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

Marita Laukkanen and Celine Nauges

MTT Agrifood Research Finland & LERNA-INRA and TSE

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

  $$C\left(y, w, z, d; \theta\right)$$

  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).

Econometric issues

- 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 (predominent 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.
- Suplemented with weather data; grain, fertilizer, plant protection and fixed asset price indices; and area based subsidies.

Estimation method and results

The adoption model

- 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.