilst the industry has decreased in size in the last 20 years, self-sufficiency is around 60-65% and the export market strengthening (trade strength estimated to be 35-37%).
- If trade strength increased to 61% (suggesting self-sufficiency drops <50%) the industry will be close to approaching unsustainability.
- However, numerous new challenges to the industry:
    - Post-EU trade
    - COVID-19 impacts on processing efficiency
    - Changes in dietary preferences
    - Health challenges (e.g. African Swine Fever)
- **Some of these impacts are currently being modelled.**

Acknowledgements

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Dr Conor Goold
Dr Will James
Dr Nik Lomax
Prof Mark Birkin
Dr Simone Pfuderer
Prof Richard Bennett
Prof Fiona Smith
Dr Helen Gray
Dr Mary Friel
Suzannah Turner
Dr Lei Zhang
Prof Xuijiong Ye

Prof Nigel Allinson
Dr Susanna Williamson
Dr Richard P. Smith
Dr Shak Hajat
Prof Phil Edwards
Dr Chloe Perkins
Hyunju Li
Daniel Gilson

All the farmers, producers, processors, retailers, policy-makers, vets and other stakeholders who have worked closely with us throughout.

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

UNIVERSITY OF LINCOLN

University of Reading

Animal & Plant Health Agency

BBSRC bioscience for the future

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

The Scottish Government Riaghaltas na h-Alba

Global Food Security Sustainable, healthy food for all