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Modelling Economies of Scale, Energy Use and Farm Size to Reduce GHG:

On Contrasting “High-Tec”-Agriculture with Labour Intensive Farming

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Problem Statement

- There is a growing discussion about more sustainable agriculture.

How can we model aspects such as energy use?

- Over the last decades, agriculture has become energy and capital intensive, especially in developed western countries.

How is energy use related to economies of scale?

- Hereby agriculture increased its labor productivity and assured the survival and income of those farmers staying in business.

How can farmers' decisions for being competitive oriented in farming be recognized ?

continuation

- In contrast small farms emitting less carbon and green house gases have become less competitive and farmers are compelled to migrate to other sectors as a result.

How can we model increased competitiveness of small farms assuming subsidies for less GHG?

- Taxing of energy use as consequence of negative externalities per se will not help.

How can taxing been directed to technology decisions?

- Rather technology choices must be addressed if large scale farming and negative impacts are envisaged.

How can technology choices (economies of scale fossil, energy substitution as cause for GHG emissions been addressed at the roots and labor intensity increase?

Objectives

- The paper discusses the modeling of tools (tax and subsidies) to identify optimal sizes of farm operations along technologies and ecological concerns for reduced use of fossil energy.
- We integrate ecology concerns as a reference to different technologies requiring different levels of labor and fossil energy.
- It will be shown that taxes and subsidies can be differently assigned to technologies with an aim to reduce energy intensity.
- Tax revenues shall be used to subsidize labor of small farms.
- We will show how to test the income effects of taxes using a programming approach. The analysis shall be budget neutral.
- The aim is to minimize external effects by land allocation between small and large farms being different in use of fossil energy.
- Hence a moderate position is taken with respect to sustainable farming.

Methodological Approach

- Linear Programming (LP) of economies of scale can provide a data set of virtual activities.
- A Maximum Entropy (ME) approache generali-zes programming delivering flexible functions.
- Generalized function deliver behavioral responses:

  - land distribution for small and large farms

  - response functions to taxes and subsidies
- Policy instruments are optimized with the objective to minimize costs or maximize benefits minus costs of GHG emission.

Programming Economies of Scale

Gross Margin unit			1000	0	1800	0	1850
Capacities	P_0		P_1 0 - 20 cows	H_1	P_2 21 - 40 cows	H_1	P_3 11 -60 cows
Labor other restirciton	3600 b_2 … b_m	≥ ≥ … ≥	100	-5 0	30 . . .	0 O	20 . . .
Technology I cows II cows III cows IV cows V cows	20 0 0 0 0	≥ ≥ ≥ ≥ ≥	1 -1	20 -20	1 -1	20 -20	1

Programming of Large Scale Farms

- Remark: Note, constraints are internally used and apply differently between small-scale and large scale farms. We can then use them later as a distinction for small and large scale farm energy use intensity.

Objective: Profit Maximization

$$\text{Max} \quad \{ [p-u]' q \quad - t'h\} \qquad (1)$$

$$A_{11}\, q < c_s$$

$$A_{12}\, q < c_l$$

$$A_{13}\, q + Z_{11}\, h < c_e$$

$$Z_{11}\, q - Z_{12}\, h < b_t$$

where c_1: standard constraints

c_e: energy constraints to be met

c_l: land constraint to be met

b_e: threshold values for economies of scale

q: production activities

h: variables controlling economies of economies of scale: help variable

t : tax

p-u: gross margin

- This formulation includes potential steps for economies of scale as a variable "h".

Behavior of Large Scale Farms

- A next step is to translate the programming results into functions.
- For the moment we only sketch a procedure how to retrieve flexible functional forms.
- The method uses positive mathematical programming. As result one can obtain a quadratic cost function (Paris & Howitt):

$$P_l(q,h,\lambda)=[p-u]'q-t'h-.5[q,h]'Q_{l1}[q,h]+[q,h]'Q_{l2}[\lambda_s,\lambda_t,\lambda_f,\lambda_e]$$
$$+.5[\lambda_s,\lambda_t,\lambda_f,\lambda_e]'Q_{l3}[\lambda_s,\lambda_t,\lambda_f,\lambda_e]$$

- Some remarks are necessary concerning observation on technologies and modeling:

(1) As been outlined by Howitt and Paris the flexible form of quadratic modeling allows a delivering of marginal values. (2) A divergence between observations and internally calculated shadow prices or unit cost, respectively, is possible and

(3) the limitations of linear programming with respect to non-equal conditions can be overcome.

- For the derivatives we get behavioral functions:

$$\delta P_l(q,h,\lambda)/\delta\lambda_e = Q_{l221}q + Q_{l3}[\lambda_s,\lambda_t,\lambda_f,\lambda_e] = c_e$$
$$\delta P_l(q,h,\lambda)/\delta\lambda_l = Q_{l211}\, q + Q_{l3}[\lambda_s,\lambda_t,\lambda_f,\lambda_e] = c_l$$

Programming of Small Farms

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- Now we work with recycling is a first steps to achieve sustainability.

Max { [p-u]´ q – [u-s]´r} (5)

$$A_{11}\, q + A_{21}\, r < c_l$$
$$A_{12}\, q + A_{21}\, r < c_t$$
$$A_{13}\, q - A_{23}\, r < n_r$$

where c_t: standard constraints

c_l: land constraint to be met

n_r: nutrients constraint in recycling

u: unit costs in recycling can be internally determined

s: subsidy

r: recycling activity

- A generalized behavioral functions corresponds

Behavior of Small Scale Farms

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- For re-formulation, as a flexible function which can accommodate policy instruments, we get, as indicated above in the same vein of positive quadratic programming but now for small scale technologies, a functional representation of a profit function.
- This profit function (6) takes into account subsidies and gives values for the constraints as shadow prices.

$$P(q,r,\lambda)=[p-c]'q-[c-s]'r-.5[q,r]'Q_{s1}[q,r]+[q,r]'Q_{s2}[\lambda_s,\lambda_n,\lambda_f]$$
$$+.5\,[\lambda_s,\lambda_n,\lambda_f]'Q_{s3}\,[\lambda_s,\lambda_n,\lambda_f]$$

- The profit function can be used to get a response function subject to the subsidy on recycling of nutrients and
- we can portray how to reach less purchase of artificial fertilizer.
- Land demand (competitiveness on land market) is

$$\delta P(q,r,\lambda)/\delta\lambda_l = Q_{s,211}\,q + Q_{s,3}\,[\lambda_s,\lambda_n,\lambda_f] = c_{l,s}$$

Government Objective

- The aim is a change in the saving in costs of carbon emission (measure in fossil energy use equivalents) given as an un-weighted function of reduction (e_t =[$e_{l,r}$+$e_{s,r}$+$e_{u,r}$]) which shall have a quadratic feature (in principle it means there is a marginal value of demand function for reduction: alternatively on can work also with fixed prices):

$$E_r = \zeta_0 \, [e_{l,r}+e_{s,r}+e_{u,r}] + 0.5 \, [e_{l,r}+ e_{s,r}+e_{u,r}]' \, \zeta 1 \, [e_{l,r}+e_{s,r}+e_{u,r}] - t'h - s'r \qquad (9a)$$

where: $e_{l,r}$: energy saved by land redistribution (increase land share of small farms: indirect)

$e_{s,r}$: energy saved by small farms through recycling based on subsidies (direct on farm)

$e_{u,r}$: energy saved by large farms through taxing of economies of scale (direct on farm)

- Then, plus constraints (which are the agents behavioural functions as outlined above) gives the

Land Market

From a re-specification of production economics and decision making towards land demand we get

$$\lambda_l = Q_{l311} A\ l_l + Q_{l312} c_{l,l} + Q_{l313}\ c_{e,l} + Q_{l314} c_{t,l} + Q_{l315} t_l + Q_{l316}[p - c_l]$$

$$\lambda_s = Q_{s321} A\ l_s + Q_{s322} c_{l,l} + Q_{s23} c_{e,l} + Q_{s324} c_{t,l} + Q_{s325} r_s + Q_{s26}[p - c_s]$$

These are inverse land demand functions and they can be equated for shadow prices and land quantity

$$l_l + l_s = l$$

$$\lambda_l = \lambda_s$$

As a result a contingent land distribution can be depicted

$$l_s = Q^*_{l1}\ t_l + Q^*_{s2} r_s + [Q_{l3} + Q_{s3}][p - c_s]$$

Energy use due to land composition:

$$e_{l,r} = l_l / l\ e_l + l_s / l\ e_s$$

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Government Objective

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- Constraints:

$$A_1[e_{l,r}+e_{s,r}+e_{u,r}]=b_{l,0}+B_1[t,s] \Leftrightarrow [e_{l,r}+e_{s,r}+e_{u,r}]= A_1^{-1}[b_{1,0}+B_1[t,s]] \quad (9b)$$

and

$$A_2[h,r]= b_{2,0}+ B_2[t,s] \Leftrightarrow [h,r] = A_2^{-1}[b_{2,0}+ B_2[t,s]] \quad (9c)$$

where: A, B and b are matrices that give behavioural equations

- Inserting of constraints (9b and c) in (9a) gives a variable reduction of policy instruments “t” and “s”.
- Finally an objective to be maximized is obtained as result (10):

$$E_r = \zeta_0[A_1^{-1}[b_{1,0}+B_1[t,s]]] +0.5[A_1^{-1}[b_{1,0}+B_1[t,s]]]' \zeta 1 [A_1^{-1}[b_{1,0} +B_1[t,s]]]- [t,s]'[A_2^{-1}[b_{2,0}+ B_2[t,s]]] \quad (10)$$

This system can be solved for the optimal taxes “t” and subsidies “s”.

Summary

- I presented a modeling approach on how economies of scale in large farms and recycling in small farms can be subject to policy instruments and become interlinked by modelling .
- We assumed diminishing returns from reduction of energy use in agriculture.
- For the individual segment of large farms we charge a tax on energy use.
- The tax is collected according to economies of scale, based on virtual technology steps, and obtainable as technology.
- For small farms we suggested a subsidy on recycling.
- We deliberately introduced the tax for the switch between technologies.
- In the modeling of policy we addressed direct and indirect effects of taxes and subsidies which means land allocation.
- As indirect effect, with regard to the competiveness, the tax and subsidy will change land occupation as structural variable.
- Finally it is indicated how tax and subsidy can be optimized using an societal objective function of carbon costs.