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RESEARCH IN ECONOMICS AND RURAL SOCIOLOGY

Do environmental regulations relating to manure land application limit the geographical concentration of pig farms?

If the geographical concentration of intensive livestock, notably pig, presents major economic advantages, however, it results in a high concentration of farming effluents, a pollution source. To limit the environmental impacts of such a concentration, public Authorities may be tempted to limit the agglomeration of animal productions. An analysis of the French and Danish hog sectors shows that the environmental rule aiming to limit the quantities of effluents locally sprayed slightly discourage (in France, chiefly) the agglomeration process of production and does not compensate the powerful centripetal force already at work. The implementation of a regulation of effluent management in areas of high animal density even seems to reinforce the role of the geographical proximity between farmers and productivity gains.

The extreme geographical concentration of the hog production in France is well-known and well-documented: 62% of the hog production comes from farms located in 5% of the French *canton*; and conversely, near 1/3 of the 3,500 French *cantons* has no hog production. It is not surprising that Brittany is the first French region to concentrate that production. The situation seems to be identical in Denmark with a geographical concentration of the production in the Jutland and Funen island (see fig1). Some powerful economic forces explain the geographical concentration of the production activity, even if some of the factors may favour its dissipation.

The economic factors influencing the agglomeration or dissipation of the hog production

Increasing yields and transport costs of goods are often considered like the two major economic variables at the origin of agglomeration processes. Geographical concentration limits transport costs between clients and suppliers when these are also concentrated and favours scale economies, these scale economies may be internal to the firm when the concentration is only economic, but may be extended to the sector when we consider the gains generated by the proximity between various producers of the same sector. In the hog sector, the search for a geographical proximity between pig farmers and their clients (slaughtering houses) and suppliers (livestock foods) is at the origin of a geographical joined concentration of the hog production and its upstream and downstream industries. It is motivated by the importance of the transport costs and scale economies at distinct production stages. In the same way, a certain geographical proximity between cereal productions (being part of the animal food composition) and hog production may also play in favour of the production agglomeration.

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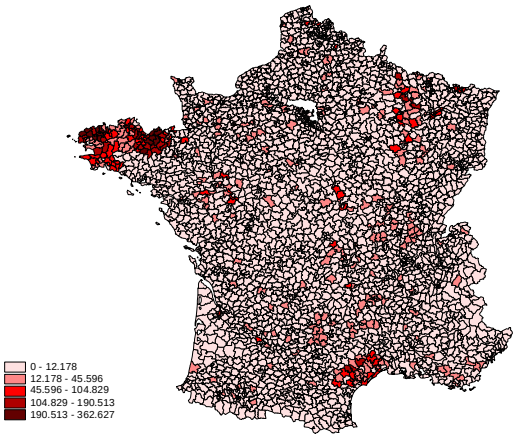
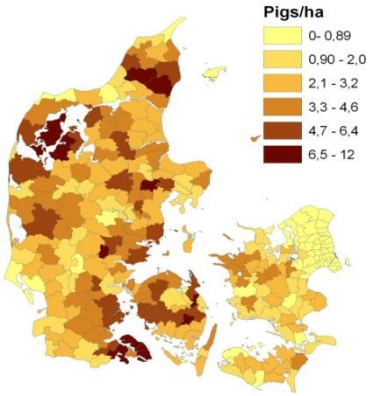
Figure 1 – Geographical distribution of the hog production in France and Denmark.



France – 2000
(pigs livestock unit /canton)
Source: SCEES, RA 2000 France.



Danemark – 2004
(Pigs density/municipality)
Source: Statistics Denmark

In parallel, every producer can look for a geographical proximity with other producers of the same sector. Various non-market interaction types which form all the more easily than producers are close, enabling the relation between cost and production to be modified and constitute what is usually called "technological externalities or marshalling externalities". The geographical proximity between producers first favours the circulation or information sharing relating to either development of input or output markets or to technical, organisational innovations or product innovations. Proximity also enables producers to share common inputs, the investments of which would be difficult to support by one sole producer. Under some conditions, proximity may enable the emergence of workforce trained to the specific tasks of that production. In other words, the productive efficacy of livestock grows with the number of livestock located in the same geographical area and decrease as the distance increases between them.

These forces contributing to the agglomeration on intensive livestock are powerful and in the case of hog production little compensated by the forces classically considered like favouring the dispersion of economic activities (competition for land use and land costs related, local work market tensions and salaried related costs which result from it; price competition between similar producers).
However, this geographical production concentration is a pollution source via the high geographical concentration of the effluents that it generates from this livestock. Today, the undesirable environmental effects of this concentration are well-known and more and more disparaged. The question of a re-location of the agricultural production, the concentration of which is a pollution source is often mentioned as a potential lever to reduce the environmental impacts of agriculture. For several years, through the Nitrates directive, the European Union has attempted to limit the water pollution linked to a too high nitrate concentration by re-introducing a link between intensive agricultural production and land. This is how manure spreading was limited to a maximum level of nitrogen per hectare of area spread and per year (The European Nitrates Directive fixing threshold at 170kg N/ha). Logically, this restriction on manure spreading rights weighs on the areas with high livestock density and where the available or accessible areas for manure spreading are weak. By re-introducing the land dimension in the decisions of "off-soil" producers, the implementation of the Nitrate directive and the non-neglecting costs, notably of transport and/or land access that it entails, play the potential role of a dissipation force by limiting the livestock development in the highly concentrated areas.

Determinants of the localisation of hog production in France and Denmark

By referring to the French and Danish cases, we attempt to know if the environmental regulations which reinforce land constraints in the intensive livestock and more particularly the constraints relating to manure spreading areas may counterbalance the economic factors in favour of the agglomeration and lead to a production dissipation. To do so, we estimate an econometric model

connecting a variable of geographical production concentration (here the number of pigs, expressed in livestock unit (LU) equivalent (UE) per km^2 within a *canton* or a municipality) to an ensemble of explaining variables aiming to identify the respective roles of the local density of the upstream and downstream activities, "technological externalities" and limitation rules of the local concentration due to available areas of manure spreading (see frame).

Table 1 presents the estimation results achieved for each of both countries at two years distance, one before or at the moment of the implementation of the regulation studied, the other one after this implementation. First, these results show the importance that market relationships have in the localisation process of hog production, those market relationships that the sector keeps with its upstream and downstream industries. As much the proximity to cattle food industries as the access to slaughtering houses and notably to their slaughtering capacity, have a significantly positive impact on the geographical livestock concentration in both countries and at various dates. However, the relative weight of both these factors differs according to national contexts. While in Denmark, the proximity to slaughter house plays a greater role than the proximity to food cattle industries, the situation is reverse in the French case where the industry localisation of the cattle food is more determinant in the concentration of hog production than in the localisation of slaughtering capacities, this last variable plays no significant role in 1988. The increasing vertical integration downstream the cattle field in Denmark may explain such a difference.
If in France, the access to final consumers has no significant influence on the spatial concentration of hog production; this factor plays a central role in the location of the Danish production and dominates all the other downstream/upstream effects. The effect of the geographical importance of Copenhagen may be seen there but also the increasing weight of German consumption basins in the organization of the Danish pork field. The emergence and reinforcement of the last factor are confirmed by the results obtained as regards distance to the Danish-German border. This distance that does not play any role in the localisation of the Danish hog production in 1999, begins to have a positive influence from 2004, a sign of the beginning of a certain importance of the export of pigs to be finished towards Northern Germany.

As expected, the size of the geographical production concentration is reinforced, even dominated, by the density of the proximity relationships that producers make between them in search of technological externalities. Though imperfectly captured by the parameters of the spatial auto-regressive terms (see frame), this role is always significant and positive and the elasticities at average point are high and increasing along time. We are really in the presence of a very significant auto-reinforced agglomeration phenomenon in both countries. In France, its impact is as great as the impact of access variables to upstream and downstream industries, while in Denmark, it dominates all the other variables very broadly. And in both cases, this phenomenon trends to get reinforced with time. The size of the role played in the production localisation by the proximity relationships between producers is evident. The weight of these technological externalities engendered by the diffusion of technical or commercial information between producers, the share of supplying or marketing networks or share of common inputs is, in the case of hog production, probably reinforced by the chain structuration and the great role played by producers' organizations as much from a trading way as from a technical one.

Is the dispersive role of the environmental regulations confirmed?

The role played by the variables relating to regulations and environmental constraints is less expected and less easy to be interpreted. As foreseen, the local density of the resident population, sensible to the potential disagreements of that livestock type, indeed, plays a significantly dispersive role in the production. Quite as logically, the environmental norm relating to dejections per hectare does not influence the pig concentration in 1988, a date at which the regulation considered was not yet implanted. This second observation is only captured for the French case, the only one of the two countries for which data is available at that time. We may assume that it could be the same in Denmark at the same time.

Table 1: Results from decreasing hog densities (UGB/km²), on a set of explaining variables in the *canton* or municipality - Elasticities at average point.

		France (cantons)		Denmark (municipalities)	
		1988 (N=3589)	2000 (N=3572)	1999 (N=262)	2004 (N=262)
	Technological Externalities (W_h.H)	0.39 ***	0.61 ***	5.37 ***	9.24 ***
Upstream	Access to cattle food (X_2)	0.25***	0.11 ***	0.02 *	0.06 ***
Downstream	Access to slaughter houses (W_s+I).S	ns	0.04 ***	0.06 **	0.10 **
	Distance from German border(G)			ns	0.54 *
	Access to final consumption (W_R.Pop)	ns	ns	0.68 ***	1.99 ***
Environment	Local population density (Pop)	- 0.01 *	- 0.01***	- 0.15 *	- 0.55 ***
	Nitrogen pressure from the Canton (N/L)	ns	0,02***	2.57 ***	3.23 ***
	Nitrogen pressure from the neighbouring cantons W_N.(N/L)	ns	- 0.03 ***	- 4.42 ***	- 6.34 ***

ns: non-significant. *, **, ***: significant at 10, 5, 1 per cent.
Note: in this table, elasticities obtained by combination of the parameter estimated value and the average of the variable concerned were reported at average point, and not the parameters themselves estimated. This way of proceeding enables a more direct comparison of the respective effects of the various variables considered in the analysis.

It is more surprising to see that, for the most recent periods, the ratio of local nitrogen dejections to local areas available for manure spreading, a variable on which the manure spreading standard weighs tends to reinforce the spatial concentration of the hog production in each of the two countries instead of limiting it, as it could be expected. This expected dispersive role is carried by the spatial lag of this same variable (that is to say by the value it takes in the neighbouring *cantons* and municipalities of the *canton* studied) which negatively influences the pig local density and plays a role in the sense of the dispersion and production. Here, we may interpret the unexpected role of the environmental constraints when this one is only picked out at the local level by some producers (notably the most productive and the most grouped together) who have the possibility to modify their management of livestock effluents by changing their manure spreading technique for treating technologies.

However, globally, the joined dispersive effects of the local population density (*Pop*) and the potential nitrogen rejection per hectare in the neighbouring cantons and municipalities ($W_N.N/L$) dominates the positive impact of the environmental constraint when it is apprehended at the strict local level (N/L). The global dispersive effect of the constraints is more marked in Denmark than in France, what translates a stricter environmental regulation in that last country or a more achieved implementation of the regulation.

In the end, the environmental regulations and constraints indeed urge to production dispersion but their weak relative weight, as well as the role of the reciprocal compensation which lessens the effect are not able to compensate the powerful agglomeration forces at work through market or non-market mechanisms previously analysed.

Estimation methodology of the effects of agglomeration economies on the location of hog production

We test the following equation:

$$H = \rho W_h H + \gamma_X X + \gamma_E E + \gamma_Z Z + \varepsilon$$

H represents the dependant variable, here the pig density (LU/km within a geographical unit *i* (*canton* for France, municipality for Denmark). Here, the « technological externalities » are classically apprehended by a proximity measure between producers which pertain to the introduction of a term called "spatial auto-decline" of the dependant variable, W_hH. The higher the parameter ρ and the more the influence of the neighbouring densities on the density in *i* will be strong and significant of an existing auto-agglomerative process of production.

The *Xs* represent the accessibility to input and output markets. Here, upstream variables are represented by the regional industrial production of livestock foods (specific to pigs) and downstream variables by an accessibility measure to slaughtering capacities, $S^* = (W_S + I).S$, and by an accessibility measure to final markets relying on a variable of population density of neighbouring *cantons*, $Pop^* = W_R.Pop$. Moreover, for Denmark, a *G* variable measuring the distance from the German border, a place of finishing and/or slaughtering Danish pigs was introduced.

The role of the *E* environmental regulation was captured through an environmental standard built from the *(N/L)* ratio of the nitrogenous quantities potentially rejected by all the local cattle (pig and not pig) on the areas available for manure spreading (70 % of the useful

agricultural area). The *N* term corresponds to the number of nitrogenous LU calculated by applying a particular LU coefficient to any present animal (pig or not pig) taking into account its nitrogenous dejections. In order to take into consideration a potential use of manure spreading areas beyond the *canton* or municipality borders, a "spatial lag" of the same environmental constraint ($W_N.N/L$) was introduced. Moreover, the assumption that there could be a restriction or rejection of the implementation or development of the hog production near the residing areas was formulated. This is why the density of cantonal or municipal population was introduced as a variable of interest liable to suffer from such pollutions (*Pop*).

In the end, a set of *Z* variables was considered which, without being interest variables of the model, enable the integration of major elements pertaining to production history, such as production structures (specialization of farms and production work-places). The results concerning those variables are not given here.

The data used come from the National Agricultural Census (from the statistical services of the Ministry of Agriculture for France), are combined with data obtained from the Technical Institutes (Institut français de la filière porcine-IFIP- for the French case). Like in many empirical works of spatial economics, appealing to spatially aggregated data, as it is the case here, may generate a great number of bias type-*ecological fallacy* or correlations at aggregated level which would not be found here if the observations were made at the farm or farmers' level.

The methodology used here to estimate this econometric model was chosen in order to take into consideration the existence of endogenous variables: the "spatial lag" but also some other explaining variables (notably the variables measuring the nitrogenous pressure *N/L* and *W.N/L*). Moreover the estimation method takes into account the possible spatial auto-correlation of the residues. So we estimated it in generalized double less ordinary squares.

Conclusion

Our analyses show that the agglomeration economies conveyed, on the one hand, by the vertical relationships which link the pig sector to the upstream and downstream sectors, and on the other hand, by the proximity between producers and technological externalities which follows, encourage the agglomeration of the hog production as much in France as in Denmark. As the theory invites us to suppose it, their influence on the agglomeration processes goes through the performances of the firms concerned.

We also showed the partly ambiguous role of the environmental constraints and regulations. Taken as a whole, those ones encourage the dispersion of the production without their intensity being such that it would compensate the previous powerful agglomeration forces. But when local tensions between manure spreading and available areas are high and are not compensated by availabilities in close areas, like in the areas with high concentration, contrary to all expectations, these constraints may reinforce agglomeration. In that case, the regulation implementation or its anticipation drives farmers to modify their productive process to reduce costs and/or encourage innovation to make up for the negative effects of the regulation.

Being authorized to process the livestock unit effluents enables cattle breeders who may do so, to loosen the constraints insofar as treatment plants are characterized by high fixed charges, and therefore, by scale economies. In other words, the average cost of the treatment diminishing with the quantity of manure to spread, the spatial concentration of the animal productions can be reinforced.

Though classical to that type of approach, the way "technological externalities" are introduced here remains rather basic. Additional analyses should permit to precise the characteristic of the factors at stake here and, notably, the reasons for reinforcing their role during time as the studied environmental regulation is implemented. One of the tracks foreseen to better capture the effects of information diffusion or technical or/and trade investments would be to introduce into the analysis the characteristics of producer organizations to which cattle farmers could locally adhere.

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For further information

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