The importance of climate and policy uncertainty in Norwegian agriculture

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Background and motivation

• Decision-making under uncertainty
  – Unknown weather at time of crop planting
  – Crop planting, farm management, and harvest differ in timing
  – Medium-term agricultural policies not known

• Methodological approach
  – Stochastic regional farm-specific module
    • Standard mean-variance model
  – Stochastic scenario method
    • Run numerous simulations where risk-averse farmers make decisions under uncertainty in an otherwise deterministic environment
Jordmod sector model

Results
Production, trade balances, factor use, prices, social welfare, GHG-emissions, multif. indicators

Deterministic market module

Stochastic farm module
Regional, farm-specific NLPs

Meat module

Dairy module

Scenarios
Policies, technologies, world market prices & input prices
Stochastic farm module

- Risk-averse farmers make crop planting decisions (activity level and N-intensity) under uncertainty regarding yields and payment rates:
  \[ E(U|\theta, \vartheta) \equiv \max_{y,x} M(PS(y,x|p,w,\theta,\vartheta)) - 1/2 \cdot \delta \cdot V(PS(y,x|p,w,\theta,\vartheta)). \]

- Nature resolves uncertainty. Farmers adjust animal production system given revealed yields and payment rates

- Farmers adjust animal production system given crop levels and N-intensity:
  \[ E(U|\theta^n, \vartheta^n) \equiv \max_x M(PS(x|y,p,w,\theta^n,\vartheta^n)) - 1/2 \cdot \delta \cdot V(PS(x|y,p,w,\theta^n,\vartheta^n)) \]

\( E(U|\theta, \vartheta) \): expected utility
\( M(PS) \): Mean of producer surplus
\( V(PS) \): Variance of producer surplus
\( \delta \): E standard error risk aversion coefficient
\( p \): vector of exogenous output prices
\( w \): vector of exogenous input prices
\( y \): vector of crop activity levels and N – intensities
\( x \): vector of animal activity levels
\( \theta \): stochastic weather variable with discrete distribution \( \tau_n \) and probabilities \( q_n \)
\( \vartheta \): stochastic policy variable with discrete distribution \( \sigma_n \) and probabilities \( \rho_n \)
Scenario set-up

- Run $N \times N$ simulations for $\tau_1, \ldots, \tau_N \times \rho_1, \ldots, \rho_N$

- Receive “pseudo-stochastic” distribution of $W$: $W(x|\theta^1, p, w, b), \ldots, W(x|\theta^N, p, w, b)$

- $N = 5$

<table>
<thead>
<tr>
<th>Description</th>
<th>Deviation from mean in terms of std.dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN3</td>
<td>-3</td>
</tr>
<tr>
<td>MIN1</td>
<td>-1</td>
</tr>
<tr>
<td>MEAN</td>
<td>0</td>
</tr>
<tr>
<td>PLUS1</td>
<td>+1</td>
</tr>
<tr>
<td>PLUS3</td>
<td>+3</td>
</tr>
</tbody>
</table>
Three scenarios

### Combined climate and policy uncertainty

<table>
<thead>
<tr>
<th>Policy uncertainty</th>
<th>Climate uncertainty</th>
<th>Climate uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min3</td>
<td>Min3</td>
<td>Min3</td>
</tr>
<tr>
<td>Min1</td>
<td>Min1</td>
<td>Min1</td>
</tr>
<tr>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Plus1</td>
<td>Plus1</td>
<td>Plus1</td>
</tr>
<tr>
<td>Plus3</td>
<td>Plus3</td>
<td>Plus3</td>
</tr>
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</table>

### Policy uncertainty

<table>
<thead>
<tr>
<th>Policy uncertainty</th>
<th>Climate uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min3</td>
<td>X</td>
</tr>
<tr>
<td>Min1</td>
<td>X</td>
</tr>
<tr>
<td>Mean</td>
<td>X</td>
</tr>
<tr>
<td>Plus1</td>
<td>X</td>
</tr>
<tr>
<td>Plus3</td>
<td>X</td>
</tr>
</tbody>
</table>

### Climate uncertainty

<table>
<thead>
<tr>
<th>Policy uncertainty</th>
<th>Climate uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min3</td>
<td>X</td>
</tr>
<tr>
<td>Min1</td>
<td>X</td>
</tr>
<tr>
<td>Mean</td>
<td>X</td>
</tr>
<tr>
<td>Plus1</td>
<td>X</td>
</tr>
<tr>
<td>Plus3</td>
<td>X</td>
</tr>
</tbody>
</table>

Uniform probability distribution
Importance of policy risk: Gross farm revenues in Norway (1986-2013)

Source: OECD (2014)
Modelling policy risk

Mean and variance of aggregate budget support, 2000-2013, 2011- prices

<table>
<thead>
<tr>
<th>Mill 2011-kr</th>
<th>Scenario</th>
<th>Application factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest</td>
<td>MIN3</td>
<td>.8714</td>
</tr>
<tr>
<td>Lowest</td>
<td>MIN1</td>
<td>.9571</td>
</tr>
<tr>
<td>Mean</td>
<td>MEAN</td>
<td>1</td>
</tr>
<tr>
<td>Std.dev.</td>
<td>PLUS1</td>
<td>1.0429</td>
</tr>
<tr>
<td></td>
<td>PLUS3</td>
<td>1.1286</td>
</tr>
</tbody>
</table>

Highest: 13 992
Lowest: 11 939
Mean: 12 915
Std.dev.: 554
Modelling stochastic grass yields

- LINGRA model
- Simulated biomass yields at four locations (g DM ha\(^{-1}\) cut & grazing) for base period (1961-90) and simulation period (2046-65)
- 1 N-level
- Yield gap 36-58 % in base period
- Calibration of explicit yield functions depending on N

<table>
<thead>
<tr>
<th>kg fodder units per ha</th>
<th>Baseline</th>
<th>Simulation</th>
<th>Application factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>9 299</td>
<td>10 670</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td></td>
<td>1 190</td>
<td></td>
</tr>
<tr>
<td>Std.dev.</td>
<td></td>
<td>34.5</td>
<td></td>
</tr>
<tr>
<td>MIN3</td>
<td>10 567</td>
<td></td>
<td>0.9903</td>
</tr>
<tr>
<td>MIN1</td>
<td>10 636</td>
<td></td>
<td>0.9968</td>
</tr>
<tr>
<td>MEAN</td>
<td>10 670</td>
<td></td>
<td>1.0000</td>
</tr>
<tr>
<td>PLUS1</td>
<td>10 704</td>
<td></td>
<td>1.0032</td>
</tr>
<tr>
<td>PLUS3</td>
<td>10 773</td>
<td></td>
<td>1.0097</td>
</tr>
</tbody>
</table>

Modelling stochastic grass yields

Modelling stochastic cereals yields

Rawdata

- CSM-CERES-wheat model
- Daily weather data generated by 15 global climate models A1B scenario
- 4 sets of representative soil profiles with various size
- 3 wheat varieties (Bjarne, Demonstrant, Zebra)
- 1 planting date
- 1 N-fertilizer level

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<th>kg/ha</th>
<th>Baseline</th>
<th>Simulation</th>
<th>Application factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5 133</td>
<td>5 724</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>437 388</td>
<td>525 883</td>
<td></td>
</tr>
<tr>
<td>Std.dev.</td>
<td>661</td>
<td>725</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th>MIN1</th>
<th>MEAN</th>
<th>PLUS1</th>
<th>PLUS3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN3</td>
<td>3 149</td>
<td>4 472</td>
<td>5 133</td>
<td>5 794</td>
<td>7 117</td>
</tr>
<tr>
<td>MIN1</td>
<td>3 548</td>
<td>4 999</td>
<td>5 724</td>
<td>6 449</td>
<td>7 899</td>
</tr>
<tr>
<td>MEAN</td>
<td>0.6913</td>
<td>0.9739</td>
<td>1.1151</td>
<td>1.2564</td>
<td>1.5390</td>
</tr>
</tbody>
</table>

Results: Cereals production

- Climate and policy uncertainty
- Climate uncertainty
- Policy uncertainty

Legend:
- Highest
- Lowest
- Mean
- Single observation
Results: Land rents

- Climate and policy uncertainty
- Climate uncertainty
- Policy uncertainty

- Highest
- Lowest
- Mean
- Single observation
Results: Milk production

![Graph showing milk production results with climate and policy uncertainty categories.](image-url)
Results: Milk quota rents
Results: Meat production

- Climate and policy uncertainty
- Climate uncertainty
- Policy uncertainty

Legend:
- Green diamond: Highest
- Red diamond: Lowest
- Blue diamond: Mean
- Black dot: Single observation
Results: Agricultural area

Graph showing the relationship between climate and policy uncertainty, climate uncertainty, and policy uncertainty with different markers for highest, lowest, mean, and single observation values.
Results: Fodder area

The chart illustrates the results of fodder area analysis under different scenarios of climate and policy uncertainty. The data points represent the highest, lowest, mean, and single observation values for each category. The x-axis shows the categories of climate and policy uncertainty, while the y-axis represents the area in thousands of hectares.
Results: Budget support

- Climate and policy uncertainty
- Climate uncertainty
- Policy uncertainty

Legend:
- Highest
- Lowest
- Mean
- Single observation

$mio\ nkr$
Results: Agricultural income

![Graph showing agricultural income with uncertainty categories.]
Results: Food consumption

Food consumption index (100 = Mean simulation)

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<thead>
<tr>
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<td>Mean</td>
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NILF
Norsk institutt for landbruksekonomisk forskning
Results: Food prices

Food price index (100 = Mean simulation)

- Climate and policy uncertainty
- Climate uncertainty
- Policy uncertainty

Legend:
- Highest
- Lowest
- Mean
- Single observation
Results: Social welfare

- Climate and policy uncertainty
- Climate uncertainty
- Policy uncertainty

Legend:
- Highest
- Lowest
- Mean
- Single observation
Discussion

• Introducing uncertainty in the sector model adds considerable complexity

• From the farmer’s perspective, climate uncertainty not necessarily more important than policy uncertainty

• Climate uncertainty does not seem to affect national food security given well-functioning trade systems

• Food security is foremost a global, not a national, problem