Climate Change, Agricultural Adaptation, and Food Prices: A Partial Equilibrium Approach using Micro Data

Iddo Kan and Ayal Kimhi*

* Authors are affiliated with the Department of Agricultural Economics and Management, the Robert H. Smith Faculty of Agriculture, Food and Environment, The Hebrew University, and with the Center for Agricultural Economic Research.

* Kimhi is currently visiting at the Research Institute for Humanity and Nature (RIHN) in Kyoto, Japan.

Helsinki, September 28th, 2012
Structure of presentation

• Methodological approach
• Application to Israeli agriculture
Modeling farm responses to climate change

• **Production approach**: experimental or empirical effects of climate change on yields
• **Ricardian approach**: empirical effects of climate change on farm profits or land values
• **Integrated approach**: empirical effects of climate change on farmers’ decisions feeding into market equilibrium changes that in turn affect farmers’ decisions.
How will climate change affect agriculture?

• **Direct effect**: Farmers will alter their crop portfolios

• **Indirect effect**: Crop prices will change as a result of the changes in supply, and this will lead to further changes in crop portfolios

• **New equilibrium**: These effects feed into each other until convergence
Previous research and our contribution

• Kaminski et al. (AJAE, forthcoming):
  A structural model of regional land allocation among crop-technology bundles

• Our contribution:
  – Adding the market equilibrium component
  – Estimating land allocations at village level
  – Allowing for corner solutions in land allocation
Analysis Flowchart

Production factors → Climate factors → Output prices → Demand elasticities

Village-level crop portfolio and land allocation model → Nationwide production

Nationwide production → Nationwide partial equilibrium

Nationwide partial equilibrium → Value of local production and imports

Nationwide partial equilibrium → Consumer surplus
Structure of presentation

• Methodological approach

• Application to Israeli agriculture
  – Why is Israeli agriculture a good case study?
SEASONS

Rainy Winter November-March

Dry Summer June -August
Varied climate conditions, topography and soil types stimulate the development of unique agricultural technologies

- **Climate**: Subtropical to Arid
- **Topography**: -408m to 1,208m
- **Soil**: Sand dunes to Heavy Loam
Value of agricultural production (2010)

2% of Net Domestic Product

Miscellaneous 5.7 %

Cattle, 18.2 %

Sheep and goats

Poultry 17.8 %

Flowers & garden plants 4.0 %

Field crops 5.3 %

Vegetables, potatoes & melons 23.4 %

Citrus 5.5 %

Fruit, excl. citrus 20.0 %

Total NIS million 26,486.3
Climate Change Forecast for Israel

### Precipitation

**mm/year**

- Precipitation: 100, 200, 300, 400, 500, 600, 700

### Temperature

- **January**
- **April**
- **July**
- **October**
- **Average**

- Temperature: 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32
Previous research on Israel

• Kan et al. (2007)
  – Mathematical programming applied to regional data
  – 20% decrease in net farm revenues by 2100

• Fleischer et al. (2008)
  – Ricardian approach applied to farm-level data
  – Moderate climate change beneficial but extreme changes harmful

• Kaminski et al. (forthcoming)
  – structural land allocation model applied to regional data from Israel
  – Up to 10% decrease in aggregate farm profits by 2060
Data

• 1992-2002 annual data from 793 communities
• 7 crop-technology bundles:
  – Irrigated field crops
  – Rain-fed field crops
  – Open-field vegetables
  – Covered vegetables
  – Deciduous fruits
  – Subtropical fruits
  – Citrus and other fruits
Agricultural communities
## Crop portfolios

<table>
<thead>
<tr>
<th>Activity</th>
<th>Fraction of growers</th>
<th>All sample (dunam)</th>
<th>Per-grower (dunam)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables, covered</td>
<td>27%</td>
<td>27</td>
<td>101</td>
</tr>
<tr>
<td>Vegetables, open field</td>
<td>73%</td>
<td>804</td>
<td>1,105</td>
</tr>
<tr>
<td>Field crops, irrigated</td>
<td>56%</td>
<td>879</td>
<td>1,573</td>
</tr>
<tr>
<td>Field crops, rain-fed</td>
<td>65%</td>
<td>1,319</td>
<td>2,016</td>
</tr>
<tr>
<td>Deciduous fruits</td>
<td>36%</td>
<td>123</td>
<td>338</td>
</tr>
<tr>
<td>Subtropical fruits</td>
<td>63%</td>
<td>174</td>
<td>274</td>
</tr>
<tr>
<td>Citrus &amp; other fruits</td>
<td>82%</td>
<td>421</td>
<td>513</td>
</tr>
</tbody>
</table>
## Climate data

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>mm/year</td>
<td>395.1</td>
</tr>
<tr>
<td>Precipitation S.D.</td>
<td>mm/year</td>
<td>121.6</td>
</tr>
<tr>
<td>Degree days - January</td>
<td>°C</td>
<td>145.1</td>
</tr>
<tr>
<td>Degree days - April</td>
<td>°C</td>
<td>328.7</td>
</tr>
<tr>
<td>Degree days - July</td>
<td>°C</td>
<td>576.9</td>
</tr>
<tr>
<td>Degree days - October</td>
<td>°C</td>
<td>441.3</td>
</tr>
<tr>
<td>Degree days – inter-annual S.D.</td>
<td>°C</td>
<td>198.9</td>
</tr>
<tr>
<td>Degree days – intra-annual S.D.</td>
<td>°C</td>
<td>5.6</td>
</tr>
<tr>
<td>Degree days above 34 °C</td>
<td>°C</td>
<td>0.46</td>
</tr>
<tr>
<td>Degree days below 8 °C</td>
<td>°C</td>
<td>6.4</td>
</tr>
</tbody>
</table>
Crop price indices

Field crops
Vegetables
Citrus
Other fruits
# Climate variables coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Vegetables Covered</th>
<th>Vegetables Open field</th>
<th>Field crops Irrigated</th>
<th>Field crops Rain-fed</th>
<th>Deciduous</th>
<th>Subtropic.</th>
<th>Citrus &amp; Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>-1.543**</td>
<td>19.69***</td>
<td>9.21***</td>
<td>8.715**</td>
<td>7.759***</td>
<td>-0.532</td>
<td>-17.73***</td>
</tr>
<tr>
<td>Precipitation S.D.</td>
<td>6.897***</td>
<td>-32.65***</td>
<td>-14.87**</td>
<td>-72.07***</td>
<td>-18.93***</td>
<td>7.521***</td>
<td>51.98***</td>
</tr>
<tr>
<td>Deg. days –April</td>
<td>-0.242</td>
<td>58.61***</td>
<td>34.44***</td>
<td>-16.03*</td>
<td>25.55***</td>
<td>-0.730</td>
<td>-7.721**</td>
</tr>
<tr>
<td>Deg. days – July</td>
<td>30.52***</td>
<td>49.3***</td>
<td>42.58***</td>
<td>50.58***</td>
<td>-18.89***</td>
<td>-9.886***</td>
<td>12.81**</td>
</tr>
<tr>
<td>Deg. days – October</td>
<td>-10.69***</td>
<td>-17.93*</td>
<td>-37.23***</td>
<td>-4.802</td>
<td>-43.71***</td>
<td>27.49***</td>
<td>11.36*</td>
</tr>
<tr>
<td>DD - inter ann. S.D.</td>
<td>2.99*</td>
<td>1.229</td>
<td>11.33**</td>
<td>82.05***</td>
<td>17.76***</td>
<td>-8.067***</td>
<td>2.681</td>
</tr>
<tr>
<td>DD - intra ann. S.D.</td>
<td>-1552***</td>
<td>-920</td>
<td>-2796***</td>
<td>-1851**</td>
<td>-1852***</td>
<td>419.4***</td>
<td>917.8***</td>
</tr>
<tr>
<td>DD above 34°C</td>
<td>61.83**</td>
<td>-476.6***</td>
<td>-885.5***</td>
<td>-1190***</td>
<td>152.3***</td>
<td>221.2***</td>
<td>-472.8***</td>
</tr>
<tr>
<td>DD below 8°C</td>
<td>-5.118**</td>
<td>20.54***</td>
<td>27.02***</td>
<td>-34.04***</td>
<td>14.61***</td>
<td>-1.568</td>
<td>5.705*</td>
</tr>
</tbody>
</table>
Climate Change Relative to 1981-2000 (%)

- Precipitation
- Degree days January
- Degree days April
- Degree days July
- Degree days October
- Inter annual degree days S.D.
- Intra annual degree days S.D.
- Degree days above 34°C
- Degree days below 8°C

Data categories:

- 2001 - 2020
- 2021 - 2040
- 2041 - 2060
Demand functions

Price Index

International price

Field crops

Quantity Index
Forecasted price indices

- **Field Crops**
- **Fruits**
- **Vegetables**

### Periods
- 1981-2000
- 2001-2020
- 2021-2040
- 2041-2060
Forecasted land allocations

- Citrus & other plantations
- Subtropic plantations
- Deciduous
- Field crops, rainfed
- Field crops, irrigated
- Vegetables, open space
- Vegetables, covered

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial equilibria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Value of Production, Imports and Consumption under partial equilibria (million NIS)

![Graph showing value of production, imports, and consumption under partial equilibria from 1981-2000 to 2041-2060.](image-url)
Summary

• Climate change is expected to bring about considerable changes in Israeli agriculture

• Ignoring price changes may lead to erroneous production expectations

• Our methodology takes into account:
  – Effects of price changes
  – Changes in crop portfolios at the farm level, including corner solutions
Wastewater recycling

Source: Lavee and Ash (forthcoming)
Water sources (million m³)

Source: Yoav Kislev, Taub Center (2012)
Water prices and direct costs

water for agriculture (in $US/CM, 2010 prices)