Environmental and production cost impacts of no-till: estimates from observed behavior

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April 15, 2010
Existing evidence of the impacts of no-till

Experimental studies

- Definition of no-till: leaves fields unturned and allows crop stubble to remain on the soil from harvest to sowing.
- Reduces soil erosion and conserves moisture.
- Reduces nitrogen and particulate phosphorus loss from fields to waterways.
- May increase herbicide application and herbicide runoff.
- Has also been linked to increased dissolved reactive phosphorus loss.
- Overall environmental impacts remain a contentious issue.
- Reduces overall production costs (labor, fuel).
Adoption of no-till worldwide

- Has been adopted in a wide range of conditions:
  - soils rich in clay to rich in sand and deep to shallow
  - climatic conditions from semi-arid or humid tropical to temperate
  - precipitation from 250 to 3000 mm a year
  - altitudes from sea level to 3000 meters

- Share of cultivated area under no-till worldwide:
  - South-America 47%
  - North America 38%
  - Australia and New Zealand 12%
  - Asia 2%
  - Europe 1% (10% in Finland)
  - Africa 0.3%

- Possible drivers of adoption: biophysical conditions, research interest, agricultural policies, machine and herbicide availability...
Contribution of this paper

- Overall environmental and economic impacts depend on farmers’ behavior, which cannot be assessed by field experiments.
- Existing economics literature:
  - Lots of studies on no-till adoption (see Knowler and Bradshaw 2007)
  - Theoretical framework for analyzing the private and social profitability of no-till by Lankoski et al. (ERAE 2006), application to short-term experimental data from Finland
- Little empirical information for evaluating the private and social benefits of no-till - key information from policy perspective.
- Purpose of this paper: combine a behavioral and biophysical models to assess the impact of no-till on
  - production costs
  - input use (labor, fertilizer, plant protection)
  - environmental damage (from nutrient and herbicide runoff)
Modeling framework

- Estimate a flexible cost function

\[ C (y, w, z, d; \theta) \]

where \( d \) indicates adoption of no-till technology.

- Input demands (labor, fertilizers, plant protection)

\[ q_j = q_j(y, w, z, d; \theta) \]

estimated simultaneously with the cost function.

- Estimated input demands fed into an environmental simulation model to approximate environmental damage.

- Assume that farmers are risk-neutral (Koundouri et al. ERAE 2009).
Adoption of no-till is not exogenous - likely to be influenced by farm characteristics that also affect production cost.

**Two-stage approach** (e.g. Khanna and Damon JEEM 1999):

1. Estimate the probability to adopt no-till technology.
2. Use the predicted probability of adoption in the estimation of the cost function.

Low number of adopters in the sample (4%) → employ a choice-based sample approach in the first estimation stage

1. Enrich the sample by over-sampling observations for adopters (25% adopters and 75% non-adopters).
2. Estimate the model using the weighted maximum likelihood estimator (Manski and Lerman, Econometrica 1977)
Study area: southern Finland

- Focus on grain production (predominant in the region).
- Temperate climate, conditions relatively harsh for agriculture. Thermal growing season is 180 days, annual rainfall 600-700 mm.
- Average yield levels about half of those in southern Europe.
- Main environmental problem related to agriculture is leaching of nutrients into waterways.
- On average a relatively flat region, but also steeply sloped fields present.
- Clay soils are predominant.
- Irregular rains caused by rapid changes in the weather.
Data

- From farm profitability bookkeeping records (basis for FADN).
- Unbalanced panel of 249 farmers over the 1998-2004 period.
- Overall 854 observations.
- Data on total variable costs and expenditures on fertilizers and plant protection, work hours, capital asset values, and grain output.
- Information on whether the farm has a no-till drill or not.
- Supplemented with weather data; grain, fertilizer, plant protection and fixed asset price indices; and area based subsidies.
Probit model, weighted maximum likelihood approach.

116 observations.

Adopters are removed from the sample after adoption.

All explanatory variables are lagged one period.

The model was significant overall even though the fit was quite low (Wald test statistic significant at the 10% level, pseudo $R^2$ 0.13).

Significant variables:

- Price for plant protection/grain price (-)
- Price for fuel/grain price (+)
- Total land area planted with grains (+)
- Farmer’s age (-)
The cost function

- Translog variable cost function.
- Estimated by 3SLS on a system combining the cost function and input share equations.
- Predicted probability of adoption interacted with all variables.
- 854 observations.
- Overall the fit is quite good: $R^2$ for the cost function 0.66, labor 0.92, plant protection 0.67.
- Tested for Cobb-Douglas form of the cost function, hypothesis rejected.
Main results

- No-till does change cost shares in total variable costs. On average no-till
  - decreases the share of labor costs
  - increases the share of plant protection costs
  - increases the share of fertilizer costs
- Directions as one would have expected based on financial analyses.
- Overall, no-till has no significant impact on total variable costs.
- Impact of no-till on labor, plant protection and fertilizer cost shares robust to the choice-based sample (analysis repeated for 100 different samples of non-adopters).
Input demand equations

- Derived from $q_j = \partial C / \partial w_j$.
- Adoption of no-till
  - decreases demand for labor by 35%
  - increases the use of fertilizers by 39%
  - increases the use of plant protection agents by 98%
- The expected change in input use varies across the sample of farms.
The environmental simulation model

Framework

- Two components: (i) nutrient loss model and (ii) herbicide loss model.
- Predicted input demands combined with functions describing nitrogen, phosphorus and herbicide loads from farmland to waterways.
- Damage from nutrient and herbicide loading evaluated in euros per hectare.
- Parameters of the nutrient load functions depend on
  - the tillage technology
  - farm biophysical characteristics
- Considered relatively flat field slopes and steep field slopes (high erosion potential) in southern Finland.
The environmental simulation model

Results

- No-till increases the total herbicide load.
- No-till decreases total nutrient load from highly erodible soils.
- On highly erodible land, the total damage from nutrient and herbicide loading is
  - 1,307 EUR/ha with conventional tillage
  - 862 EUR/ha with no-till
- In average conditions the difference in total damage seems to go in the opposite direction, but the difference is not statistically significant.
- Conclude that no-till would be beneficial to the environment in the case of high erosion potential, in average conditions the impact is not clear.
Discussion and conclusions

- Caveats
  - No information on the area under no-till
  - Low number of adopters

- Main findings for the study area:
  - No-till does not have a significant impact on production costs
  - Unambiguously beneficial to the environment only on highly erodible land

- Experimental studies are not sufficient to assess the environmental impact of no-till.
- Both farmer behavior and local biophysical conditions need to be taken into account.
- Location specific studies and targeted policies called for.