



Scenarios of future change in Norway: Results of an agent-based model

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Outline



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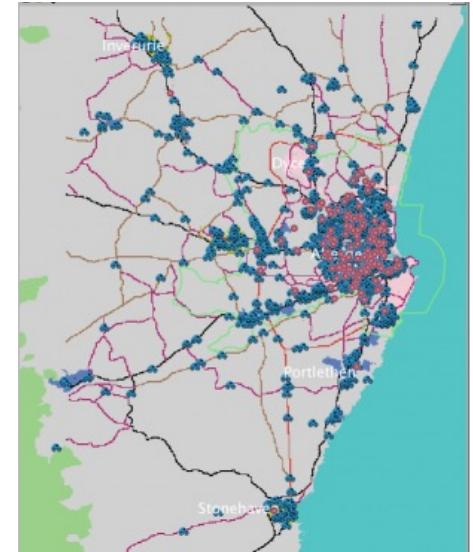
- Brief introduction to agent-based modelling
- Overview of the PROTEIN 2.0 model
- Results
- Conclusions and potential future work

Brief introduction to ABM



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- Agent-based modelling (ABM) is:
 - Computer simulation
 - of the interactions
 - of heterogeneous individuals
 - Could be people, households, businesses, governments
 - Each agent can have different attributes
 - with each other
 - e.g. Markets, norms, regulation
 - and, optionally, a spatial environment
- Empirical ABM uses spatial and social data
 - typically, to model policy scenarios
- Why ABM?
 - In relation to analytical approaches:
 - fewer restrictions on assumptions
 - In relation to purely quantitative approaches:
 - can model out-of-sample scenarios
 - In relation to purely qualitative approaches:
 - logical consistency and complexity beyond human cognition

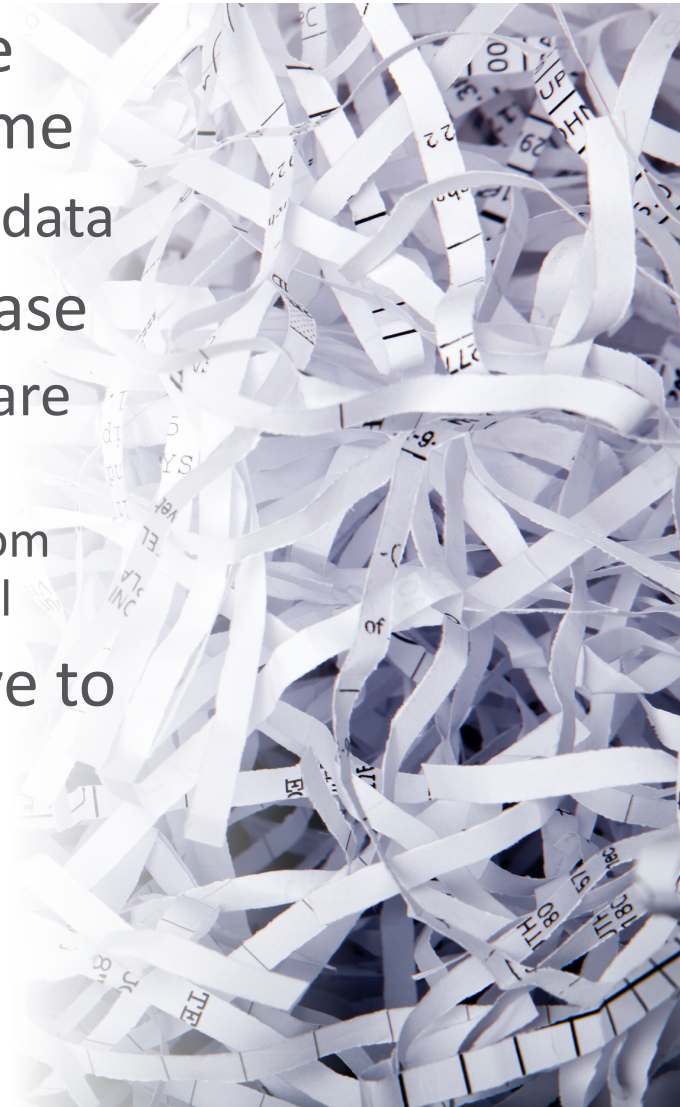


ABM of commuting
in Aberdeen
(Ge & Polhill 2016)

agents: commuters
decisions: route
interactions: queuing
environment: roads
scenario: bypass

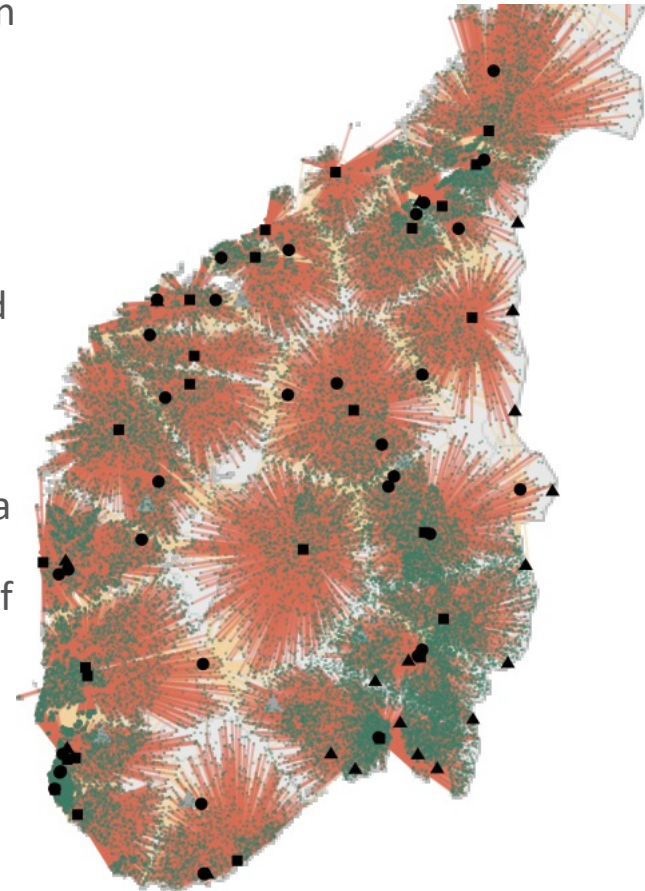
Issues with empirical ABM: data

- The data you put in to the model are important in determining the outcome
 - ABMs are particularly demanding for data
- Cultured protein is an ‘interesting’ case
 - Commercial companies would not share their data with us
 - We have to ‘estimate’, and use figures from publications and/or promotional material
- The results of the model are sensitive to what is assumed
 - Costs of production
 - Energy, labour, ingredients
 - Infrastructure costs



Overview of the PROTEIN 2.0 ABM

- Purpose
 - Model plausible effects of cultured protein on Norwegian agri-food sector
- Agents represent key parts of the value chain
 - Farms, dairies, slaughterhouses, import/export checkpoints, retail/consumers
 - All ~42k farms in Norway are simulated from 2013
 - Cultivated protein production is progressively introduced starting 2025 when cost competitive
 - Use scenarios from Vergeer et al. (2021)
- Runs continue until 2050
 - Farms cease operations entirely if revenue drops below a given threshold
 - Dairies and slaughterhouses cease operations if supply of raw products from farms drops below a given threshold
 - Farms cease dairy activities if there ceases to be dairies within a given radius
 - Farms cease livestock rearing if there ceases to be slaughterhouses within a given radius
 - Consumers purchase products from the cheapest source to the extent possible - market share of each CF is capped at 53.9%

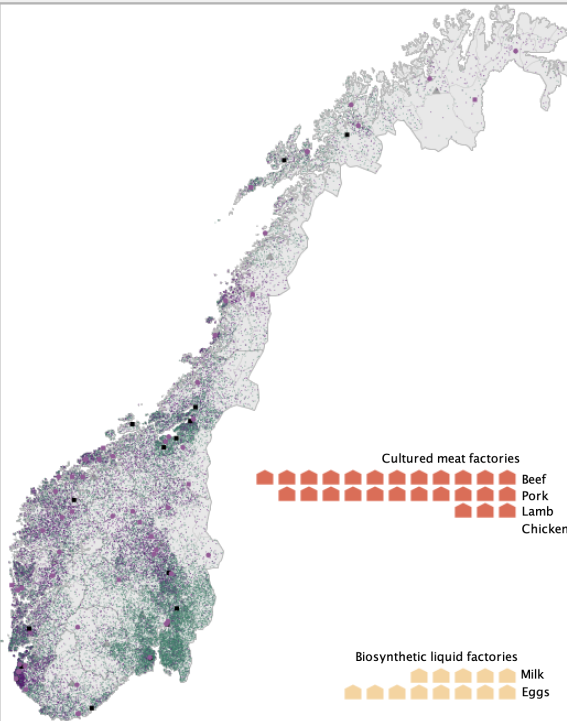


Screenshot of the PROTEIN 2.0 ABM

NetLogo — Protein_v6 (/Users/nickroxburgh/Library/CloudStorage/OneDrive-TheJamesHuttonInstitute/Documents/Projects/Protein 2.0)

Interface Info Code

Edit Delete Add abc Button normal speed view updates ticks: 36 continuous Settings...



Cultured meat factories
Beef
Pork
Lamb
Chicken

Biosynthetic liquid factories
Milk
Eggs

Year: 2050
Setup Step Run simulation

Simulation settings (pt. 1)

- param-scenario: Default
- sim-end-yr: 2050
- num-farms-to-sim: 42437
- animal-yield-trajectory: Constant
- population-growth: Medium
- farm-income-viability: -15%
- slaughter-min-capacity: 80%
- max-dist-to-slaughter: 230 km
- dairy-min-capacity: 80%
- max-dist-to-dairy: 140 km
- price-scenario: Determined by markets
- price-baseline-year: 2020
- price-response-ratio: 1.00%
- sim-cm?: On
- cm-init-yr: 2024
- cm-factory-capacity: 5000 tonnes
- cm-max-share: 53.9%
- cm-scenario: Scenario 8

Simulation settings (pt. 2)

- efficiency-gain-multiplier: 0.95
- efficiency-step-in... 20000 tonnes
- efficiency-step-i... 340000 tonnes
- sim-pf?: On
- pf-init-yr: 2024
- pf-factory-dairy... 170000 tonnes
- pf-factory-egg-ca... 5000 tonnes
- pf-max-share: 53.9%
- pf-scenario: Scenario 2

Visualisation settings

- hide-farms?: On
- hide-kommuner?: On
- hide-fylker?: On
- hide-slaughterhouses?: On
- hide-farm-slaught-links?: On
- hide-dairies?: On
- hide-farm-dairy-links?: On
- hide-checkpoints?: On

Farm-gate price growth post-2020

- price-growth-beef: 0.00%
- price-growth-pork: 0.00%
- price-growth-lamb: 0.00%
- price-growth-chicken: 0.00%
- price-growth-eggs: 0.00%
- price-growth-raw-milk: 0.00%
- price-growth-wool: 0.00%
- price-growth-crops: 0.00%

Per-capita consumption growth post-2020

- consum-growth-beef: 0.00% per yr
- consum-growth-pork: 0.00% per yr
- consum-growth-lamb: 0.00% per yr
- consum-growth-chicken: 0.00% per yr
- consum-growth-eggs: 0.00% per yr
- consum-growth-milk-cream: 0.00% per yr
- consum-growth-yoghurt: 0.00% per yr
- consum-growth-butter: 0.00% per yr
- consum-growth-cheese: 2.75% per yr

Overview metrics

- Population (m)**: 6.021 (Active: 2802)
- Total farms**: 46700 (Active: 0)
- Total slaughterhouses**: 34.1 (Active: 0)
- Total dairies**: 48.4 (Active: 0)

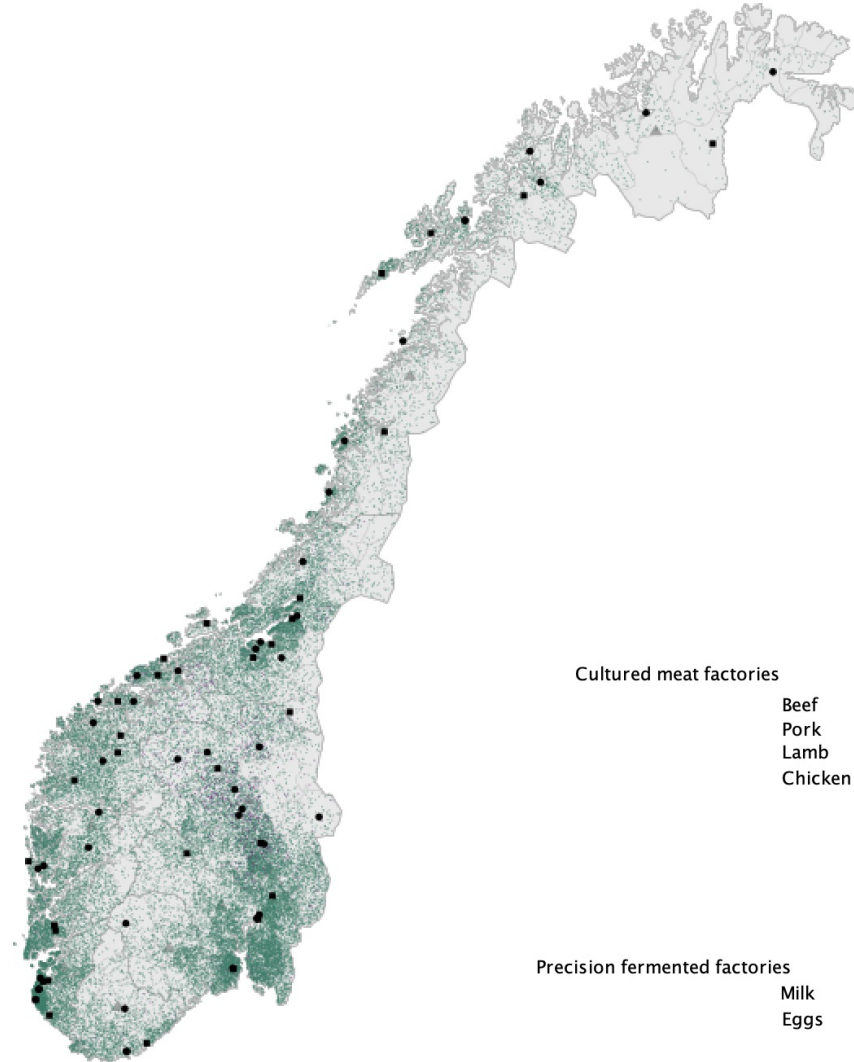
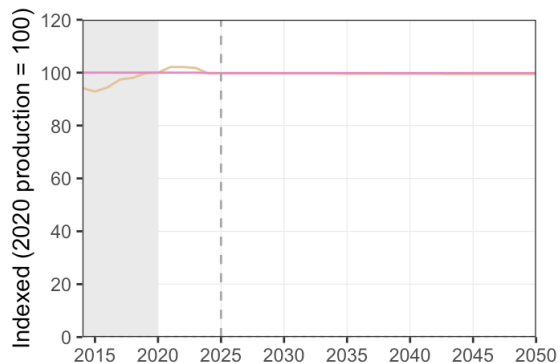
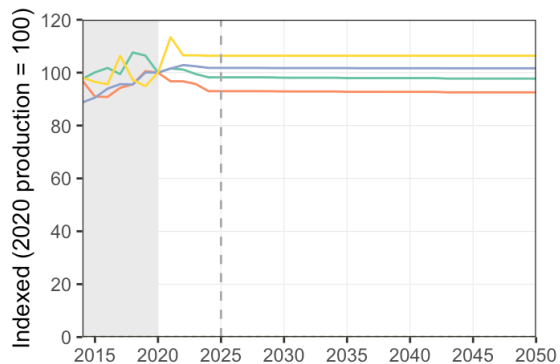
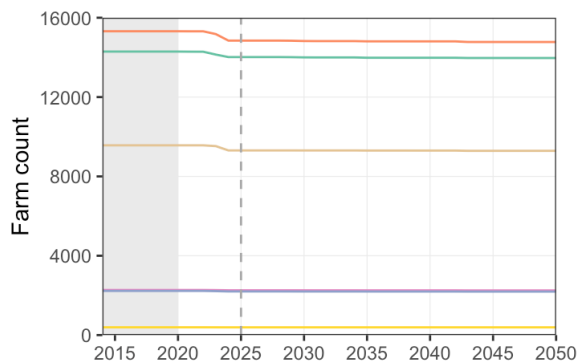
Command Center
observer>

Results: Business-as-usual scenario

Vergeer et al. (2021) Scenario < 6



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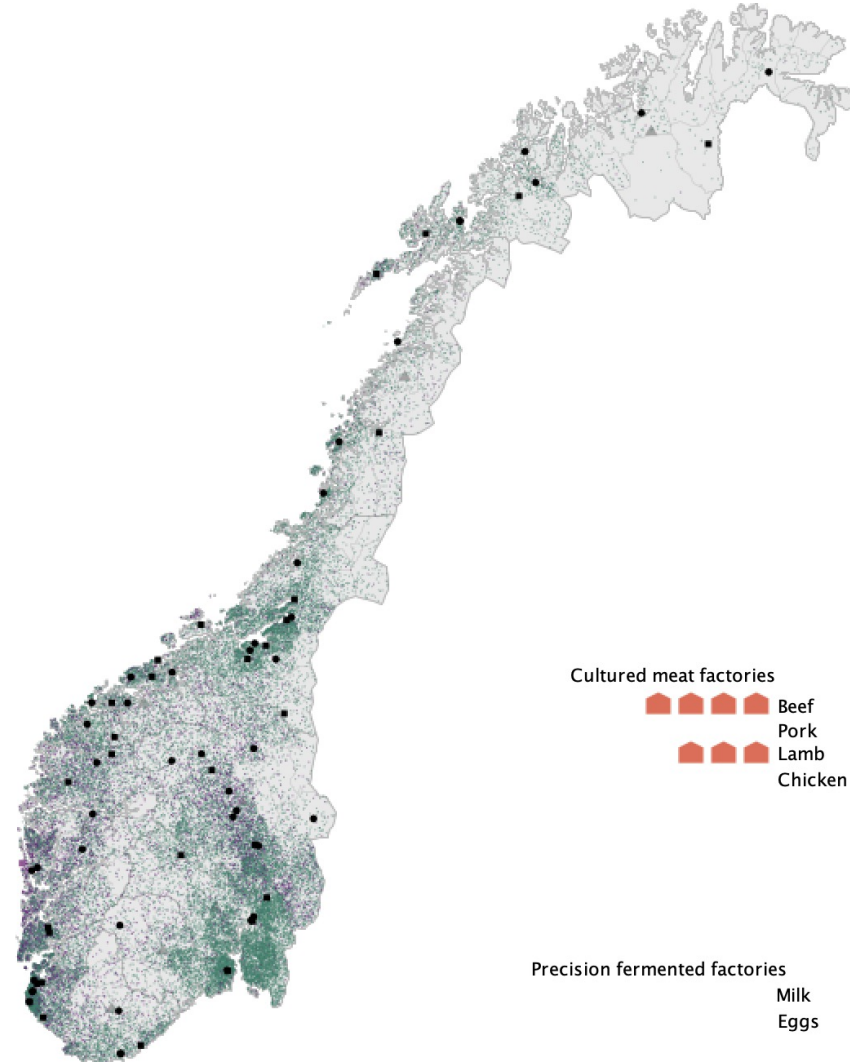
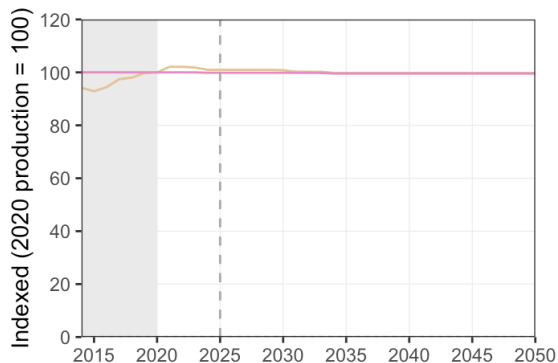
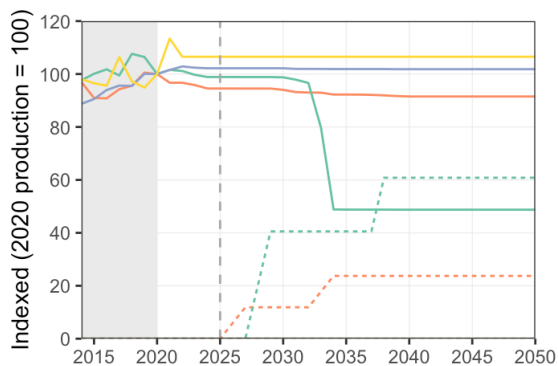
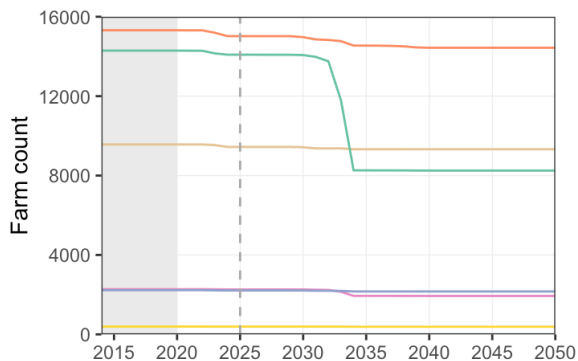


Results: Partial CF narrative scenario

Vergeer et al. (2021) Scenario 6



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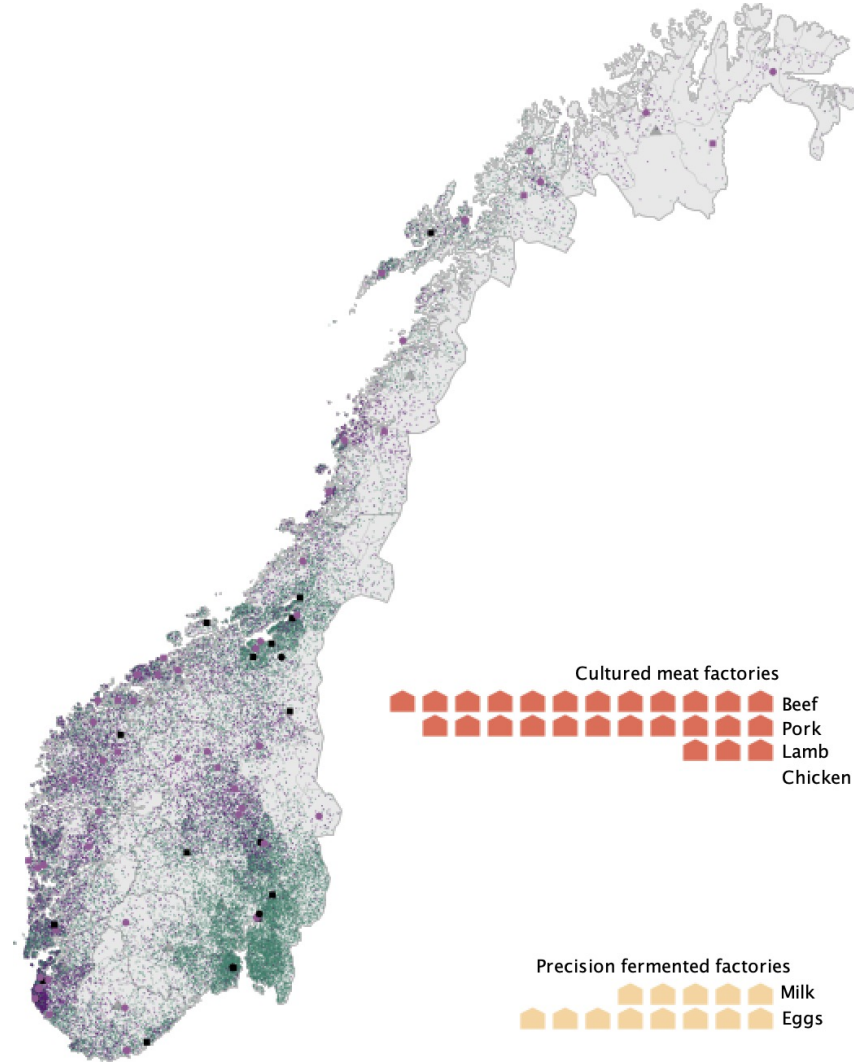
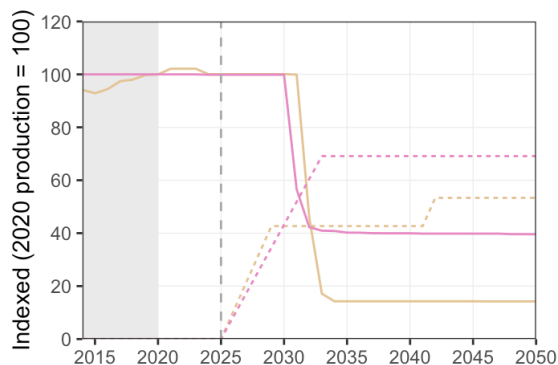
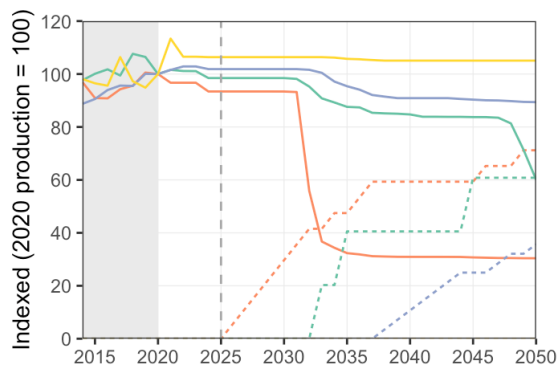
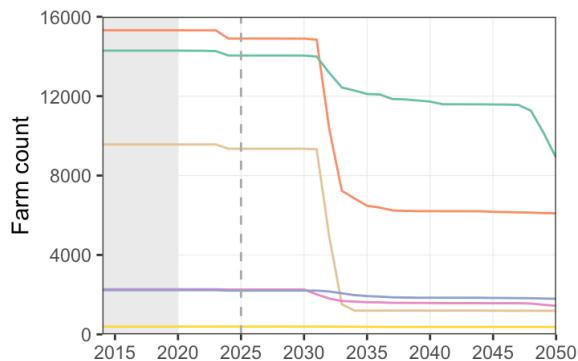


Results: Full CF narrative scenario

Vergeer et al. (2021) Scenario 8



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Conclusions and future work

- Conclusions
 - Complex spatial interactions in the value chain mean impact of cultured protein varies in Norway
 - For cultured protein to ‘disrupt’ the whole Norwegian agri-food sector, some strong assumptions are needed
 - Poultry less ‘vulnerable’ than beef/dairy
 - Continuing global increase in demand for meat and dairy may mitigate the impact
- Possible future work
 - Relaxing some of the earlier assumptions
 - Improving farm decision-making
 - Adaptive location and production of cultured protein factories
 - Adaptive consumer behaviour

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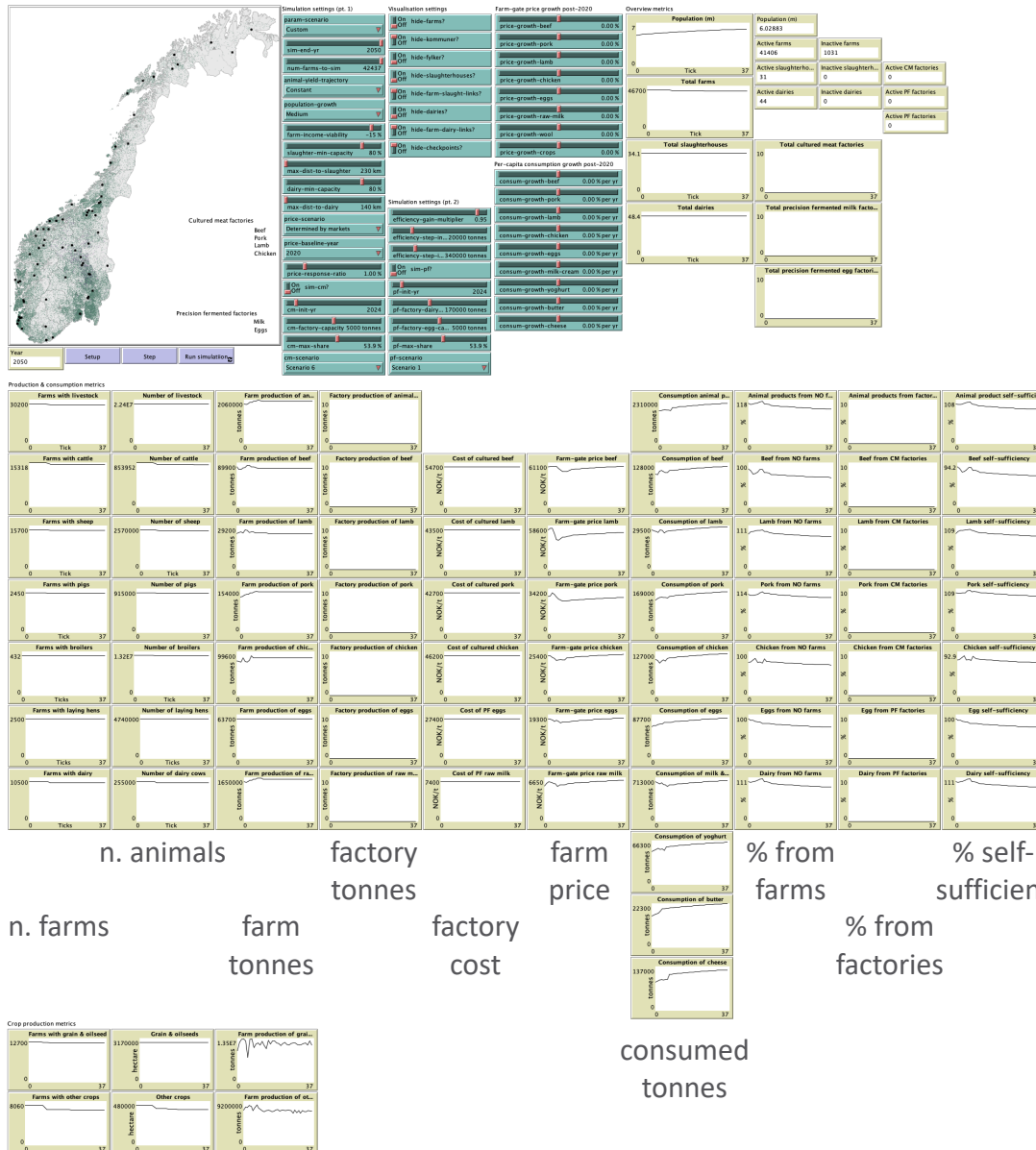
Thanks to our partners at...



Summary of assumptions made

- Farm decision making is driven by revenue and access to services, and is limited to whether they remain in operation or not.
- Farms will tolerate a drop in revenue in excess of a defined threshold for a limited time (5 years by default) only.
- There is an upper limit on the distance that farms can be from dairies and slaughterhouses if producing livestock products.
- Dairies & slaughterhouses must process a certain quantity of raw agricultural outputs to remain operational.
- There is an upper limit on the market share that cultured & precision fermented products can obtain.
- Each cultured meat and precision fermented product factory will specialize in a single product.
- Cultured & precision fermented products will not be imported or exported.
- Cultured & precision fermented products are perfect substitutes for their farm produced equivalents.
- Domestic per capita supply relative to 2020 determines prices.
- There is no substitution between meat products.
- There will be no increase in livestock productivity post-2020.
- There will be no change in per capita consumption post-2020.

Results: Business-as-usual scenario



All animal products

Beef

Lamb

Pork

Chicken

Egg

Dairy

Yoghurt

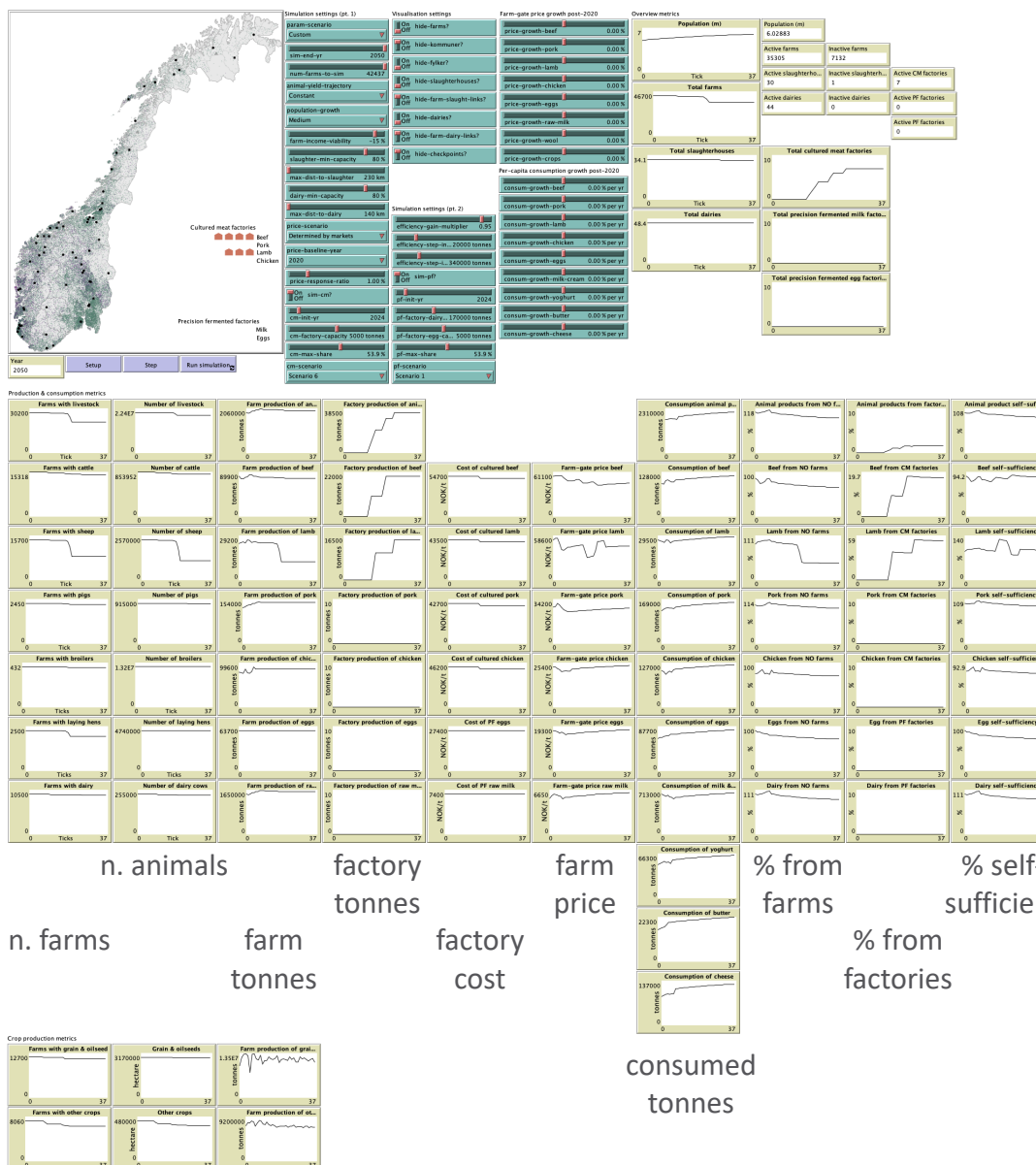
Butter

Cheese

Grain & oilseed

Other crops

Results: Partial CF narrative scenario



All animal products

Beef

Lamb

Pork

Chicken

Egg

Dairy

Yoghurt

Butter

Cheese

Grain & oilseed

Other crops

