An empirical study of the distribution of crops in agricultural land in Belgium: 1900-1939

Bettendorf, Leon; Blomme, Jan

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CURRENT RESEARCH

An Empirical Study of the Distribution of Crops in Agricultural Land in Belgium: 1900-1939

L. *Bettendorf, J. Blomme**

Abstract: The observed distribution of a number of crops in a certain area can be thought of as the result of a decision process influenced, among other factors, by the expected financial yields. This allocation problem is very similar to the one encountered in portfolio theory, that is, the distribution of certain wealth into different assets given a fixed interest rate structure (for example, Parkin, Gray and Barrett (1970), Bettendorf and Verjans (1988)). This led us to the idea of the estimation of a modified portfolio model with data collected from Belgian agriculture[1]. The results of this model allow interesting interpretations about the sensitivity of the different cultivated areas to changes in the total available area and in financial yields. In the next section the specification of the allocation model will be theoretically derived. After the description of the data used, the results will be discussed in section 4. The last section is devoted to concluding remarks.

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[1] Models with similar specifications are also used in studies of consumption patterns e.g. Schokkaert and Van der Wee (1988). An extensive survey of alternative specifications of area response equations in the context of Nerlove models can be found in Askari and Cummings (1977).

2. The Model

In this section a system of allocation equations will be theoretically derived[2]. Each allocation equation explains the cultivated area for a particular crop as a function of the total available area and of the expected yields of all crops considered.

The objective of such an allocation model is to give an explanation of the observed distribution of a number of crops, denoted by n, in a given area, denoted by m. Let q_i be the cultivated area of crop i and p_i its financial yield per ha (equal to the physical yield per ha multiplied by the market price). The farmer cannot cultivate more land than is available, thus by definition it holds that

$$q_1 + q_2 + \dots + q_n = \Sigma_i q_i = m \tag{1}$$

The total area is assumed to be exogenous, that is, it will not be explained by the model. The p_i's are stochastic variables because at the time that land is allocated to various crops there is uncertainty about both the physical returns and about the market prices. The mean value of the yield of crop i and its covariance with other yields are denoted by

$$E(p_i) = \pi_i \qquad i,j = 1, \dots, n$$
$$E(p_i - \pi_i)(p_j - \pi_j) = v_{ij}$$

(where E stands for expected value). The π_i's can be interpreted as the yields expected by the farmer. A positive (negative) covariance means that the yields of two crops move in the same (opposite) direction on the average. The expected value and the variance of the farmer's returns from all crops are equal to

$$\mu = E(\Sigma_i p_i q_i) = \Sigma_i \pi_i q_i$$
$$\sigma^2 = E(\Sigma_i p_i q_i - \Sigma_i \pi_i q_i)^2 = \Sigma_i \Sigma_j q_i E(p_i - \pi_i)(p_j - \pi_j) q_j$$
$$= \Sigma_i \Sigma_j q_i v_{ij} q_j$$

The farmer is assumed to maximize the expected value of a utility function, which is a function of μ and σ^2, under the »total area« constraint (1). It can be shown that this is equivalent to the following maximization problem:

$$\max_q 0 = \mu - 0.5\, c\, \sigma^2 \qquad \text{subject to} \qquad \Sigma_i q_i = m$$

That is, the combination of the q_i's will be chosen in such a way that the function 0 reaches its maximum, given the total available area. If the farmer does not pay attention to the risks (reflected in the second part of the maximand: σ^2), the maximization of his earnings (that is the first part: μ.) will imply the cultivation of only one crop: the one with the highest expected yield. But

[2] The technical appendix with detailed derivations is available on request.

since he is aware of the great income risks involved with this option, he will prefer to diversify his crop mix. The parameter c can be interpreted as a weight he attaches to risks.

From the first order conditions, which must hold in the optimum, the following specification of the allocation equations can be derived:

$$w_i \, d\ln q_i = b_i \, d\ln m + \Sigma_{j=1,n} s_{ij} \, d\pi_j \qquad i = 1, ..., n$$

with din x: the change in the logarithm of variable x

w_i - q_i / m : the share of crop i in the total area

b_i, s_{ij} : the coefficients to be estimated.

Thus each crop has its own equation; together the n-equations form the allocation model. The cultivated area of each crop is explained by the same variables: the total area and the expected yields of all crops. The coefficients b_j's show how a marginal change of the total area is allocated into the different crops. The s_{ij}'s reflect the effect of a change in the yield of a crop on the size of its own area. However, a change in the yield of one crop will not only affect its own area, but will also have cross effects on the sizes of the areas of the other crops, represented by the s_{ij}'s ($i \neq j$).

The theoretical framework from which the equations are derived indicates that the coefficients must satisfy four kinds of restrictions (well known in demand theory, see Barten and Geyskens (1975) and Schokkaert and Van der Wee (1988)). Imposing these restrictions leads to an attractive reduction in the number of parameters to be estimated. The first set of restrictions called the adding-up conditions, follows from the »total area« constraint (1):

$$\Sigma_i b_i = 1 \qquad \Sigma_j s_{ij} = 0$$

That is, the sum of the changes of the cultivated areas must always equal the change of the total area. For example, an increase in the cultivated area of some crop, as an effect of a yield increase, has to be compensated by a decrease somewhere else, given that the total area is constant. The second group represents the ***homogeneity conditions***, which state that a proportional increase of all yields will not change the distribution of the land or

$$\Sigma_j s_{ij} = 0$$

A third set of constraints results from the ***symmetry conditions***

$$s_{ij} = s_{ji}$$

That is, the effect of the change in the yield of crop j on the cultivated area of crop i is equal to the effect of the change in the yield of crop i on the area of crop j. Finally, the ***positivity condition*** amounts to the restriction that

$$\Sigma_i \Sigma_j x_i s_{ij} x_j > 0 \qquad \forall \; x_i, x_j \neq \text{constant}$$

$$\Sigma_i \Sigma_j x_i s_{ij} x_j > 0 \qquad \forall \; x_i, x_j \neq \text{constant}$$

with its most important feature that all the s_{ij}'s must be positive, that is, the cultivated area of a crop must increase if its yield increases.

The estimated coefficients can be converted to the more interpretable concept of elasticities. The elasticities with respect to the total area and the yields reflect the per cent of change in the cultivated area as the effect of a one per cent change in the total area and the yields. They can be calculated as

$$\eta_i = b_i / w_i$$
$$\varepsilon_{ij} = (s_{ij} / w_i)\ p_j$$

Note that the elasticities vary from year to year since they involve the variable shares and yields.

The finite form used for estimation, where the differentials are replaced by finite differences, now reads

$$w_{it}\ \Delta \ln q_{it} = b_i\ \Delta \ln m_t + \Sigma_{j=1,n}\ s_{ij}\ \Delta\ p_{jt} \qquad i = 1, ..., n$$

where the subscript t denotes the time.

3. The Data

The model is estimated with a combination of yearly data from two subperiods: 1900-1913 and 1919-1939. We have confined ourselves to eight crops: five cereals (wheat, rye, spelt[3], barley and oats), sugar beet, potatoes and flax. Concentration on these cereals and their substitutes, neglecting other (industrial) crops is acceptable under certain assumptions of separability. In the interbellum period these eight crops took up 79 per cent and 58 per cent of the acreages of total arable and agricultural land, on the average.

One can wonder why just these eight agricultural crops have been taken into account in this paper, but no pastureland or fodder beets. In the first place, reliable series of figures for these agricultural products are often lacking. Also, in this period there is a general shift from arable land to pasture, in which annual fluctuations hardly appear. Moreover, due to geographical circumstances, certain regions are completely insensitive to shifts in cultures caused by price fluctuations of other vegetations (for example typical pasture areas such as 'Het Land van Herve'). By confining ourselves to eight agricultural crops, we get a more homogeneous group in which the mutual competition of the various crops is a much more realistic fact, and in which the mutual area division can be better accounted for by price effects and total area effects.

Areas and physical yields per crop for the period 1900-1913 are taken from Gadisseur's study (1980). For the period 1900-1909, they are based on the annual agricultural censuses (December 31). As only farms larger than one

[3] Spelt is a variant of wheat which has better resistance to soil deficiencies than pure wheat

hectare were taken into account in these censuses, a correction for the areas was made in order to bring the data set up to the level of total Belgian agriculture. For 1910, the Algemene Landbouwtelling (General Agricultural Census) (including all farms) was available, and for the years 1911 up to and including 1913, the estimates of the State agricultural experts published in the Belgisch Statistisch Jaarboek (Belgian Statistical Yearbook) were used.

For the interbellum period areas and yields were taken from Blomme's study (1988). This study was based on the annual reports of the State agricultural experts, the Algemene Landbouwtelling van 1929 (General Agricultural Census of 1929), and a number of additional sources.

The prices of the various agricultural products taken into account in this paper are based on the monthly prices that were published for all the years involved per province in the Belgisch Staatsblad (Belgian official gazette). They are averages of the prices taken down at a number of market places in every province. The national price was calculated as the weighted sum of these provincial prices where the acreages that were taken up by each crop in the provinces were used as weights. For certain products such as sugar beets, the annual price was calculated in a roundabout way[4].

For the ***expected yields*** **(π_{it})** we have taken the observed yields from one year earlier (p_{ij}-1), that is, the farmer is assumed to expect that the yields will remain more or less constant. Experiments with other expectation schemes (p_{it}, adaptive expectations) were tried, but proved to be less successful. Even in the case that the plants are only cultivated for the farmers own use, the market prices are relevant since they can be interpreted as opportunity costs (that is foregone returns). Strictly speaking, not the expected yields, but the profitability of each crop should be considered. However, reliable data about the cost components for each crop were not available.

The influence of these cost aspects were alleviated by taking first differences while assuming that the costs do not display great yearly fluctuations. For the case of flax, the returns of the seeds and of the fibers are added. For the years 1934, 1935, 1936 and 1939, subsidies of the central government for the first four cereals are taken into account. By taking differences and lagging the yields, 31 observations were available for estimation.

Addition of other variables to the equations, such as wages and livestock, did not increase the power of explanation significantly. The model has been estimated by means of a maximum likelihood method, as described in Barten and Geyskens (1975).

[4] For a more detailed approach, see Blomme (1988).

4. The Results

In table 1 the elasticities, with respect to the total area and the expected yields, evaluated for the mean value of w and π's, are presented. A double star means that the coefficient is estimated with great precision. Concerning the elasticity of the areas assigned to the various crops, with respect to the total area, a clear distinction can be made between two groups:

1. market crops: these are crops with an immediate output value, that is a considerable part of the production is sold outside of the agricultural sector either as direct food for people (wheat, potatoes), or as raw material for the processing industry (barley, sugar beets, flax). In general, they are crops for which a certain professional knowledge of the culture techniques is necessary, and they are often connected to a specific soil constitution.

2. intermediary crops: these are agricultural crops that are mainly used as intermediary products (rye, spelt, oats), that is for the production of other final agricultural products, and more specifically, for cattle-breeding-products. They are usually less demanding crops, both as far as cultivation and soil fertility are concerned. They usually have a smaller market value (fodder crop) and, in addition, demand relatively limited labor (mechanical corn harvesting and threshing machines).

Table 1 confirms this distinction. All the market crops (with the exception of flax) have an elasticity that is smaller than 1, which means that their cultivated area is relatively insensitive to changes of the global cultivated area. In light of our definitions of this group of products, the following causes can be mentioned: they are crops that are strongly linked to human consumption, characterized by an inelastic demand in the short run. Above all, the increase in population in the period we are investigating was rather minimal (especially during the interbellum period) and could not compensate for the decreasing importance of these crops in the human consumption pattern[5]. In addition, these crops were confronted with an extensive import of similar crops (wheat, barley), or substitution products (certain textile fibers, cane sugar).

Only regions with strong comparative advantages (soil, possibility for mechanization, skill of the producers) were able to face this competition. Possibilities for geographical extension for these crops, often tied to specific, richer soils such as loam (wheat, sugar beets, barley) were rather limited. Also, the professional knowledge needed for the cultivation of crops such as flax or sugar beets was an additional limiting factor. The cultivation techniques used for these crops cannot be transplanted to another large group of farmers in a short period of time. The negative elasticity of flax indicates the hopeless marginalization of this product during these years.

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[5] The evolution of the consumption pattern in interwar Belgium is documented in Schroeven (1991).

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Table 1: Elasticities evaluated for the mean shares and expected yields

Elasticities with respect to	Total area	Expected yields							
Of		Wheat	Rye	Spelt	Barley	Oat	Sugar beet	Potatoes	Flax
1. Wheat	0.586	0.079 **	-0.058 **	-0.014 **	-0.020 •*	0.023 **	-0.001	0.065 •*	-0.057 **
2. Rye	2.048 **	-0.058 *•	0.044 •*	0.006 *	0.015 »•	-0.011 *	-0.003	-0.049 **	0.042 *•
3. Spelt	1.562 *	-0.318 **	0.138 *	0.347 *»	0.023	-0.478 **	0.232 **	-0.183 **	0.262 •*
4. Barley	0.636	-0.095 •*	0.072 **	0.005	0.110 **	0.0.14	-0.056	-0.142 *«	-0.176 **
5. Oats	1.576 **	0.020 **	-0.010 *	-0.018 **	0.002	0.039 **	-0.043 *•	-0.002	0.001
6. Sugar beet	0.509	-0.001	-0.005	0.019 **	-0.022	-0.092 M	0.194 *	-0.015	-0.035
7. Potatoes	0.449 *	0.024 M	-0.018 *m*	-0.003 **	-0.011 *«	-0.001	-0.003*	0.089 **	-0.059 **
8. Flax	-6.247 **	-0.108 M	0.080 **	0.022 •*	-0.069 **	0.003	-0.035	-0.311 **	0.682 **
Mean share		0.188	0.237	0.013	0.038	0.254	0.063	0.182	0.025

Note : * and ** denote that the coefficient is larger than or larger than twice its standard error, respectively

One can also wonder why potatoes belong to this group, as a considerable part is always fed to livestock (especially pigs). This is also true for wheat and barley. Not only did the share of potatoes decrease in the food range, but also its part in cattle feeding was taken over more and more by high quality fodder such as corn and extracted oil seeds. Potato cultivation was rather labor intensive since the potato lifter was only moderately introduced during the interbellum period. It was tied to light sandy soils so that its expansion in the short term implied areas with a considerable agrarian labor reserve. This happened in a period when a growing number of agricultural workers switched over to the industrial sector.

It can also be noticed that, if the total area were shrinking these crops would show a greater stability than intermediary agricultural products. In that sense, these market crops can be described as traditional, inert, even conservative crops.

The success of 'poorer', intermediary crops such as rye, spelt and oats at area extensions can be explained by their different characteristics compared to the first group. Being crops especially destined for cattle fodder, they were favorably influenced by the gradual shift of the consumption pattern to more 'noble* animal products. When the area was extended, the cattle breeding sector and the production of fodder supply products especially profited from this phenomenon.

An extension of the cultivated area almost always involved the use of more marginal, poorer land. Less demanding crops, such as rye, oats and spelt, lend themselves admirably to this purpose. In addition they are all corn crops, which means that they are better suited to the possibilities of mechanization, so that the limiting labor factor could be neutralized to a certain extent. It should be no surprise that a total area extension led to an increase of the area destined for oats. More area automatically implied that the farmer needed more horses, and so there was a bigger demand for oats.

Broadly speaking the elasticities, with respect to the expected yields, are estimated with a great precision, and they are rather small. This is actually an ascertainment that could be expected. It is not merely the profit expectation that plays a part in the decision to increase or decrease the area of a crop. Also, the limitations imposed by the ecosystem should be taken into account; most crops are grown following ancient crop rotation schemes, of which the rotation cycles strongly depend on the available labor supply. Moreover such a crop rotation scheme depletes the soil less, and reduces the risk of plant diseases. Consequently, most farmers will only alter their cultivation techniques that have been passed on for generations in a slight way, partly from tradition, but also partly from a justified fear of dislocating the ecosystem by these changes.

Concerning their own yield elasticities, the relatively high values of clearly commercial crops such as flax and sugar beets immediately draw attention. Their complete production is destined for the market, and they are cultivated mainly by highly specialized commercial farmers, which explains the sensitivity of these crops with regard to yield expectations.

It is more difficult to explain spelt's own high elasticity. Probably the cause for this should be looked for in the special character of its cultivation. Next to its very small share in the total production package, this crop was almost exclusively grown in the Condroz, a region of large corn farmers who used extensive agricultural methods and a simple crop rotation system. It is not impossible - and the negative cross-elasticity with the yield of wheat seems to confirm this - that during certain years spelt was again temporarily used as bread grain. In addition, the agrarian structure of the region allowed a rapid change of the area division compared to other districts.

Crops with mixed destinations, both as market - and fodder - products (wheat, barley and potatoes), reach average elasticities. Their sensitivity to market stimuli was weakened more than with industrial crops probably because a part of this produce was destined for cattle feeding.

Typical intermediary crops such as rye and oats, of which the largest part was feed, hardly react to the expected yields. A first explanation is that these are not really market crops, so they are less sensitive to price fluctuations. They are predominantly feed products for cattle, of which the weighted index in the short term remains relatively constant. Possible high cost prices after a crop failure can be absorbed, to a considerable extent, by the purchase of other commercial fodder. The effects of a possible general scarcity of fodders are seldom dramatic as they are smoothed by the higher number of slaughters and a lower milk yield.

Explaining the cross-elasticities is, of course, a much more delicate matter. A negative cross-yield elasticity means that the two crops are substitutes (in production), that is an increase in the yield of one crop leads to a decrease in the cultivated area of the other crop. A positive cross-yield elasticity means complementarity. Wheat and potatoes are clearly complementary crops; from the production point of view, both crops are only marginally competitive. Both crops were the basic food for human consumption and so showed an almost identical development from the demand point of view.

Rye, but also barley and spelt, are compared to wheat and potatoes, clearly substitute crops. This should not be a surprise; when the prices for basic food rise, more wheat and potatoes are grown at the cost of the qualitatively inferior grains. When the price evolution for basic food turns around, the producers limit the wheat and potato cultivation more to regions with comparative soil advantages.

The interaction of potatoes with other agricultural products is rather limited as the number of regions that are suited for potato cultivation was limited, and as the crop often had an important place in the local, usually very ingenious, crop rotation schemes.

The relatively high cross-elasticities of spelt with the other crops seem rather strange at first sight. The clearly negative cross-elasticity with wheat and oats leads one to suspect that the part played by spelt as bread corn and as feeding corn strongly decreased.

The cross-elasticities of oats, just as those of sugar beets, are very low. This points to the fact that they were relatively independently cultivated crops that were influenced by the yield expectations of the other crops to a very moderate extent. For oats, the explanation can be found, as we have already pointed out, in the relative stability of the horse population, the main consumer of this product. The very low flexibility of sugar beets was probably more a consequence of its regional character (loamy soils) and also of its specific form of exploitation (contract culture). It is somewhat amazing to notice the rather strong negative cross-elasticity between oats and sugar beets, which points to the fact that these products can be substituted to a certain extent.

Finally flax, which lost a lot of ground in this period, just as spelt did, showed a certain sensitivity to the yield expectations of the other products. The negative cross-elasticities with wheat, barley, sugar beets, and especially, potatoes, lead one to suspect that especially these crops have pushed the flax-cultivation into its marginal position.

5. Conclusion

The following conclusions can be made from this quantitative analysis, in which the decision mechanisms for the area allocation were investigated as the result of changes in the total area and in the expected yields :

The elasticity of the respective agricultural crops can be explained as the consequence of both exogenous factors (the evolution of the demand: the growth of population and consumption pattern) and endogenous factors (specific to the crop: the adaptation of the crop in relation to soil restraint, and level of specialization and mechanization).

Fodder and intermediary crops generally show a much larger elasticity with respect to the total area than market crops. The most important reasons for this phenomenon are the shifts in the consumption pattern towards cattle breeding products and the less demanding soil conditions of these crops.

The elasticities of the market oriented crops with respect to their own yields are relatively high, and this means that they can influence the area allocation to a large extent. The less market oriented the product, the lower the elasticity, with the possible exception of spelt.

With the cross-elasticities, the mutual complementarity of the basic food products of wheat and potatoes is striking. Rye is clearly a substitute crop for this group. For various reasons oats and sugar beets are relatively insensitive to yield changes of other crops. However, the declining cultivation of spelt and flax shows that it is more strongly influenced by the yield expectation of other crops.

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Grain and Potato Production in 19th-century Estonia

Juhan Kahk*

Abstract: This article is based on the annual reports of the governors of Estland (Northern Estonia) and Livland. Although the statistical correctness of the information is questionable, it can be used to fmd out relative tendencies. Especially we are interested in the similarities and differences involved in the economic development of the large estates of Baltic-German landowners.

This article is based on the annual reports of the governors of Estland (Northern Estonia) and Livland (the southern counties of Estonia and the island of Saaremaa). Although the statistical correctness of the information is somewhat questionable, as it reflects the level of administrative practice at the time, according to the opinion of specialists in agrarian history, it can be used to find out relative tendencies.[1] In this case we are not so much interested in the absolute values of agricultural production as in the similarities and differences involved in the economic development of the large estates of Baltic-German landowners versus those of Estonian peasants and between the different geographical regions in the area.

As we can see from Figures 1 and 2, the amount of winter grain sown on the fields increased insignificantly in the 19th century while the yields - strongly fluctuating as elsewhere in Europe in these times - increased to some degree in the second half of the century (especially in Southern Estonia). The quite significant progress in agriculture revealed itself in the explosive increase of yields of potatoes beginning from the 1860s (Figures 3 and 4). With the Peasant Laws of 1849, 1856, and 1860, radical changes took place in the Baltic countries - the peasants got real opportunities to buy their lands (although for very high prices). In the 1870-80s the peasants began to buy their lands (in perpetual property«) very intensively and went over from »open field« villages to

* Address all communications to Juhan Kahk, Estonian Academy of Sciences, Division of Humanities and Social Sciences, Estonia Bvd. 7, EE0100 Tallinn, Estonia, Phone: (3772M49370, Fax: 446608.

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