Economic and environmental impacts of Herbicide Tolerant maize cultivation in the EU: a modelling assessment

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Impact of HT maize: an ex-ante evaluation

- Weed control in the EU context
- Methodology of the study
  - Economic model
  - Methodology for the environmental assessment
- Simulation scenarios
- Results
- Discussion
Weed control in maize in the EU

• Weed control is an important determinant of maize yield
• Triple challenge in the EU:
  • Declining number of authorized active ingredients (Reg 1107/2009), new directive on Endocrine Disruptors to come
  • Greening of the CAP
  • Development of weed resistance but no new Mode of Actions
• GM HT maize for the EU?
  • NK603 received a positive risk assessment report by EFSA, but the petition for cultivation was withdrawn by the applicant
  • High adoption throughout the world
  • However, after a decade of adoption some users of the technology are experiencing weed resistance
Objective of the paper

• Provide an *ex-ante* assessment of the potential impacts of the introduction of a GMHT maize for the EU agricultural sector...
  • ... with both economic and environmental considerations taken into account
  • ... heterogeneity of farms included
  • ... and taking into account the possible changes in practices due to weed resistance development
• 3 scenarios with different:
  • Weed control strategy
  • Technology pricing strategy
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Methodology: the economic model (1)

- Stochastic partial budgeting model to tackle heterogeneity and price biases
  - Average farmer do not exist, but heterogeneity does
  - Adoption rate $\rho$:
    $$\rho = \int_{\theta}^{\infty} f(v) dv$$
    where $v$ represents farmer's individual valuation of the technology
    $\theta$ represents the price of the technology
    and $f(v)$ is the pdf of $v$ in the farmers' population
  - Average profit for adopters $\bar{\pi}$:
    $$\bar{\pi} = \int_{\theta}^{\infty} (v - \theta) f_a(v) dv$$
    where $f_a(v)$ is the pdf of $v$ in the adopters' population
    (Demont et al. 2008)
  - Endogenous price for the technology provider:
    $$\pi_{in}(\theta) = (\theta - c) \lambda_{adop} = (\theta - c)(1 - F(\theta)) \lambda_{tot}$$
    where $\lambda$ is land
    $c$ is LT marginal cost
    (Dillen et al. 2009)
Methodology: the economic model (2)

• How to elicit $f(v)$?
  • Under the assumption of profit maximizing farmers and considering only pecuniary benefits:

\[
v = \left[ (p_c y_c) - h_c - k_c \right] - \left[ (p_g y_g) - h_g - k_g \right]
\]

• And with $p_c = p_g; \ y_c = y_g$ and $k_c = k_g$

\[
v = \left[ h_c - h_g \right]
\]

• With $h$ the cost of herbicide treatments;
  y yield
  k other costs
  c for conventional, g for GM
Methodology: the environmental impact

- Assessment of environmental and health impacts of herbicide
  - Quantity of Active Ingredients / unit of land
  - Indicators
    - Exposure-toxicity Ratio (ETR) (eg. POCER)
    - Non-ETR indicators (eg. EIQ)
- The EIQ indicator
  - Most widely used, developed at Cornell University (Kovach et al. 1992)
  - EIQ = \{C[(DT*5)+(DT*P)]+[(C*((S+P)/2)*SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\}/3
  - One EIQ value for each AI
  - Data on rate of application lead to "field-use rating EIQ":

\[
FieldEIQ = \sum_{ai} EIQ_{ai} \cdot Rt_{ai}
\]
Methodology: the data

- A 2009-farm survey to maize growers
  - Telephone-based
  - 7 EU countries (CZ, DE, ES, FR, HU, PT, RO)

<table>
<thead>
<tr>
<th></th>
<th>CZ</th>
<th>DE</th>
<th>ES</th>
<th>FR</th>
<th>HU</th>
<th>PT</th>
<th>RO</th>
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<tbody>
<tr>
<td>Number of interviews</td>
<td>55</td>
<td>100</td>
<td>249</td>
<td>101</td>
<td>104</td>
<td>54</td>
<td>102</td>
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<tr>
<td>Utilised agricultural area (per farm in survey)</td>
<td>ha</td>
<td>1687</td>
<td>155</td>
<td>91</td>
<td>140</td>
<td>373</td>
<td>43</td>
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<tr>
<td></td>
<td>Std dev</td>
<td>1279</td>
<td>236</td>
<td>122</td>
<td>83</td>
<td>813</td>
<td>67</td>
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<tr>
<td>Utilised agricultural area (per farm in country)</td>
<td>ha</td>
<td>89</td>
<td>45</td>
<td>6</td>
<td>23</td>
<td>52</td>
<td>13</td>
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<tr>
<td></td>
<td>Std dev</td>
<td>192</td>
<td>27</td>
<td>48</td>
<td>36</td>
<td>241</td>
<td>65</td>
</tr>
<tr>
<td>Area cultivated with maize per farm in 2009</td>
<td>ha</td>
<td>230</td>
<td>33</td>
<td>37</td>
<td>37</td>
<td>117</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Std dev</td>
<td>192</td>
<td>27</td>
<td>48</td>
<td>36</td>
<td>241</td>
<td>65</td>
</tr>
<tr>
<td>Grain maize yield</td>
<td>tonnes/ha</td>
<td>9,9</td>
<td>10,4</td>
<td>10,6</td>
<td>9,6</td>
<td>10,0</td>
<td>8,7</td>
</tr>
<tr>
<td></td>
<td>Std dev</td>
<td>4,3</td>
<td>2,1</td>
<td>2,7</td>
<td>2,8</td>
<td>4,2</td>
<td>4,6</td>
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</tbody>
</table>
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**Weed control strategies in maize cultivation**

- Potential herbicide programs for GMHT maize in the Europe

<table>
<thead>
<tr>
<th>Program name</th>
<th>Description</th>
<th>Active ingredient</th>
<th>Rate of application (g of Al/ha)</th>
<th>EIQ of Al</th>
<th>EIQ field-use rating per Al</th>
<th>Total EIQ field-use rating of program</th>
<th>Estimated cost of the herbicide program (€/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program A</td>
<td>Only glyphosate applications</td>
<td>Glyphosate</td>
<td>2160</td>
<td>15,33</td>
<td>33,11</td>
<td>33,11</td>
<td>18-22</td>
</tr>
<tr>
<td>Program B</td>
<td>Pre + Gly Pre-emergence residual (low rate) and glyphosate</td>
<td>TBA S-metachlor Glyphosate</td>
<td>375 625 1080</td>
<td>42 22 15,33</td>
<td>15,75 13,75 16,56</td>
<td>46,06 48,52</td>
<td></td>
</tr>
<tr>
<td>Program C</td>
<td>EarlyPost + Gly Tank mix of post-emergence residual and glyphosate then glyphosate</td>
<td>Mesotrione Glyphosate</td>
<td>100 2160</td>
<td>18,67 15,33</td>
<td>1,87 33,11</td>
<td>34,98 53-57</td>
<td></td>
</tr>
<tr>
<td>Program D</td>
<td>Gly + Post Glyphosate + tank mix of glyphosate and dicamba</td>
<td>Glyphosate Dicamba</td>
<td>2160 240</td>
<td>15,33 26,33</td>
<td>33,11 6,32</td>
<td>39,43 43-47</td>
<td></td>
</tr>
</tbody>
</table>

Based on Dewar 2009 and expert opinions.
The scenario for weed control

- 3 scenarios to account for:
  - Change in weed management practices over time
  - Different strategy for the monopolistic pricing decision
- **Scenario 1: short run scenario**
  - Herbicide program for GMHT maize based on glyphosate (option 1)
  - Uniform technology price (exogenous)
- **Scenario 2: mid-term scenario**
  - Farmers switch to a diversified chemical weed management program (option 2)
  - Uniform technology price (exogenous)
- **Scenario 3: long-term scenario**
  - Diversified weed management program (option 2)
  - Third degree price discrimination (on spatial attribute) (endogenous)
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- Results and discussion
- Some policy recommendation
## Results

- **Baseline:** current weed control practices of EU farmers (conventional maize)

<table>
<thead>
<tr>
<th>Rate of herbicide application (g of active ingredient / ha)</th>
<th>CZ</th>
<th>DE</th>
<th>ES</th>
<th>FR</th>
<th>HU</th>
<th>PT</th>
<th>RO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-emergence</td>
<td>2531</td>
<td>1166</td>
<td>3273</td>
<td>1331</td>
<td>1462</td>
<td>1505</td>
<td>1534</td>
</tr>
<tr>
<td>Post-emergence</td>
<td>614</td>
<td>795</td>
<td>1074</td>
<td>396</td>
<td>511</td>
<td>470</td>
<td>792</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost of herbicide treatment (€/ha)</th>
<th>Average</th>
<th>Std dev</th>
<th>Average</th>
<th>Std dev</th>
<th>Average</th>
<th>Std dev</th>
<th>Average</th>
<th>Std dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-emergence</td>
<td>45</td>
<td>25</td>
<td>75</td>
<td>44</td>
<td>70</td>
<td>57</td>
<td>72</td>
<td>34</td>
</tr>
<tr>
<td>Post-emergence</td>
<td>25</td>
<td>25</td>
<td>44</td>
<td>22</td>
<td>57</td>
<td>34</td>
<td>51</td>
<td>29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field-use rating EIQ/ha</th>
<th>Average</th>
<th>Std dev</th>
<th>Average</th>
<th>Std dev</th>
<th>Average</th>
<th>Std dev</th>
<th>Average</th>
<th>Std dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-emergence</td>
<td>62</td>
<td>43</td>
<td>24</td>
<td>22</td>
<td>59</td>
<td>30</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Post-emergence</td>
<td>24</td>
<td>22</td>
<td>59</td>
<td>30</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>21</td>
</tr>
</tbody>
</table>

- **Average use of AI:** 2.15 kg / ha in PRE + 0.72kg / ha in POST
- **Average EIQ:** 37.7 EIQ / ha
- **Average expenditure:** about 70 €/ha
Results: Scenario 1

- Adoption of GMHT maize and economic impacts

![Graph showing economic impacts and percentage adoption for different countries.]

Average gross margin increase for adopters of GMHT maize (€/ha)

% of farmers adopting GMHT maize
Results: Scenario 2

• Adoption of GMHT maize and economic impacts

Average gross margin increase for adopters of GMHT maize (€/ha)

% of farmers adopting GMHT maize
Results: Scenario 3
- Adoption of GMHT maize, endogenous technology fee and economic impacts
Results: Scenario 1

- Environmental impacts
Results: Scenario 2 & 3

- Environmental impacts
Results: summary

• Results should not be over-interpreted
• The big picture is that GMHT could be profitable for many farmers in the EU, especially in the short run
• Two groups of countries
  • ES, PT and CZ: most farmers would realize both economic and environmental benefits of technology, even in the longer run
  • FR, DE and HU: only fraction of adopters would experience a decrease in EIQ
• The adoption of resistance management strategies is not in contradiction with economic attractiveness
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Policy recommendations

- The behaviour by farmers will determine sustainability of the technology
- Literature shows that farmers are often short-sighted
  - Weed resistance evolves fast => shift towards alternative programs (less profitable and less environmental friendly)
- Farmers have to be guided to reduce the pressure towards resistance build up
  - Management guidelines (rotation, mechanical control, ...)
  - Efficient extension services educating the farmers about the long term effects
Future research

- Make the decision of farmers dynamic based on the probability of weed resistance to evolve in the future following their own past practices
  - Dynamic programming
  - Heterogeneous risk adversity

- Incorporate other changes induced by the introduction of GMHT maize
  - Flexibility and easiness of weed control
Modelling *ex-ante* the economic and environmental impacts of Genetically Modified Herbicide Tolerant maize cultivation in Europe

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Thanks for your attention!