Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, University of Podlasie in Siedlce, Agricultural University of Szczecin and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2005
Volume 8
Issue 3
Topic
ECONOMICS

BŁAŻEJCZYK-MAJKA L., KALA R. 2005. THE EFFECT OF TECHNICAL CHANGE IN FRENCH AGRICULTURE, 1980–1999
Electronic Journal of Polish Agricultural Universities, Economics, Volume 8, Issue 3. Available Online http://www.ejpau.media.pl

THE EFFECT OF TECHNICAL CHANGE IN FRENCH AGRICULTURE, 1980–1999

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ABSTRACT

In the paper the Hicksian hypothesis postulating that technical change is directed first of all at saving of these production factors, the price of which increases faster than the prices of the other factors, is verified in case of French agriculture, 1980 - 1999. The analysis was performed basing on the two-level CES production function with the use of four main production factors: labour, fixed capital, working capital, and land. It was established that different patterns of technical change were induced by differences in the relative factor prices changes, so the generalized Hicksian hypothesis in French agriculture was confirmed. However, considering only the use of separate pairs of production factors with respect to their prices and to the biases of technical change, indicates areas in which the Hicks conjecture is not satisfied.

Key words: technical change, Hicksian hypothesis, production function.

INTRODUCTION

In any production activity many production factors are involved. Among the main factors usually the following are mentioned: labour, fixed capital (next called capital), working capital (next called expenditure), and land. In industrial production the land factor is generally omitted, as it plays an indirect role. However, in the analysis of agricultural production, due to its specific character, it is necessary to include it. If production is analyzed over the period of many years, the effects of technical change need to be additionally included, which in case of agriculture is connected with improvement in machines and cultivation methods, or better organization of labour. As is well known [19], technical change is a process facilitating the substitution between inputs, which makes it possible to increase the effectiveness of production, and thus – improve the production capacity.

There are several hypotheses concerning the sources of technical change. Some suppose that technical change is primarily the effect of conducted research. Others claim that technical change is directed at saving these factors for which the relative demand increases most significantly [1]. On the other hand, according to the hypothesis of induced innovations postulated by Hicks [12], the technical change is directed first of all at saving these production factors, the price of which increases faster than the prices of the other factors.

The aim of this study is to analyze the relations between production factors and their prices, in connection with technical change, and to attempt to confirm the Hicksian hypothesis with reference to agricultural production.

For the purpose of the study one of the biggest EU food producers, France, was selected, the agriculture of which – since its accession to the common market – has been subjected to constant transformations enforced by competition and reforms, resulting from the EU agricultural policy, as well as the strong state interventionism [16,18]. The analysis is conducted on the sector level on the assumption that in the production process the four above mentioned main production factors are involved. It is based on the data from years 1980–1999, which makes it possible to verify the validity of the Hicksian hypothesis in a situation, in which so many additional restrictions coexist.

It is also worth noting that in 1970 the percentage of rural population in France involved in agricultural activity was 50% and in the late 1970's agriculturally utilized area amounted to 59% total area (FAOSTAT). At present the situation of Polish agriculture is similar. In the course of years changes have taken place in French agriculture, leading among other things to the reduction in both these indexes. In spite of that, agricultural production has shown a constant increasing trend. Thus, the changes which have occurred in French agriculture in the last two decades may be of some value in prediction of the direction and rate of changes for Polish agriculture in the nearest future.

An important factor affecting the selection of French agriculture, as the object of the analysis, was also a relatively easy access to uniform, long-term statistical data supplied by the EU agencies.

TECHNICAL CHANGE AND HICKSIAN HYPOTHESIS

A relationship between production factors and the production level is described by the production function. It reflects the maximum volume of output *Q*, which may be achieved using specific inputs $X_1, X_2, ..., X_n$, at a given level of technological knowledge [3]. In a situation when the production function is considered in a dynamic form, it is necessary to include effects resulting from the changes in the level of technological knowledge over the years. In such case the production factors are modified by the additional functions, $E_1, E_2, ..., E_n$, (factor augmenting coefficients) determining the effects of technical change on individual inputs. The production function in that case takes the form:

$$Q = f\left(E_1 X_1, E_2 X_2, ..., E_n X_n\right).$$

Assuming that the production is conducted under the condition of perfect competition, Hayami and Ruttan [10] expressed the cost function in the following form:

$$C = Qg\left(\frac{P_1}{E_1}, \frac{P_2}{E_2}, ..., \frac{P_n}{E_n}\right),$$

where *g* is the unit cost function. The prices of inputs are divided here by the factor augmenting coefficients, because the proportional increase of the augmenting coefficient E_i has the same effect as the proportional decrease in the price P_i. Moreover, it should be noted that the inputs, prices and effects of technical change are all functions of time.

As the unit cost function is linearly homogenous and the demand functions for factors are homogenous of degree zero, the factor shares s_j and the Allen partial elasticity of substitution σ_{ij} (see e.g. Allen, 1961) meet the relations:

$$\sum_{j=1}^{n} s_j = 1, \qquad \sum_{j=1}^{n} s_j \sigma_{ij} = 0, \qquad i = 1, 2, ..., n. \tag{1}$$

They were used by Hayami and Ruttan [10] to derive a system of equations:

$$\sum_{j,j\neq i} s_j \left(\frac{\dot{X}_i}{X_i} - \frac{\dot{X}_j}{X_j}\right) = \sum_{j,j\neq i} s_j \sigma_{ij} \left(\frac{\dot{P}_j}{P_j} - \frac{\dot{P}_i}{P_i}\right) + \sum_{j,j\neq i} s_j (1-\sigma_{ij}) \left(\frac{\dot{E}_j}{E_j} - \frac{\dot{E}_i}{E_i}\right), \quad i = 1, 2, ..., n, \tag{2}$$

where a dot over a variable denotes its derivative with respect to time. Since

$$\sum_{j,j\neq i} s_j\left(\frac{\dot{X}_i}{X_i}-\frac{\dot{X}_j}{X_j}\right)=\frac{\dot{X}_i}{X_i}-\sum_j s_j\frac{\dot{X}_j}{X_j}, \quad i = 1, 2, ..., n,$$

the left-hand side of equation (2), for a given *i*, is the difference between the rate of change in demand for the *i*-th input and the weighted average of such changes for all inputs. Thus, if the left-hand side of equation (2) is negative, it means that the rate of use of the *i*-th input is lower than the average rate of use for all inputs. The right-hand side of equation (2) is a sum of two components. The first is dependent on the change rate of prices of inputs, which may be linked with a shift along the fixed isoquant of the production function [9], while the second is dependent on the rates of technical changes.

The Hicks hypothesis referred to the two-factor production function $(n = 2)$ postulates that the increase of the price P_i relative to the price P_j induces the technical change that augments effect E_i relative to E_j which, in consequence, should results in saving input X_i relative to X_j. This statement is in agreement with equation (2), since the negative sign of ($\dot{P}_j / P_j - \dot{P}_i / P_i$) and the negative sign of ($\dot{E}_j / E_j - \dot{E}_i / E_i$), together with the assumption that $\sigma_{ij} < 1$, imply the negative sign of ($\dot{X}_i / X_i - \dot{X}_j / X_j$), which actually means that a rate of use of input X_i is lower than the rate of input X_j.

In case of the multi-factor production function Kawagoe, Otsuka, and Hayami [14] have modified the Hicksian hypothesis by postulating that the negative sign of the sum

$$\sum_j s_j(\dot{P}_j / P_j - \dot{P}_i / P_i) \tag{3}$$

induces the negative sign of the second component on the right-hand side of equation (2), which they called the Hicksian bias in technical change. If this is the case, the *i*-th factor is classified as *saving* in accordance with the terminology of Hicks. Moreover, observe that

$$\sum_{j,j\neq i} s_j(1-\sigma_{ij})(\dot{E}_j / E_j - \dot{E}_i / E_i) = \sum_j s_j(1-\sigma_{ij})(\dot{E}_j / E_j) - (\dot{E}_i / E_i), \tag{4}$$

which, in view of (1) and the assumption $\sigma_{ij} < 1$, means that the Hicksian bias in technical change is a difference of the weighted average of rates of augmenting coefficients for all factors and the same rate for the *i*-th factor.

TWO-LEVEL CES PRODUCTION FUNCTION

In order to include four inputs in the analysis, i.e. labour (*L*), capital (*K*), land (*U*), and expenditure (*N*), following Kawagoe, Otsuka, and Hayami [14] we will use a two-level CES production function proposed by Hayami and Ruttan [10]. The first level consists in constructing two CES functions, each combining two inputs. In the second level, both outputs from the first level are combined, again using the CES function.

Since capital (*K*), in the form of machines and equipment, is considered to be the main labour (*L*) substitution factor, and expenditure (*N*), including e.g. fertilizers and seeds, to be the land (*U)* substitution factor, in the first-level the CES functions are expressed as:

$$Q_1 = [\alpha(LE_L)^{-\rho_1} + (1-\alpha)(KE_K)^{-\rho_1}]^{-\frac{1}{\rho_1}}, \quad Q_2 = [\beta(UE_U)^{-\rho_2} + (1-\beta)(NE_N)^{-\rho_2}]^{-\frac{1}{\rho_2}}, \tag{5}$$

where α and β $(0 < \alpha, \beta < 1)$ are distribution parameters determining the shares of inputs in both functions, E_L, E_K, E_U, E_N are factor augmenting coefficients for respective inputs, while ρ_1 and ρ_2 $(\rho_1, \rho_2 > -1)$ are substitution parameters. As is well known (see e.g. Intriligator, Bodkin, and Hsiao, 2000), they are connected with the direct elasticity of substitution,

$$\sigma_1 = \frac{d\ln(L/K)}{d\ln(P_K/P_L)} = \frac{1}{1+\rho_1}, \qquad \sigma_2 = \frac{d\ln(U/N)}{d\ln(P_N/P_Z)} = \frac{1}{1+\rho_2}.$$

In the second level the total volume of production Q is related, again with the use of the CES function, with the first-level outputs Q_1 and Q_2,

$$Q = [\gamma Q_1^{-\rho} + (1-\gamma)Q_2^{-\rho}]^{-\frac{1}{\rho}}, \tag{6}$$

where γ $(0 < \gamma < 1)$ and ρ $(\rho > -1)$ are the parameters of distribution and substitution, respectively, while

$$\sigma = \frac{1}{1+\rho}.$$

Direct elasticity of substitution σ, σ_1 and σ_2 may be linked with the Allen partial elasticity of substitution (Allen, 1961) through equations:

$$\sigma_{LU} = \sigma_{LN} = \sigma_{UK} = \sigma_{KN} = \sigma,$$
$$\sigma_{LK} = \sigma + \frac{1}{s_1}(\sigma_1 - \sigma), \tag{7}$$
$$\sigma_{UN} = \sigma + \frac{1}{s_2}(\sigma_2 - \sigma),$$

where s_1 ($s_1 = s_L + s_K$) and s_2 ($s_2 = s_U + s_N$) are the input shares from equation (5) ($s_1 + s_2 = 1$), while s_L, s_K, s_U, s_N are the input shares from equations (6).

In the dependencies presented in equation (5) the functions E_i, $i = L, K, U, N,$ representing the effects of technical change on the production factors, remain to be defined. They are usually expressed using exponential functions [21]. If it is assumed that the exponent of such a function is positive and linearly dependent on time, then the effect of technical change increases at a constant rate in all time units. To overcome this restriction, it is assumed here that

$$E_L = e^{\delta_L t^2},\ E_K = e^{\delta_K t^2},\ E_U = e^{\delta_U t^2},\ E_N = e^{\delta_N t^2}. \tag{8}$$

These functions admit changes in the rates of technical change, while ignoring the linear components in their exponents makes the model more parsimonious.

REGRESSION MODEL

Direct evaluation of parameters of the dynamic CES production function on the basis of time series data causes typical problems resulting from its non-linearity. A review of approximate iterative methods of estimation of parameters may be found in a monograph by Żółtowska [21]. Another solution is to adopt the condition of profit maximization [4], which makes possible to estimate the unknown parameters by the use of regression methods. In this approach the starting point is to compare the ratio of the input prices to the marginal rate of substitution [13], which for function Q_1, defined in (5), along with functions E_L and E_K given in (8), leads to the equation:

$$\frac{P_L}{P_K} = \frac{\alpha}{1-\alpha}\left(\frac{K}{L}\right)^{1+\rho_1} e^{(\delta_K - \delta_L)\rho_1 t^2}.$$

Taking logarithms, gives

$$\ln\frac{K}{L} = -\frac{1}{1+\rho_1}\ln\frac{\alpha}{1-\alpha} + \frac{1}{1+\rho}\ln\frac{P_L}{P_K} + \frac{\rho_1}{1+\rho_1}(\delta_L - \delta_K)t^2, \tag{9}$$

which applied to the time series data leads to the regression model

$$Z = X\beta + \varepsilon,$$

where

$$Z=\begin{bmatrix}\ln\left(\frac{K}{L}\right)_{t_0}\\ \cdots\\ \ln\left(\frac{K}{L}\right)_{t_n}\end{bmatrix},\quad X=\begin{bmatrix}1 & \ln\left(\frac{P_L}{P_K}\right)_{t_0} & t_{t_0}^2\\ \cdots & \cdots & \cdots\\ 1 & \ln\left(\frac{P_L}{P_K}\right)_{t_n} & t_{t_n}^2\end{bmatrix},\quad \beta=\begin{bmatrix}\beta_0\\ \beta_1\\ \beta_2\end{bmatrix}=\begin{bmatrix}-\frac{1}{1+\rho_1}\ln\frac{\alpha}{1-\alpha}\\ \frac{1}{1+\rho_1}\\ \frac{(\delta_L-\delta_K)\rho_1}{1+\rho_1}\end{bmatrix},$$

while indexes t_0, t_1, ..., t_n number successive periods. The appropriate model for function Q_2 with dependent variable ln(N/U) and with parameters $\beta, \rho_2, (\delta_U - \delta_N)$ has a similar form. Since variables ln(K/L) and ln(N/U) are possibly correlated and simultaneously both models have separate parameters, their estimation can be completed using the Zellner method [20], which is more precise than the simple least squares method. As a result the values of parameters $\alpha, \beta, \rho_1, \rho_2, (\delta_L - \delta_K)$ and $(\delta_U - \delta_N)$ can be obtained. The latter estimates provide the differences in rates of technical change for pairs of inputs, i.e.

$$\left(\frac{\dot{E}_L}{E_L}-\frac{\dot{E}_K}{E_K}\right)=2(\delta_L-\delta_K)t\,,\quad \left(\frac{\dot{E}_N}{E_N}-\frac{\dot{E}_U}{E_U}\right)=2(\delta_N-\delta_U)t\,. \tag{10}$$

As individual parameters $\delta_L, \delta_K, \delta_U$ and δ_N cannot be estimated, then it is not possible to obtain first-level outputs Q_1 and Q_2 directly. Thus, in the second level estimation, we follow Kawagoe, Otsuka, and Hayami [14], and assume that

$$Q_1=\hat{Q}_1 E_K\,,\quad P_1=\hat{P}_1/E_K\,,\quad Q_2=\hat{Q}_2 E_N\,,\quad P_2=\hat{P}_2/E_N\,.$$

Then

$$\hat{P}_1\hat{Q}_1=P_1Q_1=P_LL+P_KK\,,\quad \hat{P}_2\hat{Q}_2=P_2Q_2=P_UU+P_NN\,,$$

which leads to the equation:

$$\ln\left(\frac{\hat{Q}_2}{\hat{Q}_1}\right)=-\frac{1}{\rho+1}\ln\left(\frac{\gamma}{1-\gamma}\right)+\frac{1}{\rho+1}\ln\left(\frac{\hat{P}_1}{\hat{P}_2}\right)+\frac{\rho}{\rho+1}(\delta_K-\delta_N)t^2\,. \tag{11}$$

It makes possible to estimate the missing parameters, i.e. γ, ρ as well the difference $(\delta_K - \delta_N)$.

SOURCE DATA

The basis for analysis are data presented in Table 1. Labour involved in the production process is expressed in agriculture work units (Target methodology for agricultural labour input (ALI) statistics (Rev.1.), 2002), while land – by the agriculturally utilized area. In turn, indexes of the gross value of fixed capital formation involved in the process of agricultural production were adopted as the measure of fixed capital (GFCF). It is an aggregate variable expressed as a value, including among other things: plantation yielding repeat products, livestock, machines and other capital goods, farm buildings, transport equipment and land improvement. In the estimation of this variable the value of fixed capital in a given year was replaced by the price, which farmers would have to pay in the investigated period for the replacement of the assets with new ones, possibly most similar to the replaced ones. In this way values of fixed capital in individual years were obtained.

The aggregate variable, presented in the form of indexes, is also the value of expenditure used in the production process in a given year. In is composed of such items as seeds and planting stock, animal feeding stuffs, fertilizers and soil improvers, plant protection products and pesticides, veterinary expenses, energy, lubricants, maintenance of materials and buildings, agricultural services [15].

Data pertaining to the prices of labour, fixed and working capital, as well as land rent are also available in the form of indexes. The values of all variables presented in such a form are taken from reports of The European Commission. They are expressed in fixed prices and constructed according to the Laspeyres formula [8]. In case of land rent the indexed values pertained to one base year (1990), while indexes for wages, capital and expenditure, and the prices of the latter pertained to several base years (wages, capital and expenditure: 1980, 1985, 1990, 1995; capital and expenditure prices: 1985, 1990). As a consequence all the available indexes were calculated in relation to 1980. In this way data from various periods, pertaining to specific base years, were obtained, but calculated in relation to the year of 1980.

In case of wages in agriculture and values of capital and expenditure, differences between such calculated values of indexes related to different base years were slight. Thus, for years, for which indexes pertaining to several base years were determined, mean values of these indexes are given in Table 1. In case of prices of capital and expenditure a different situation occurs. The collected indexes covered the years 1980–1993 (related to the base year of 1985) and years 1985–1999 (related to 1990). The construction of these indexes is based on weights dependent on the consumption of individual capital components in a base year. However, in the course of time the proportions of consumption for these components have changed considerably, which limits the possibility to unify the indexes. In this situation indexes pertaining to the base year of 1985 were adopted as the initial value for these variables in the period of 1980–1984, while for the period of 1985–1999 it was the indexes referring to 1990, with all these values calculated in relation to 1980. Additionally, both these periods were distinguished in the analysis by introducing the corresponding dummy variable into the regression model.

Table 1. Statistical data for French agriculture, 1980 – 1999

Year	*Agricultural production indexes*	*Labor in agriculture work unit*	*Gross fixed capital formation*	*Agriculturally utilized area*	*Expenditures*	*Indexes of wages in agriculture*	*Price indexes of capital*	*Indexes of land rent*	*Indexes of expenditure*
	Y	L	K	U	N	P_L	P_K	P_U	P_N
1980	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1981	97.68	96.95	117.00	99.89	100.20	116.60	99.41	92.18	99.58
1982	103.27	93.90	124.50	99.76	100.30	121.70	100.82	82.66	99.83
1983	99.68	90.85	136.06	99.51	100.70	152.90	100.43	74.71	99.97
1984	107.80	87.80	126.62	99.33	102.30	162.40	100.21	68.91	100.10
1985	104.85	84.71	131.35	99.12	103.20	175.80	99.52	64.54	97.12
1986	103.48	81.61	122.22	98.97	104.90	183.00	101.11	60.70	91.45
1987	107.27	78.46	123.15	98.84	107.84	190.30	102.23	58.16	87.40
1988	105.80	75.30	141.99	97.19	109.60	197.95	103.58	56.48	86.62
1989	104.64	72.10	168.29	96.68	111.97	205.69	103.99	55.63	86.32
1990	105.80	68.90	164.63	96.37	114.14	214.48	104.18	53.84	83.00
1991	105.69	66.21	161.23	95.91	113.73	224.85	104.47	51.65	81.19
1992	111.17	63.62	151.56	95.62	110.63	233.78	104.91	48.91	79.55
1993	103.79	61.13	141.19	95.21	109.92	239.78	104.99	45.75	77.88
1994	103.27	58.69	159.03	94.95	112.66	244.93	104.30	44.52	76.83
1995	106.22	56.35	179.94	94.76	116.08	252.65	104.60	44.76	76.86
1996	111.70	54.07	192.98	94.57	117.68	261.66	104.91	44.59	78.35
1997	112.43	51.83	208.90	94.45	119.33	269.17	105.12	44.98	78.77
1998	113.59	49.70	207.56	94.34	121.42	277.10	105.43	45.85	76.03
1999	114.01	47.66	223.12	94.26	123.62	281.82	105.95	47.56	74.29

Source: FAOSTAT„European Commission. The agricultural situation in the European Union. Reports", Brussels, Luxembourg

Production indexes for the whole agriculture, published by FAOSTAT, were adopted as the measure of the obtained production level. They are also constructed according to the Laspeyres formula, while the base value was the mean agricultural production in the years 1989–1991 expressed in current prices. Data concerning labour, agriculturally utilized land, and the volume of production are published by FAOSTAT, while to unify the form of variables they were also calculated in relation to the year 1980.

ESTIMATION OF ELASTICITY OF SUBSTITUTION

In the first-level estimation, regression coefficients were obtained using the Zellner method according to equation (9), referred to the ratio of fixed capital and labour (variable ln(*K*/*L*)), and to the ratio of land and working capital (variable ln(*U*/*N*)), as well as including the time variable and dummy variable distinguishing the periods of 1980–1984 and 1985–1999. They are included, along with standard deviations, in the first rows of Table 2.

Table 2. Estimated regression coefficients

Levels	Depended variables	Regression coefficients			
		β_0	β_1	β_2	β_3
I	ln (*K*/*L*)	**0.1978** **(0.0704)**	**0.2978** **(0.0996)**	**0.0027** **(0.0002)**	– 0.0660 (0.0650)
	ln (*U*/*N*)	**0.0822** **(0.0119)**	**0.3535** **(0.0819)**	**0.0004** **(0.0001)**	**– 0.0619** **(0.0142)**
II	ln (Q_1/Q_2)	**– 0.0726** **(0.0248)**	0.0873 (0.0850)	**– 0.0013** **(0.0001)**	

Source: own calculations

In the second level, regression coefficients connected with equation (11) were estimated. Since this analysis was based on the results of estimation from the first level, in the second level the dummy variable was omitted. The obtained results are presented in the last row of Table 2.

Although on the basis of the obtained regression coefficients it is possible to estimate all parameters of the CES function, but due to the applied indexed variables, only substitution parameters ρ_1, ρ_2, ρ and differences ($(\delta_L - \delta_K)$ and $(\delta_N - \delta_U)$, $(\delta_K - \delta_N)$ still retain their economic interpretation. Thus, to evaluate the shares of individual production factors the Cobb–Douglas function was applied, which is resistant to the indexation of variables. In this case, indexes of agricultural production presented in the first column of Table 1 were adopted along with the explanatory variables. Moreover, the effect of technical change was also included in the model and a restriction was imposed so that elasticity of output with respect to each input considered here, after Henrichsmeyer and Witzke [11], as equivalent with input shares, sum up to one. Due to the correlation of explanatory variables the analysis was performed using ridge regression [5]. The obtained estimates are listed in Tables 3 and 4, while in Table 4 the Allen partial elasticity of substitution, evaluated in accordance with formula (7), are additionally given.

Table 3. Estimated parameters of the production function

Parameter estimates						
CES functions			*The Cobb-Douglas function*			
ρ_1	ρ_2	ρ	s_L	s_K	s_U	s_N
2.358	1.829	10.4501	0.300	0.109	0.318	0.273

Source: own calculations

Table 4. Differences in the technical change and Allen partial substitution elasticity

Elasticity of substitution Differences $\delta_i - \delta_j$	*i* = *L*	*K*	*U*	*N*
j = *L*	*	0.603	0.087	0.087
K	– 0.004	*	– 0.002	0.087
U	– 0.002	0.087	*	0.537
N	– 0.002	0.001	– 0.001	*

Source: own calculations

From the contents of Table 3, it may easily be noted that, in the years 1980–1999, the biggest shares in French agriculture production were related with land and labour, while the smallest with capital. On the other hand, from the estimated Allan partial elasticity presented in Table 4, it follows that the main substitution effect in the investigated period was, as expected, between labour and capital $(\sigma_{KL} = 0.6029)$, and between land and expenditure $(\sigma_{UN} = 0.5371)$. The possibility of substitution of the other production factors was very limited.

ESTIMATION OF RELATIVE TECHNICAL CHANGE EFFECTS

On the basis of data contained in Table 1 it can be observed that in the investigated period the prices of labour and capital were increasing, while the prices of land rent and expenditure were decreasing. The difference in rates of changes of prices $(\dot{P}_j / P_j - \dot{P}_i / P_i)$ for an individual pair (*i*, *j*) of inputs was established as the difference of averages of rates of changes, observed in successive years. They are listed in the first four rows in Table 5. In turn, in the last row the weighted averages of these differences, calculated in accordance with formula (3), are given.

The estimates established in Table 5 lead to the conclusion that, during 1980-1999, the rate of growth of wages was by approximately 4.9% higher than the weighted average of relative changes of prices for all inputs (in the table the difference is –4.953). This difference, on the one hand, results from the increase of wages, which is higher than that of prices of capital (the difference of rates of growth DRG = –5.772), and, on the other hand, from the increase of wages supported by the drop in values of land rent (DRG = –6.970) and by the drop in prices of expenditure (DRG = –7.707). In contrast, the rate of values of land rent decreased by approximately 2.0% faster than the weighted average of rates of changes of prices for all the factors (the difference of 2.016), whereas in comparison to the other two factors, the prices of which were increasing, they were getting cheaper faster than the prices of capital (DRG = 1.197) and much faster in relation to wages (DRG = 6.970).

Table 5. Differences of rates of changes in input prices

Inputs	*i = L*	*K*	*U*	*N*
j = L	*	5.772	6.970	7.707
K	– 5.772	*	1.197	1.935
U	– 6.970	– 1.197	*	0.738
N	– 7.707	– 1.935	– 0.738	*
Weighted averages	– 4.953	0.819	2.016	2.754

Source: own calculations

The differences in technical change effects for individual input pairs were established with the use of formulas (10) and the estimates contained in Table 4. They are presented in the first four rows of Table 6. The last row contains the Hicksian biases in technical change, obtained by formula (4).

Taking into account the signs of values calculated in the last row of Table 6, it can be stated that in the investigated period the technical change was directed towards labour saving (negative value –2.778) and the other inputs used (positive values: 3.111, 0.442, 1.294). Simultaneously, as it follows from the last row of Table 5, in the same period, a much higher than the average, relative increase in wages was observed along with the relative decreases in prices of the other production factors. This dependency expressed in simple terms by the consistency of the signs of values in the last row of Tables 5 and 6, respectively, indicates the correctness of the Hicks conjecture. Thus, it may be stated that in French agriculture, despite the specificity of this sector of economy, technical change acts in the same way as in the typically industrial sectors, i.e. these production factors are eliminated from the production process, the prices of which are increasing relatively faster.

Table 6. Hicksian biases in technical change

Inputs	*i = L*	*K*	*U*	*N*
j = L	*	8.387	3.865	5.182
K	– 8.387	*	– 4.522	– 3.204
U	– 3.865	4.522	*	1.317
N	– 5.182	3.204	– 1.317	*
Biases in technical change	– 2.778	3.111	0.442	1.294

Source: own calculations

Considering the detailed individual differences, which corresponds to the case of two-factor production function, it can be observed that in terms of wages there is a complete consistency with the Hicks hypothesis, i.e. an increase in the rate of price of wages in relation to the rate of prices of the other inputs is accompanied by an increase in the effects of technical change effect directed at saving labour and using the other production factors. Actually, labour was reduced the most considerably in relation to capital and the least considerably in relation to land.

For the other inputs the situation is not so clear. From the Table 5 it follows that, in the investigated period, the capital prices were increasing relatively faster than those of land and expenditure (DRG = –1.197, –1.935). In such a situation, assuming the Hicks hypothesis, the technical change should be directed to use land and expenditure for the sake of saving the capital. However, from Table 6 it results that the technical change was directed at saving land and working assets.

The first of these inconsistencies can be linked with the limited acreage of land utilized agriculturally. In such case, even at a relative decrease in land rent in relation to the prices of the other production factors, the necessity arises to conserve land connected with the limitations resulting from ecology (e.g. areas destined for nature reserves) or demand for land competitive to agriculture (e.g. industry, infrastructure). The second inconsistency can be explained by high quality requirements, imposed on food produced by EU agriculture. These sanctions force farmers to limit the demand for working capital, e.g. in plant production the reductions pertain primarily pesticides and mineral fertilizers, while in animal production – the application of pharmaceuticals.

In such a case even at a high relative decrease in prices of land and expenditure in relation to the price of capital (which actually was slowly increasing) the technical change is transferred from the area where its introduction is being reduced, such as capital, into the area of land and expenditure, where its introduction is still possible.

CONCLUSIONS

In the years 1980–1999, the main substitution effect in French agriculture occurred between labour and capital $(\sigma_{KL} = 0.603)$ and between land and expenditure $(\sigma_{UN} = 0.537)$. The possibility of substitution between the other production factors was considerably limited. Moreover, the investigated relative changes in the prices of the four basic production factors indicate that relative wages were increasing by 4.9% faster than the weighted average of relative changes in prices of all the production factors. On the other hand, the relative prices of land and of fixed and working capitals were decreasing (by 2.0%, 0.8%, 2.8%, respectively) faster than the weighted average of relative changes in all the other factors. Simultaneously, in the investigated period, the technical change was directed at saving labour and at using other factors. Therefore, in case of French agriculture, the Hicks hypothesis that technical change is directed at these production factors, the prices of which increase relatively faster, was confirmed. However, the analysis of changes between each pair of production factors with respect to their prices and to the biases of technical change makes it possible to indicate areas in which the Hicks conjecture is not satisfied.

On the basis of the conducted analysis, which concerns the French agriculture in the years 1980–1999, it may be attempted to draw conclusions pertaining to Polish agriculture. Assuming that the process of adapting Polish agriculture to the EU requirements will be similar to that experienced by French farmers, a relatively faster increase in wages than the increase in the prices of the other inputs may be expected. These changes should result in the reduction of demand for labour, which will result in the decreasing index of people employed directly in agriculture. Such a conclusion is consistent with the rather common opinion that in the nearest future it is necessary to transfer a considerable proportion of those employed directly in agriculture into the service sector [18]. As for the other agricultural production factors, it may be expected that the effect of technical change on them will be much smaller than in the relation to labour.

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