BUCHENRIEDER, G., and J. MÖLLERS (eds.). (2009): *Structural Change in Europe's Rural Regions – Farm Livelihoods Between Subsistence Orientation, Modernization and Non-farm Diversification*. Vol. 49 of IAMO Studies Series (IAAE 2009 Mini-symposium), pp. 69-89.

The flexibility of family farms in Poland

Swetlana RENNER, Heinrich HOCKMANN, Agata PIENIADZ
and Thomas GLAUBEN

Leibniz-Institute of Agricultural Development in Central and Eastern Europe

renner@iamo.de, hockmann@iamo.de, pieniadz@iamo.de & glauben@iamo.de

Abstract

This paper investigates the flexibility of the Polish farming sector during transition, where flexibility is considered to be a farm's ability to change output by sustaining average costs. We argue that flexibility is a crucial factor in a farmer's competitive advantage, especially under dynamic environmental conditions. We propose a flexibility measure that accounts for both input and output flexibility. This measure is used to empirically investigate the magnitude and sources of flexibility in Polish family farming. We also identify the main factors that explain the proposed flexibility indices. The empirical findings reveal that Polish farms use different technologies regarding their input and output flexibility. While small and specialized farms can easily adapt their input structure, the larger and highly diversified producers adjust their output levels according to price changes. Farmers who use more capital-intensive production technologies, i.e., milk producers, are less flexible with regard to input and overall adjustments. Furthermore, access to bank credit increases a farm's ability to adjust.

Keywords: Flexibility, family farm, Poland

Table of contents

1 Introduction
2 Definition and measure of flexibility
3 Data and empirical analysis
4 Estimation of flexibility
5 Conclusions

1 Introduction

Agricultural enterprises in transition countries are faced with dynamic economic, legal, and political conditions. Output adjustment in response to these changes is often associated with an increase in the average costs of production at the farm level. Thus, flexible production technology is required to meet this challenge. In our study we define flexibility as farmers' ability to modify output by sustaining its average costs. In this context, flexibility can be considered a crucial factor of competitive advantage. The agricultural sector in the EU's New Member States is often dominated by small family farms. Despite their relatively low productivity, family farms did not disappear during transition nor after EU accession. One possible explanation could be that small farms use more flexible technologies as their source of competitive strength. The main question of this study, then, is whether small farms in Poland are more flexible and thus better able to respond effectively to changes in demand than large farms.

Researchers have been interested in firms' flexibility since the topic was introduced by Stigler (1939), who defined flexibility as those attributes of cost curves that determine how responsive output decisions are to demand fluctuations. Stigler discussed flexibility in terms of the relative convexity (the second derivative) of the average cost curve. Thus, the flatter the average curve, the greater the flexibility. Therefore, in line with Stigler, we consider flexibility as an extent of average cost changes in response to output variations. Using duality of production technology, we present two alternative indices in terms of elasticities of the cost and production functions. While the existing flexibility literature focuses on either input or output flexibility, the proposed measure allows us to distinguish between both dimensions and analyze their interdependence and contributions to the overall flexibility of the firm. Thus far, little work has been done to investigate the determinants of flexibility in the agricultural sector. With the exception of Weiss (2001), there are no empirical studies that consider the impact of family and individual characteristics of farmers on flexibility.

The goal of this paper is to empirically investigate the magnitude and distribution of flexibility across Polish farm households, as well as the relationship between farms' flexibility and several farm characteristics. In the first step, we calculate flexibility indicators using estimated parameters of the production function. We apply an approach developed by Alvarez et al. (2003,

2004) that is able to account for farm-specific technologies. In the second step, we use a two-stage regression procedure proposed by Hsiao (2005) to explain flexibility by determining various factors. Polish agriculture is dominated by family farms. Thus, we consider various economic factors as well as socio-demographic variables in the empirical model.

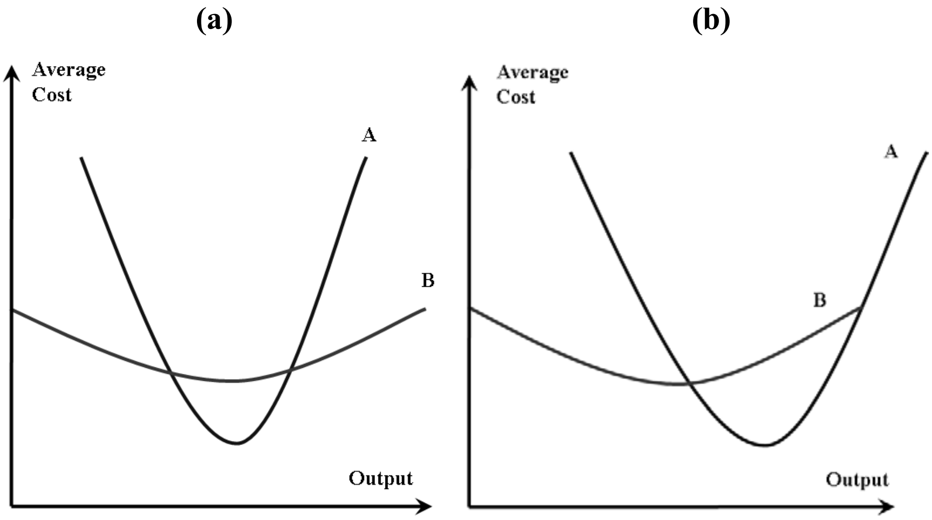
The structure of this paper is as follows. Section 2 introduces and discusses the proposed flexibility measure. Section 3 provides empirical analysis. We first discuss the approach used for the estimation of flexibility and present obtained parameters of the production function. Afterward, we present our hypothesis and empirical results regarding the explanation of flexibility. The fourth section concludes the paper.

2 Definition and measure of flexiblity

Following Stigler (1939), we consider flexibility as an attribute of the production technology to accommodate output variations at the lower costs. According to Stigler's definition, flexibility varies inversely with the curvature of the average cost curve. To illustrate this concept we consider two single-product firms with U-shaped average cost curves, as shown in Figure 1a. In this example, firm B, with a flatter average cost curve, uses more flexible technology than firm A, which has a steeper curve, because the average costs of firm B change less than the average costs of firm A in response to a change in output levels. Because the curvature of a function is measured by the second derivative, the firm is considered to be more flexible the smaller is the second derivative of its average cost curve.

Although Stigler's example, illustrated in Figure 1a, considers two firms with the same optimal output level, the argument can also be applied when firms have their optimum at different production levels. Such a situation arises when the average cost curve of the inflexible firm A is shifted to the right, as illustrated in Figure 1b. In this case, the smaller firm B, with a higher minimum average cost, uses a more flexible technology than the relatively larger firm A. Such a situation, in which there is a trade-off between the static efficiency of large firms and the flexibility (dynamic efficiency) of small firms, is widely analyzed in theoretical and empirical studies (see e.g. Mills and Schumann, 1985; Das et al., 1993; Weiss, 2001). The opposite case, when larger firms are more flexible, is also conceivable. Thus, the relationship between the production scale (firm size) and flexibility can only be assessed with an empirical analysis.

Figure 1 Average cost and flexibility



Based on the definition provided above, we use the second derivative of the average cost function with respect to output as a flexibility measure for single-output firms:

$$Flex = \frac{\partial^2 AC}{\partial y^2} = \frac{C_{yy}}{y} - \frac{2C}{y^3}(\varepsilon_{cy} - 1), \qquad (1)$$

where AC is the average cost, C_{yy} is the second order derivative of the cost function $C(y)$ with respect to the output y, and ε_{cy} is the cost elasticity with respect to the output, $\varepsilon_{Cy} = \frac{\partial C}{\partial y} \cdot \frac{y}{C}$.

The cost elasticity is reciprocal to the scale elasticity ε_{sc}, defined as the sum of the output elasticities given the production function $f(x)$: $\varepsilon_{sc} = \sum_i \frac{\partial f(x)}{\partial x_i} \cdot \frac{x_i}{y}$.

Under perfect competition, marginal cost is equal to the output price. Differentiating this equality with respect to output price yields the following relationship between the second derivative of the cost function and supply elasticity:

$C_{yy} = \varepsilon_{yp}^{-1} \cdot \frac{p}{y}$ with $\varepsilon_{yp} = \frac{\partial y}{\partial p} \cdot \frac{p}{y}$ - own price supply elasticity.

After some transformations, the flexibility measure (1) can be expressed in terms of the supply and scale elasticities:

$$Flex = \frac{p}{y^2}\varepsilon_{yp}^{-1} - \frac{2C}{y^3}(\varepsilon_{sc}^{-1} - 1)\,. \qquad (2)$$

The measure of flexibility can be decomposed into two terms: output and input flexibility. Output flexibility measures the ability of the firm to adjust production in response to output price changes:

$$OutputFlex = \frac{C_{yy}}{y} = \frac{p}{y^2}\varepsilon_{yp}^{-1}\,. \qquad (3)$$

This term encloses the second derivative of the cost function from (1) or, alternatively, the reciprocal of the supply elasticity from (2), weighted by the output price and the output level. An increase in the supply elasticity will generate flatter average cost curves, implying more flexible production technologies. Thus, the higher the *OutputFlex*, the lower the flexibility.

The notion of flexibility expressed in terms of supply elasticity is widely used in the existing literature (e.g. Mills/Schumann, 1985; Das et al., 1993). On the other hand, some authors suggest using the second derivative of the cost function, i.e., the slope of the marginal cost function, as a measure for flexibility (e.g. Tisdell, 1968; Zimmermann, 1995).

Input flexibility considers input adjustments in response to output changes. This measure encloses the cost elasticity (or scale elasticity) weighted by the cost and the output level. Firms with higher economies of scale will cause steeper average cost curves, which is associated with inflexible production technology. Thus, the higher the *InputFlex*, the lower the flexibility. Chambers (1997) uses the cost elasticity as an indicator for flexibility:

$$InputFlex = -\frac{2C}{y^3}(\varepsilon_{cy} - 1) = -\frac{2C}{y^3}(\varepsilon_{sc}^{-1} - 1)\,. \qquad (4)$$

Thus, the proposed flexibility measure takes into account the alternative flexibility measures used in the existing literature. The advantage of the decomposed flexibility measure is that it allows us to analyze the flexibility as a whole, as well as its components separately, to distinguish some sources of flexible technologies by different firms.

3 Data and empirical analysis

We used a data set consisting of eight years of observations, from 1994 to 2001, from 580 Polish farms; the total number of observations was 4,455. The data set was provided by the Polish Institute of Agricultural and Food Economics - National Research Institute (IERiGZ-PIB). Variables contain both farm-specific accountancy information and socio-demographic characteristics. More detailed information on several variables used for the particular empirical estimation will be presented in the following corresponding sections.

The empirical analysis proceeds as follows. In Section 3.1 we present the procedure and the empirical results of the flexibility estimation. Because flexibility indices can be calculated using alternative specifications of the cost and the production function, we first discuss the choice of approach. Parameters of the production function, estimated using the empirical approach developed by Alvarez (2003), are presented and discussed. Section 3.2 deals with an explanation of flexibility. Based on the estimated parameters of the production function, we calculate flexibility indices and discuss their distribution over Polish family farms. We then formulate a hypothesis regarding the factors affecting farms' flexibility and discuss empirical results.

4 Estimation of flexibility

The indicator of flexibility could be directly derived from a cost function. However, estimating a cost function requires information on input prices, and the data set contains only information on quantities (labor, land) and expenditures (variable inputs, capital). For some farms the cost of land and labor can be taken from the expenditures and quantity of hired labor and rented land. However, the majority of farms employ only family-owned resources. Using the information available would either decrease the number of observations dramatically or would induce, if average prices were used, an unacceptable bias in the exogenous variables.

An alternative would be to estimate a restricted cost function with labor, land, and capital as fixed inputs. Variable inputs could be captured by their price indices. Official statistical publications provide detailed information about input price indices for various categories of variable inputs. With this information, firm-specific input price indices could be constructed using the shares of the categories in the variable input aggregate. This approach, even if firm-specific price developments could be considered, has one major drawback: It must be assumed that in the base year all farms face the same price relations. Moreover, because the base year can be chosen arbitrarily, the estimation results cannot be interpreted consistently. Moreover, they differ according to the base year.

In addition, our experiments indicate that the restricted cost function is not theoretically satisfactory: cost increased in fixed factors, even at the sample mean. Moreover, the concavity in input prices was not satisfied for the majority of observations. Given these empirical and conceptual problems, we refrained from using a cost function and applied a production function instead. The required information for calculating the flexibility indicator can be taken from the production function as well, because both approaches characterize the technology.

A consistent interpretation of the technology indicator requires it to be differentiated between various technologies. Several methods are available for dealing with this problem. First we experimented with a latent class approach. Within this framework the technologies are differentiated endogenously. Because of parameter restriction in econometric packages, this approach can only identify a rather limited number of different technologies. In addition, the estimation results showed that the classification does not provide a homogeneous, but rather a heterogeneous group with regard to farm size or specialization in production. We proceed by conducting a cluster analysis to provide an exogenous classification of farms according to various technologies. We considered variables for farm size (hectare), specialization (number of cows and hogs), and technology (land productivity, man-to-land ratio). However, the estimation of the group-specific production functions led to theoretically inconsistent technologies. Because of these problems we chose an approach that assumes each firm has a specific technology. This approach is explained as follows:

We specify technology as a translog production function ($y_{it} = f(\mathbf{x}_{it})$):

$$\begin{aligned}\ln f\left(\mathbf{x}_{it}\right) &= \alpha_0 + \alpha_m m_i + \frac{1}{2}\alpha_{mm} m_i^2 + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2 + \alpha_{tm} m_i t \\ &\quad + \boldsymbol{\alpha}_{\mathbf{x}}' \ln \mathbf{x}_{it} + \boldsymbol{\alpha}_{\mathbf{x}t}' \ln \mathbf{x}_{it} t + m_i \boldsymbol{\alpha}_{\mathbf{x}m}' \ln \mathbf{x}_{it} + \frac{1}{2} \ln \mathbf{x}_{it}' \mathbf{A}_{\mathbf{xx}} \ln \mathbf{x}_{it}\end{aligned} \quad . \tag{5}$$

Here, $\mathbf{x}_{it}$ represents observable inputs and outputs, t accounts for productivity change over time, and m_i represents a non-observable firm-specific factor. Subscripts $i = 1,\ldots,N$ and $t = 1,..,T$ denote firm and time, respectively.

It is assumed that output increases in m_i. In addition, we assume that an optimal level of the firm-specific factor exists, m_i^*, with $m_i \leq m_i^*$. When $m_i = m_i^*$, these presumptions imply that (5) can be considered as a metaproduction function, i.e., the envelope of firm-specific technologies (Hayami and Ruttan, 1970). In order to identify firm-specific technologies, we assume that m_i is not necessarily on its optimal level. In this case production occurs not on, but below the metaproduction function. However, since both m_i^* and m_i are not observable, a direct estimation of the functions is not possible.

The assumption can be reformulated in an efficiency context in which an estimation is possible. The difference between the metaproduction and the actual technologies is:

$$\ln f\left(\mathbf{x}^e{}_{it}\right) - \ln f\left(\mathbf{x}^e{}_{it}\right)_{|m_i=m_i^*} = -u_{it} = \ln TE_{it} = \leq 0 . \quad (6)$$

Correspondingly, the observed output and the metaproduction function are linked through the following relationship:

$$\ln y_{it} = \ln f\left(\mathbf{x}^e{}_{it}\right)_{|m_i=m_i^*} - u_{it} + v_{it} . \quad (7)$$

Equation (7) represents a traditional efficiency model. Because m_i^* cannot be observed, conventional estimation techniques cannot be applied. However, based on a random parameter setting, Alvarez et al. (2003, 2004) showed that (7) can be estimated by the maximum simulated likelihood technique. They apply the following distributional assumptions: $\ln TE_{it} \sim N^+(0,\sigma_u)$, $m_i^* \sim \bullet(0,1)$. The symbol $\bullet$ indicates that m_i^* might possess any distribution with zero mean and unit variance. In addition, random effects are considered in a variable $v_{it} \sim N(0,\sigma_v)$.

Moreover, with (6), TE_{it} is defined by:

$$\ln TE_{it} = \gamma_0 + \gamma_t t + \boldsymbol{\gamma}_{\mathbf{x}}' \ln \mathbf{x}_{it}, \text{ with } \begin{aligned} \gamma_0 &= \alpha_m (m_i - m_i^*) + \frac{1}{2}\alpha_{mm}\left(m_i^2 - m_i^{*2}\right) \\ \gamma_t &= \alpha_{tm}(m_i - m_i^*) \\ \boldsymbol{\gamma}_{\mathbf{x}} &= \boldsymbol{\alpha}_{\mathbf{x}m}'(m_i - m_i^*) \end{aligned} \quad (8)$$

According to (8), within this setting technical efficiency is totally defined by the difference between m_i and m_i^* and the intensity of input use. Moreover, (8) can be used to indentify the actual level of the specific factor because m_i is the only unknown.

The production function was estimated using the following variables. We consider one output and four inputs (land, labor, capital, and intermediate inputs). Output is the sum of crop and animal gross productions. This indicator is a more comprehensive measure of output than sales, because they include sales, home consumption, and stock changes. Because the individual figures for crop and animal production were in current values, the variables were deflated by the output price index provided by the Statistical Office in Poland (GUS var. issues, a, b).

Table 1 Variable definitions and descriptive statistics

Variable	Description	Symbol	Mean	Std. dev.	Minimum	Maximum
Production	gross production, deflated	Y	352.7	344.2	13.7	4565.8
Labor	hours of work (family and hired labor)	A	3903.9	1799.1	82.0	17648.0
Land	arable land and grassland in use	L	14.9	14.8	1.1	185.8
Capital	depreciation of farm assets plus expenditures on services, deflated	K	41.3	29.5	4.7	330.2
Intermediate inputs, crops	variable costs of crop production, deflated	V1	30.9	51.8	0.5	1204.0
Intermediate inputs, animals	variable costs of animal production, deflated	V2	90.4	122.2	0.1	2650.6
Intermediate inputs, general	other costs minus depreciation and expenditure on services, defl.	V3	27.3	24.4	0.3	228.55

Source: IERiGZ-PIB, own estimates.
Note: No. of observations: 3,434.

Land input was approximated by the sum of arable land and grassland in use. Unused land was excluded to provide a more accurate indicator of land used in production. Labor was considered as agricultural working units for both family and hired labor. Capital input was approximated by the sum of the expenditures on capital services and depreciation on buildings, machinery, and equipment. We deflated the data by the price index of agricultural investment because the information was delivered in current values. Intermediate inputs were separated into three groups: variable cost of crop production, animal production, and general inputs. Again, because the data set contains only current cost values, we deflated the series by the corresponding price indices of purchased goods and services in agriculture. The definition of variables including some descriptive statistics is provided in Table 1. For the estimation, all variables were divided by their geometric mean. Moreover, the homogeneity restriction was imposed with regard to crop production.

Table 2 provides the coefficients estimated by model (7). The estimated first order coefficients (A, L, K, V1, V2, V3) represent the elasticities at the sample mean since all variables were normalized. Most of the coefficients are significant; moreover, the parameters for monotonicity and (quasi-)concavity have the expected sign, so that at least at the approximation point the estimates are theoretically consistent (H > 0, and H*H + H^2 – H <0, for H = A, L, K, V1,V2,V3). The scale elasticity at the sample mean can be computed by adding the parameter estimates for the first order effects. With a value of approximately 1.1, the calculation provides that substantial economies of scale are present in Polish agriculture. This finding is consistent with the small farm sizes, i.e., Polish farmers operate in general at a suboptimal scale. Moreover, technical progress (T > 0) affected agricultural production in Poland positively.

In Section 2 we mentioned two requirements that the estimates should fulfill for them to be consistent with a metaproduction function: production must be increasing in mi* and the actual firm-specific effects must be smaller than the optimal effect (mi ≤ mi*). In Figures 2a and 2b, both requirements are fulfilled for all observations; therefore, the further computations can use existing and not virtual production technologies.

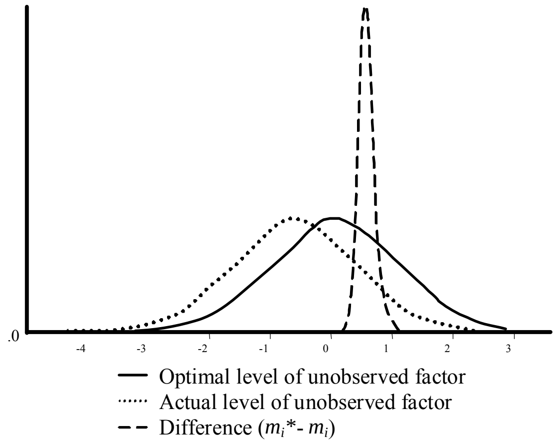
Table 2 Estimation results for the random coefficient model with unobserved input

means of the random process	C	0.00105	Second order effects	
	T	0.02869***		
	A	0.19918***	A*A	0.18810***
	L	0.17614***	L*L	0.03121
	K	0.10323***	K*K	0.05482**
	V1	0.14257***	V1*V1	0.08978***
	V2	0.38470***	V2*V2	0.12719***
	V3	0.09617***	V3*V3	0.02179*
coefficients on firm-specific effect	C*M	0.14408***	A*L	-0.07531***
	T*M	0.00613***	A*K	0.00477
	A*M	0.01246**	A*V1	0.01141
	L*M	-0.01140**	A*V2	-0.05147***
	K*M	0.02945***	A*V3	-0.00569
	V1*M	-0.00800*	L*K	0.03761**
	V2*M	-0.04722***	L*V1	-0.02414**
	V3*M	0.01734***	L*V2	-0.03784***
	M*M	-0.00489	L*V3	0.01581
further coefficients capturing technical change	T*T	-0.00100	K*V1	-0.04017***
	A*T	0.00463**	K*V2	0.00483
	L*T	0.01178***	K*V3	-0.04154**
	K*T	-0.00341	V1*V2	-0.04041***
	V1*T	-0.00792***	V1*V3	0.01741*
	V2*T	0.00197*	V2*V3	-0.00503
	V3*T	0.00141		

Source: Own estimates.

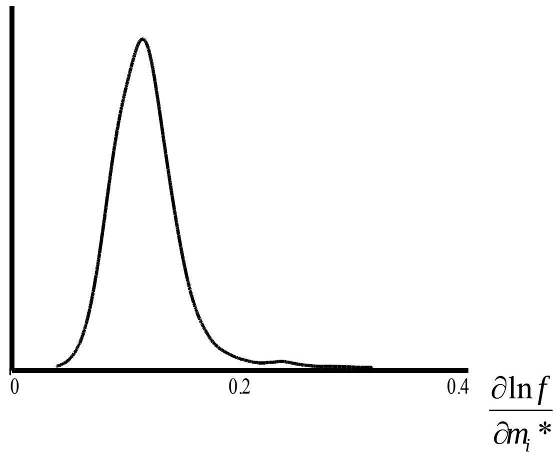
Notes: C denotes a constant. *, **, *** denote significance at a=0.1, 0.5, and 0.01 levels, respectively. No. of observations: 4,434, No. of farms: 580.

Figure 2a Distribution of the firm-specific factor, kernel density estimate



Source: Own estimates.

Figure 2b Marginal effect of m_i* on log output, kernel density estimate



Source: own estimates.

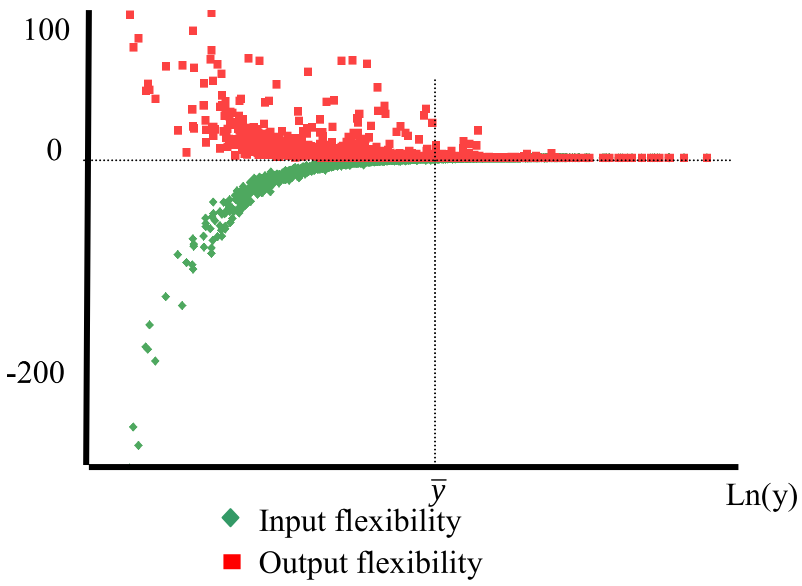
4.1 Determinants of Flexibility

We start by presenting information about the estimated flexibility indicator, which we use as an endogenous variable in the following regression model. Corresponding to the theoretical consideration, we differentiate between output and input flexibility. While input flexibility can be estimated using a first order effect, the calculation of output flexibility requires comparative statics. Meaningful results require that both the monotonicity requirements (first order effects) and the curvature conditions are satisfied (second order effects). Only if both conditions hold will supply elasticities have correct signs.

Checking the curvature conditions revealed that the estimated function was not (quasi-) concave for all observations. This holds especially when we considered all inputs to be variable. However, the results changed significantly when we considered land, capital, and labor input as fixed inputs. We skipped all observations which violate theoretical consistency. This resulted in a reduction of the firms' number from 580 to 523 and to a decline in the number of observations from 4,455 to 2,708.

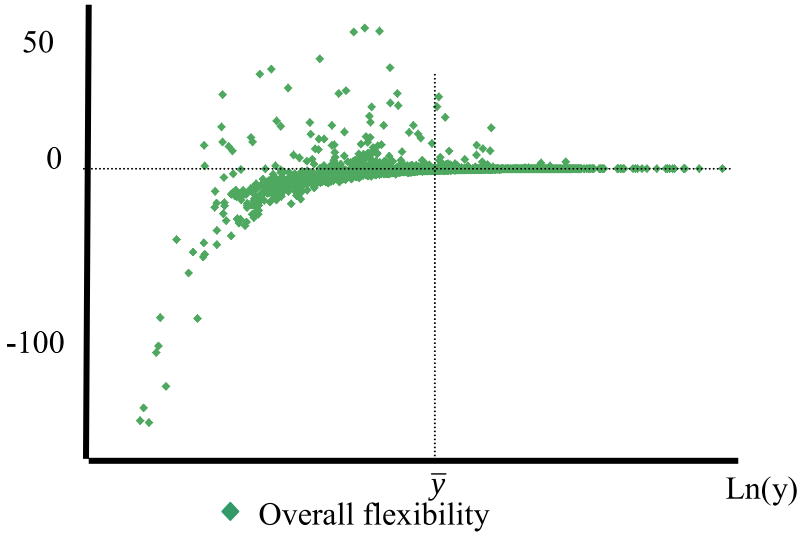
Figure 3 presents the results regarding output and input flexibility. Interestingly, the two indicators have opposite levels for small farm sizes. Input flexibility is high but output flexibility is low. Moreover, there is a larger variation in output than in input flexibility. For larger firms, the difference in the flexibility indicators vanishes. Indeed, both types of flexibility tend to be positive, though on a relatively low scale. The results for overall flexibility provide that large farms are medium flexible (Figure 4). The highest flexibility is observed for small farms. On average, medium-sized farms have the lowest flexibility; however, the group of farms is not homogeneous because the flexibility indicator varies significantly among the farms.

Figure 3 Input and output flexibility by output



Source: Own estimates.

Figure 4 Overall flexibility by output



Source: Own estimates.

4.1.1 Determinants of flexibility

We distinguish between two groups of factors that influence a farm's flexibility. These are economic and socio-demographic farm-specific factors. Factors in the first group are based on accounting data and vary over time. Variables from the second group vary across the farms but not over the time. We first discuss our hypothesis, followed by the regression analysis in the next section.

One of the most important research questions of this paper concerns the relation between farm size and flexibility. Based on Stigler's definition, Mills and Schumann (1985) hypothesize an inverse relationship between flexibility and firm size. They argue that large firms have greater economies of scale and are less flexible than small firms. Although large firms are statically more efficient than small firms due to lower average costs, the comparative advantage of small firms is their flexibility. Large and small firms are likely to have different cost structures. While small firms use more variable inputs, large firms rely more on capital-intensive fixed production factors. Based on this argument, we expect that input flexibility decreases with farm size. On the other hand, large farms might be better integrated into the market, have better access to the relevant information, and thus cope easier and quicker with changing market conditions. Therefore, we argue that large farms have greater output flexibility. Because these two flexibility measures affect overall flexibility in opposite directions, the relationship between farm size and overall flexibility is ambiguous. For the empirical analysis of this relationship, farm size is measured by gross agricultural output, deflated by the corresponding investment price index provided by the Central Statistical Office in Poland.

In addition, we controlled for the role of diversification, measured by the Berry index.[1] Product diversification is one of the most important strategies that firms use to adjust to fluctuating demand. Although we use a single-product flexibility measure, we can assume a positive effect of diversification on flexibility, especially output flexibility.

Besides output specialization, we also include an indicator that is supposed to capture the effects of farm specialization on capital-intensive production technologies. Milk production requires high specific investments and ongoing monitoring, so we assume the high share of this product in total agricultural production to be negatively correlated with the farms' flexibility.

Access to external sources of production factors might help agricultural enterprises meet the changing demand (Gasson and Errington, 1993). We expect additional capital flows to have a positive influence on the farms' flexibility. We consider two variables to capture for these effects: off-farm incomes and access to bank credit.

Further, we assume that commercialization, defined as a share of sales in the gross output value, has a positive influence on all measures of flexibility. Farmers who sell a large portion of their product on the market will be more flexible, irrespective of farm size. Such farmers are more involved in market relationships and must consider changes in demand and other market conditions.

Polish agriculture is dominated by family farms, so we investigate the influence of family and individual socio-demographic characteristics on farms' adjustment abilities. Pollak (1985) argues that some roots of farm heterogeneity may lie in differences in the internal organization and structure of families and households, as well as in the attitudes of farm holders toward risk-taking. We assume that flexibility decreases with the age of the farm holder. Older farmers are more risk-averse decision-makers than their younger counterparts, and hence prefer organizational forms with lower flexibility (Weiss, 2001; Zeller and Robinson, 1992). On the other hand, older farmers might be more experienced.

[1] The index has the form of $BI = 1 - \Sigma(s_{ij})^2$, where s_{ij} is the share of the j-th agricultural product in the total sales of the i-th farm.

Nevertheless, given the drastic changes in the economic and institutional environment during transition, it can still be expected that formal education has become more relevant to the ability to adjust than longer practical experience. Thus, we expect that agricultural education has a positive influence on farms' flexibility. Additionally, we include the variables 'gender' and 'family size' (defined as the total number of family members living in the farm household) in the model to control their influence on flexibility. Table 3 provides a summary of the explanatory variables, as well as some descriptive statistics.

Table 3: Definition and descriptive statistics of variables used to explain farm-specific flexibility

Variable	Description	Mean	Standard deviation	Mini-mum	Maxi-mum
Farm size	Agricultural gross output, deflated	0.27	0.23	0.01	3.23
Prod. diversification	Berry-Index, based on 28 typical agricultural products	0.78	0.12	0.33	0.98
Specialization on milk production	Share of milk production in gross agricultural production	0.20	0.16	0.00	0.90
Off-farm income	Share of non-agricultural labor hours in total family labor	0.18	0.31	0.00	3.85
Access to credit markets	Share of bank credit in total debts	0.39	0.47	0.00	1.00
Commercialization	Share of sales in gross agricultural production	0.56	0.17	0.00	1.73
Age	Average age of the head of household	46.35	9.88	19	79
Agr. education	Agricultural education of farm head	2.38	1.34	0	6
Gen. education	General education of farm head	3.41	0.92	0	9
Gender	Dummy variable: 1 if the farmer is male, 0 otherwise	0.83	0.37	0	1
Family size	Number of family members	4.45	1.58	1	14

Source: Own estimates.
Note: No. of observations: 2,708.

4.1.2 Empirical results

We used the two-step procedure proposed by Hsiao (2005) to take into account the data's panel structure, which contains both time-variant and time-invariant variables. In the first stage we estimate the panel fixed-effects model including only the first group of time-variant variables on the right-hand side. These regressions provide the vector of mean effects of all neglected variables, including the effect of time-invariant variables. In the second stage we regress the vector of the fixed effects on variables included in the second group to obtain estimates for the socio-demographic and other time-invariant variables. The estimation results are reported in Table 4. The high significance of the F-test in all regressions indicates joint significance and confirms the relevance of the variable used in the models.

Before providing an interpretation of results, the following should be mentioned: Smaller values of estimated flexibility indicators imply a flatter average cost curve and thus, more flexibility. Therefore, we must turn over the sign of the estimated parameters, i.e., the negative sign would mean that the investigated variable positively influences flexibility. The parameters indicate that the impact of the various determinants on output and input flexibility goes in opposite directions. The overall effect on the overall flexibility is dominated by the influence on input flexibility.

According to our theoretical considerations, our findings reveal a significant negative influence of the farm size on the input flexibility and a positive effect on the output flexibility. Hence, it is easier for smaller farms to adjust their inputs, but larger farms are more flexible with respect to their output adjustment ability. Because these two effects compensate for each other, the overall flexibility is not affected by the farm size, as indicated by the non-statistically significant estimated coefficient.

The estimates show that only output flexibility is positively affected by the diversification of agricultural production. Thus, highly diversified farms can adjust their output more easily to changing demand. One possible interpretation of this finding is that diversified (multi-product) firms have more possibilities to reduce the adjustment costs via allocation of resources (labor, capital) to the more profitable production line in a given year, and hence to stabilize or even increase total farm output. On the contrary, more specialized farms are characterized by greater input flexibility.

Table 4 Estimated parameters of the two-step procedure for time-variant and time-invariant factors determining flexibility

Determinants	Output Flexibility	Input Flexibility	Overall Flexibility
Economic factors, time-variant (Fixed-effects regression)			
Farm size	-4.60***	6.93***	2.32
Prod. diversification	-9.31***	14.04***	4.73***
Specialization in milk production	-6.98	15.99***	9.00***
Off-farm income	0.57	-0.63	-0.06
Access to credit markets	0.29	-0.90**	-0.60***
Commercialization	1.02	0.72	1.73*
R^2	0.53	0.72	0.57
F-statistic	4.62*** [528, 2179]	10.59*** [528, 2179]	5.41*** [528, 2179]
Socio-demographic factors, time-invariant (OLS)			
Constant	16.480***	-22.217***	-5.737**
Age	0.029	-0.058	-0.029
Agr. education	-0.651***	0.757**	0.106
Gen. education	-0.194	-0.115	-0.310
Gender	-1.659**	2.320**	0.662
Family size	-0.559***	0.468*	-0.091
R^2	0.074	0.044	0.01
F-statistic	8.27*** [5,517]	4.71*** [5,517]	0.86 [5,517]

Source: Own estimates.
Note: No. of observations in the first model: 2,708, in the second model: 523. ***, **, * indicate that the variable is significant at the 1, 5, or 10 percent levels, respectively.

Further, they are likely to be better integrated into input markets and vertical supply chains, and thus can adjust their input structure more easily by sustaining average costs than highly diversified farms. However, the significant positive estimates for the variable ‘Specialization in milk production’ indicate that in the case of specialization in capital-intensive technology, which requires high investments in fixed capital, the adjustment ability might be affected negatively. Moreover, access to bank credit, measured by the share of bank credits in debts, increases input and the overall flexibility of the farm. However, the estimated parameters for off-farm income and commercialization were not significant.

A less clear picture emerges for the role of socio-demographic factors. Our findings reveal that agricultural education, family size, and gender have a significant influence on flexibility. However, the estimates sometimes contradict our expectations. The results support only our expectations regarding the positive relationship between output flexibility and the level of agricultural education. On the contrary, farms operated by better-educated managers are less flexible with respect to input adjustments. A possible explanation could be that well-educated farmers have better access to know-how and capital. Thus, they are more likely to operate large farms, which usually specialize in capital-intensive technologies, which in our case influence input flexibility negatively. Furthermore, the impact of family size and gender on flexibility indicators is ambiguous. Parameter estimates of farmer's age and general education were not statistically significant. Thus, further research is needed to assess the impact of interaction effects of some variables and to explain the influence of socio-demographic factors on flexibility.

5 Conclusions

This paper empirically investigates the magnitude and the determinants of flexibility across Polish family farms. The production technologies of Polish farms differ in their ability to accommodate output variations. Moreover, farmers use different strategies to avoid significant cost increases associated with production adjustments. Using the proposed flexibility measure, we examined two sources of farmers' abilities to adjust their output to changing conditions: input and output flexibility. While smaller farms could easily adapt their input structure, the larger ones have the advantage of being able to adjust their output levels according to price changes. Thus, the trade-off between flexibility and static efficiency is characterized only by considering input flexibility. More diversified farms can more easily alter their production mix to changing market conditions, and thus have higher output flexibility. On the contrary, more specialized farms exhibit greater input flexibility unless they specialize in capital-intensive milk production. Moreover, flexibility is positively affected by additional capital flows from the credit market. The effects of family and individual characteristics of the farmer are ambiguous and require further investigation.

The results show that the adjustment of agricultural production is driven by changes on the input and output markets. Thus, farms have the chance to react flexibly, either by adapting to input or output markets, or both. Some of the effects may compensate for others. Thus, both input and output flexibility should be analyzed separately to correctly assess farm flexibility.

The flexibility analysis presented in this paper is based on a single-output case. Thus, the results might be biased, especially when investigating highly diversified production sectors (e.g. Polish agriculture). Therefore, the flexibility measure must be extended for the multi-product case. However, the estimation and derivation of such a measure will be more complex and requires further research.

List of references

Álvarez A., Arias C., Greene W. (2003): Fixed management and time invariant technical efficiency in a random coefficient model. Working Paper, Department of Economics, Stern School of Business, New York University.

Álvarez A., Arias C., Greene W. (2004): Accounting for unobservables in production models: management and inefficiency. Economic Working Papers at Centro de Estudios Andaluces E2004/72, Centro de Estudios Andaluces.

Chambers, R. G. (1997): Applied production analysis. A dual approach. Reprint. Cambridge: Cambridge University Press.

Cremieux, P. Y., Ouellette, P., Rimbaud, F., Vigeant, S. (2005): Hospital Cost Flexibility in the Presence of Many Outputs: A Public-Private Comparison. *Health Care Management Science* 8 (2): 111–120.

Das, B. J.; Chappell, W. F., Shughart, W. F. (1993): Demand fluctuations and firm heterogeneity. *The Journal of Industrial Economics* 41 (1): 51–60.

Gasson, R., Errington, A. (1993): The farm family business, CAB International, Wallingford, UK.

GUS (var. issues a): Statistical Yearbook of the Republic of Poland. Central Statistical Office of Poland, Warszawa.

GUS (var. issues b): Statistical Yearbook of the Polish Agriculture. Central Statistical Office of Poland, Warszawa.

Hayami, Y., Ruttan, V. W. (1970): Agricultural Productivity Differences Among Countries. *The American Economic Review* 60 (5): 895–911.

Hsiao, C. (2005): Analysis of panel data. 2. ed., reprinted. Cambridge: Cambridge University Press (Econometric Society Monographs, 34).

Mills, D. E., Schumann, L. (1985): Industry structure with fluctuating demand. *The American Economic Review* 75 (4): 758–767.

Pollak, R. A. (1985): A Transaction Cost Approach to Families and Households. *Journal of Economic Literature* 23 (2): 581-608.

Stigler, G. J. (1939): Production and distribution in the short run. *The Journal of Political Economy* 47 (3): 305–327.

Tisdell, C. A. (1968): The theory of price uncertainty, production, and profit: University Press.

Weiss, C. R. (2001): On flexibility. *Journal of Economic Behavior and Organization* 46 (3): pp. 347–356.

Zeller, M., Robison, L. J. (1992): Flexibility and risk in the firm. *European Review of Agricultural Economics* 19: 473-484.

Zimmermann, K. F. (1995): Flexibility in the face of demand fluctuations. Employment, capacity utilization, and industry structure. *International Journal of Industrial Organization* 13 (2): 179–193.