Cropping / land-use choices and water management

Cropping choices and agricultural water demand in the Midi-Pyrénées region: First results from an econometric model[1]

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Main question

- How does a farmer react to a change input relative prices? Is the reaction related to the decision to allocate land across crops?
- In the short run, land is a (quasi) fixed input due for example to crop rotation constraints:
  - only changes in input use
- In the long run, land enters the production technology as any other input :
  - change in input use
  - change in land use $\rightarrow$ reallocation of inputs
- Specific focus on crop land allocation and water use. Water price change $\rightarrow$
  - short run: input substitutions
  - medium run water demand price elasticity by considering, in addition to the input substitutions that can take place within a period, the adjustment on water use generated by the modifications of land allocations.

How to answer

- Develop and estimate an agricultural production model for the Midi-Pyrénées region in which land use allocated to crops is endogenous
  - cropping choice model depending upon context (soil, climate, economic conditions)
  - agricultural production model (link between input use and cost of production or/and production level)
  - use of RICA/FADN data: results representative for Midi-Pyrénées
- Model agricultural water demand for the Midi-Pyrénées region
  - does agricultural water demand react to economic instruments (i.e. price)?
  - substituability/complementarity between water and other inputs (i.e. fertilizers)
  - link between cropping choice (endogenous) and agricultural water demand

Background information - Midi-Pyrénées region

Water use in the Adour-Garonne river basin in 2010

- Agriculture with 1200 million m^3 represents 40% of total withdrawals
- In summer agriculture represents up to 70% of total withdrawals
- Irrigated crops = 10% of agricultural land (national av. is 5.4%)

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Policy changes

- CAP reform (decoupling, greening)
- Withdrawable volume ("volume prélevable") defined as the total volume that farmers can collectively withdraw. These volumes are supposed to be in line with ecosystem needs.

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Observed changes

- Irrigated crop areas have decreased by 18% from 2000 à 2010
- Irrigated corn areas have decreased by 20% from 2000 à 2010

Stage 1 :Cropping choice model

Objectives

- Explain for each farmer using observable variables land allocation across possible crop
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Model specification

- Two issues: land allocation to crops is a joint process & a lot of zeros
- Estimate the surfaces allocated to each crop as system of censored equations (one by output) on the basis of the methodology of Yen and Shonkwiler (1999).

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Main determinants of cropping choices (land shares)

- Economic context : crop prices, subsidies, input costs
- Local conditions : location in space, climate, soils

Stage 2 : Production cost model

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- Model to explain the production costs for each farmer by accounting for (endogenous) cropping choices (crop land shares / areas)
- Model to explain use of the the main inputs (water, pesticides, labor, etc.) in order to minimize production costs

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Specification of the production cost model

- Multi-product cost function estimated on panel data
- Joint estimation of the cost model with derived demands inputs
- Zellner's (1962) technique for estimation of a seemingly unrelated equations was used to estimate the system

Main determinants of production costs and input demands

- Levels of agricultural production
- Unit costs of inputs (water, pesticides, labor, etc.)
- Observable characteristics of farms (capital intensity, livestock intensity)
- Predicted crop land shares / areas

A representative sample of farmers in Midi-Pyrénées

- Data from "Réseau d'Information Comptable Agricole" (RICA/FADN)
- Period : 1998-2004 (to be extended)
- OTEX considered : field crop farms, mixed livestock farms (13,14,41,42,44,60,81)
- Sample size : on average 388 farms per year (unbalanced panel)
- Spatial/temporal distribution of farms (by French Department)

Department	Year						
	1999	2000	2001	2002	2003	2004	Total
9	28	28	31	31	31	28	177
12	78	77	77	73	69	68	442
31	60	62	59	61	57	58	357
32	87	83	81	82	74	73	480
46	40	41	41	39	38	34	233
65	28	32	33	32	28	28	181
81	54	53	52	51	46	51	307
82	30	23	26	25	24	24	152
Total	405	399	400	394	367	364	2,329

7 agricultural products considered

- Corn irrigated (15.8%) : **grain**, **seed**, forage maize
- Corn (12.7%): grain, seed, forage maize
- Oilseed irrigated (4.2%) : **peas**, **soybean**, sunflower
- Oilseed (14.1%) : **peas**, **soybean**, sunflower
- Wheat (23.3%) : durum wheat, soft wheat
- Other cereals irrigated (0.7%) : **sorghum**, barley, other
- Other cereals (29.2%) : sorghum, barley, other

Descriptive statistics on agricultural productions

Variable	Unit	**Mean**$^{(*)}$	**Std. Dev.**	**Min.**	**Max.**
Production					
Corn irrigated	q	1,855.1	2,221.4	8.2	22,492
Corn	q	470.3	575.5	3.7	6,635
Oilseed irrigated	q	330.4	358.4	0.7	2,642
Oilseed	q	462.2	540.2	1.0	6,343
Other cereals irrigated	q	432.4	404.9	0.6	2,350
Other cereals	q	321.2	355.5	2.2	3,900
Wheat	q	939.3	1,258.3	4.0	13,751
Yield					
Corn irrigated	q/ha	85.2	26.9	13.0	165.3
Corn	q/ha	68.9	19.7	11.5	124.2
Oilseed irrigated	q/ha	25.7	10.4	0.1	70.1
Oilseed	q/ha	21.8	9.3	0.1	273.0
Other cereals irrigated	q/ha	58.0	18.1	6.1	103.3
Other cereals	q/ha	42.7	13.1	3.2	103.6
Wheat	q/ha	48.5	11.8	4.0	85.8

5 inputs included into the model

- Fertilizers : mainly mineral fertilizers
- Culture protection : pesticides, herbicides, etc.
- Labor : paid labor + opportunity cost for unpaid labor
- Water : expenses related to irrigation (operational expenses)
- Other : other operational expenses

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Model to explain operational costs

- Variable to be explained in the cost model: variable (operational) cost including the opportunity cost for unpaid labor

Descriptive statistics on inputs (input cost shares and unit price)

Variable	**Unit**	**Mean**$^{(**)}$	**St. Dev.**	**Min**	**Max**
Variable cost	euros	74,178	46,409	25,820	529,654
Cost share					
Fertilizers	-	0.0806	0.0401	0.0000	0.2680
Protection	-	0.0549	0.0504	0.0000	0.2663
Water	-	**0.0121**	0.0270	0.0000	0.1795
Labor	-	0.3649	0.1183	0.0668	0.7479
Other	-	0.4875	0.1099	0.2045	0.8635
Price or price index (source : IPAMPA)					
Fertilizers	-	101.8	26.1	12.1	243.9
Protection	-	96.7	32.2	5.1	251.3
Water	euro/m^3	0.106	0.038	0.052	0.200
Labor	euro/hour	8.3	1.1	6.1	10.5
Other	-	101.5	11.8	56.5	156.8

$^{(**)}$ Weighted means representative at the region level.

Stage 1 : Cropping choice model

Empirical specification

For a given crop c at year t, the land area allocated to this crop S_{ct} is modelled as a function of:

- elevation
- number of days with rainfall in summer (historical mean over 1996-2006)
- mean minimal temperature in summer (in $t-1$)
- subsidies (euro/ha) allocated to each crop c
- average crop price for each crop c (in $t-1$)
- average yield for each crop c (historical departmental mean over 1989-98)
- unit water price (mean at department level)

Results : Land share equation for irrigated corn

- elevation (-)
- number of days with rainfall in summer (+)
- mean minimal temperature in summer (+)
- subsidies (euro/ha) allocated to irrigated corn (+)
- subsidies (euro/ha) allocated to corn(-)
- average price for irrigated corn (+)
- average yield for irrigated corn (+)
- unit water price (-)

Results : Quantifying the impact of selected variables on land share for irrigated corn

Elasticity of the surface allocated to irrigated corn with respect to variable **x**: What is the variation in % of the surface allocated to irrigated corn when we increase by 1% variable **x**.

Water price	**Corn price**	**Irrigated corn subsidies**
-1.28***	0.55***	1.68***
(1.15)	(0.42)	(1.27)

*, **, *** significatively different from 0 at 10%, 5%, et 1% respectively.

Stage 2 : Production cost model (cost function + derived input demands)

Multi-product cost function (flexible form, Translog)

The total cost of production C_{it} for a farmer i in year t is modelled as a function of:

- production level of each crop c
- input prices (fertilizers, plant protection, labor, water)
- observable characteristics of farms (capital intensity, livestock intensity)
- land area allocated to each crop c (predicted by the crop choice model)

By using the predicted land areas allocated to each crop we account for a potential endogeneity bias

Derived demand x_k for input k: fertilizers, plant protection, labor, water

By construction x_k is a function of :

- production level of each crop c
- input prices (fertilizers, plant protection, labor, water)
- observable characteristics of farms (capital intensity, livestock intensity)
- land area allocated to each crop c (predicted by the crop choice model)

Multi-product cost function: main results

Cost elasticity with respect to the production level: change in cost (%) to be expected from a change of 1% of the production for a given output

- Corn irrigated : 1.22
- Corn : 0.33
- Oilseed irrigated: 2.22
- Oilseed: 2.01
- Other cereals irrigated: 3.48
- Other cereals : 1.15
- Wheat : 2.82

- Overall : 1.73

Derived demand in water : x_{water}

Elasticity of the water demand with respect to

- water price : -0.812
- fertilizer price : 0.118
- plant protection price : 0.226
- labor price : 0.680
- production of irrigated corn : 0.963
- production of irrigated oilseed : 0.085
- production of other irrigated cereals : 0.03

Direct and indirect effects of a water price change

Mechanisms accounted for by the model

- Increase in the water price $\Delta P_{eau} = +10\%$
- Direct effect: Water is reduced for each irrigated crop depending of crop water price elasticity
- Indirect effect : Water use may change due to reallocation of land across crops
  - Impact on land areas allocated to each crop $\Delta \widehat{S_c}$
  - Impact on total cost of production $\Delta \widehat{C}$ and on water demand $\Delta \widehat{x_{water}}$

Increase in the water price by 10%: results

Average impacts on the full sample

- Water consumption : -22%
  - Direct impact on water use : - 7%
  - Change in water use due to modification of cropping patterns : -15%
- Variable cost : +4%
  - Change in cost due to modification of irrigation levels : + 0.8%
  - Change in cost due to modification of cropping patterns : +3.2%

It is important to model crop choices!

Conclusion

- Model agricultural production representative at the scale of the Midi-Pyrénées region
- A model which can be applied to other regions of interest (smaller or bigger)
- Explicit account for endogenous crop choice in the agricultural water demand function
- Change in water consumption driven more by indirect effect (land use) than by direct effect (irrigation intensity)

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