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Flexibility in Agriculture

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"The farm family business has certain strengths and weaknesses in comparison with the non-family farm. Its strength can be summed up in one word 'flexibility'" (Gasson and Errington, 1993, p. 240).

1. Introduction

There is a long tradition in agricultural economics of studying why some farms are more successful than others, and in particular, why small (family) farms are able to survive despite the existence of economies of scale in agricultural production (Weiss, 1999). The focus of the present paper is the explanation offered by Stigler (1939), who argued that small firms are able to compete successfully with large, more static-efficient producers by using more flexible production technologies. Large rivals own the comparative advantage of lower minimum average costs while small competitors have the offsetting advantage in their superior responsiveness to exogenous shocks. The concept of flexibility used in Stigler is the ability of a single-product firm to adjust output to exogenous shocks at relatively low costs. Following Carlsson (1989) we will call this dimension of flexibility "tactical flexibility". The trade-off between tactical flexibility and firm size has been translated into a formal model (assuming a perfectly competitive product market) by Mills and Schumann (1985) and tested empirically for manufacturing industries (Mills and Schumann, 1985, and Das et al., 1993, for the U.S. as well as Zimmermann, 1995, for Germany).

By exclusively focusing on tactical flexibility, these studies however ignore one of the most important means by which firms adjust to exogenous shocks which is by diversification into several products and switching capacity from one good to another one. The "product-switching" flexibility studied in Ungern-Sternberg (1990) will be called "operational flexibility"

(Carlsson, 1989). The purpose of this paper is to investigate both dimensions of flexibility (tactical and operational flexibility) as well as analyze their interdependence empirically.[1]

Two additional aspects, in which this paper differs from previous work, are to be mentioned. First, the available empirical literature considers the behavior of firms in the manufacturing sector. The significant degree of market power experienced by firms in some industries, however, contradicts the assumption of perfect competition in Mills and Schuman's model.[2] This note considers a sector of the economy where market power of firms is negligible and where the flexibility of firms has not been investigated so far, the farm sector.

And secondly, the available empirical literature does not take into account the existence of important additional reasons for firms to differ within a given industry. Lucas (1978), Jovanovic (1982) and Oi (1983) for example emphasize the importance of entrepreneurial ability of principals or managerial agents. The empirical model controls for these influences by considering additional socio-economic variables such as schooling, age, and sex of the farm operator, the size and structure of the farm family as well as regional dummy variables.

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1 We also extend the basic theoretical model outlined in Mills and Schumann (1985) to consider multiple product firms along the lines suggested by Baumol, Panzar and Willig (1988). The following five hypothesis can be formulated from the theoretical model: (H1) There is a positive correlation between „operational“ and „tactical“ flexibility. (H2) „Tactical“ flexibility decreases with firm size. (H3) „Operational“ flexibility decreases with firm size. (H4) The trade-off between „operational“ flexibility and firm size (in H3) is stronger for more diversified firms. (H5) „Operational“ flexibility decreases with the number of products produced by a single firm (decreases with diversification). The model is outlined in more detail in an appendix, which is available upon request.

2 In particular, Lukacs (1996) has shown that imperfect competition effects and flexibility effects are inseparable and observationally equivalent. The reason for the breakdown of the negative size-flexibility relationship is that the zero expected profit constraint, which is essential for the trade off between size and flexibility in Mills and Schumann is no longer applicable in a non-competitive environment.

2. The data and the empirical results

The empirical approach in the present paper utilizes a panel of 39,235 Upper Austrian farm households for three years, 1980, 1985, and 1990 (farm census). For each year, the farm censuses collect extensive information on family characteristics, age and schooling of various family members, current herd size, area under cultivation and the off-farm employment status. Given the importance of dairy farming in Upper-Austria, we use livestock (measured in median large animal units)[3] as our primary measure of farm size. The data set allows to disaggregate this index into nine different product categories.

Following the existing empirical literature tactical flexibility of farm *i* (*i* = 1, ..., *n*) is defined as $T\_FLEX_i = \frac{1}{t-1}\sum_{t=1}^{T}[\log(Q_{i,t}) - \overline{\log(Q_i)}]^2$, where *n* represents the number of farms, *t* is time, Q_i is aggregate output of firm *i*, and $\overline{\log(Q_i)}$ is the average of the log aggregate output of firm *i* over time *t* = 1, ... *T*. The short period of time available in the data set prevents the adjustment of aggregate output for a linear trend.

With respect to operational flexibility, two commonly used indices of structural change will be applied: the Michaely/Stoikov index (Michaely, 1962 and Stoikov, 1966) *O_FLEX_MS* as well as the Lilien index (Lilien, 1982) *O_FLEX_L*. They are defined as:[4]

$$O\_FLEX_i\_MS = \frac{1}{T+1}\sum_{t=1}^{T}\sum_{j=1}^{J}\left|\Delta_t s_{j,i}\right|,$$

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3 A median large animal unit is an index of the number of livestock which is defined according to the live weight of an animal. A live weight of 650 kg (1,433 pounds) corresponds to one median large animal unit.

4 The performance of these indices in measuring structural change is evaluated and compared in Driver and Saw (1996).

$$O\_FLEX_i\_L = \frac{1}{T-1}\sum_{t=1}^{T}\sqrt{\sum_{j=1}^{J} s_{j,i}[\Delta_t \log(s_{j,i}) - \Delta_t \log(Q_i)]^2}\ ,$$

where $s_{j,i} = \frac{q_{j,i}}{Q_i}$ is the share of product j (j = 1, ... J) in total output of firm i, and Δ_t refers to first differences (over time). Note that $0 \le O\_FLEX\_MS \le 1$, $0 \le O\_FLEX\_L \le \infty$, and $0 \le T\_FLEX \le \infty$. If *O_FLEX_MS* = 0 and *O_FLEX_L* = 0 (*T_FLEX* = 0) there has been no change in output mix (aggregate output) over time while *O_FLEX_MS* = 1 and *O_FLEX_L* = ∞ (*T_FLEX* = ∞) refers to a situation where a firm has completely readjusted its output between different products (its total output over time).[5]

To guarantee a homogenous data base the analysis is restricted to individual and family farms that could be identified in all three years and where all relevant information for estimating the equations was available. The farm households satisfying these criteria number 39,235. The definition and descriptive statistics of the variables used are reported in Table 1.

Table 1

Table 2 reports the results of Tobit models analyzing the determinants of tactical and operational flexibility (as measured by the Lilien index),[6] respectively. According to Table 2 the relationship between farm size and tactical flexibility (in model [1]) as well as operational flexibility (in model [2]) is highly significant and negative. A 10% increase in farm size reduces tactical (operational) flexibility by 28.6% (10.4%). This finding of a significant negative impact of size on both, the flexibility in adjusting aggregate output to exogenous shocks as well as the

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5 In order to avoid computational problems for the Lilien index if $s_{j,i}$ = 0, we add a constant $k = 0.1^{-5}$ to q_i.

6 The results when using the Michaely/Stoikov index are very similar. They are available from the author upon request.

ability to switch quickly and cheaply between products, supports the idea that large and small farms each have their own efficiency niches.

Table 2

Levy and Harber (1986) and more recently Fernandez-Cornejo et al. (1992) argued that "... when facing changes in demand for a certain output, a multiproduct firm may be able to transfer the firm-specific inputs into a "higher-valued use" in another product line within the firm. Thus, unlike a single-product firm, multiproduct firms are able to reduce adjustment costs" (Fernandez-Cornejo et al., 1992, p. 333). To consider this diversification - operational flexibility relationship, model [2] includes the degree of product diversification measured by the Berry index $\overline{B}$ (Berry, 1971). The highly significant positive parameter estimate for $\overline{B}$ suggests that operational flexibility is higher for more diversified farms. According to Table 2, a 10%-points increase in $\overline{B}$ raises operational flexibility by 2.6%.

Table 2 also reports a significant impact of the farm operators' age (A) on tactical and operational flexibility. In both equations, flexibility decreases with age, reaches a minimum at an age of 54 to 56 years, and then increases moderately again. The negative impact of age on flexibility corresponds to the observation that older farmers are more risk averse (Sumner and Leiby, 1987), are not well equipped with modern production technologies (Batte, Jones and Schnitkey, 1990) and have more experience in running the farm which helps them to reduce the variability of output in an uncertain environment (Jovanovic, 1982). The positive impact of age on flexibility observed during the later stages of a farmers life cycle might be related to the increasing influence of the farm successor.[7]

The impact of farm succession on flexibility is explicitly modeled in Table 2 by including the variable *SUCC*, which is set equal to 1 if the farm has been taken over by a younger farm operator between 1980 and 1990 and is equal to zero otherwise. Both, tactical as well as operational flexibility is significantly higher in farms where succession has taken place. A change in the person who operates the farm often is associated with a significant restructuring of the farm business.

Sumner and Leiby (1987) suggest that an important effect of human capital on farm performance is that it "makes farmers more flexible in their response to changes in prices and technology" (p. 466). The significant and positive impact of agricultural specific (*DSA*) as well as general schooling (*DSG*) in model [1] supports this argument. General schooling also significantly increases operational flexibility; the parameter estimate of *DSA* in model [2], however, is significantly different from zero only at the 10% level. The hypothesis of a declining importance of schooling as the farm operator ages was not supported by the data; an interaction effect between the schooling variables and the farm operators age did not contribute significantly to the explanatory power of the model and is thus not shown here.

The size of the farm family is another important factor determining farm flexibility. Five different variables characterizing family size and structure are included. According to Table 2, the tactical (operational) flexibility is about 37.4% (8.9%) higher for farms where the farm operator is married (*MARR*=1). The number of other family members living on the farm

[7] A similar life-cycle pattern has also been observed in various empirical investigations on related issues. Sumner and Leiby (1987) and Weiss (1998) report a non-linear impact of age on farm growth; the relationship between age and off-farm employment (Huffman, 1980, Weiss, 1997) and the farmers investment behavior (Elhorst, 1993) has also been extensively studied.

($FAM_{<6}$, $FAM_{<16}$, $FAM_{\geq 16}$) also influences flexibility. An additional family members aged 16 and above ($FAM_{\geq 16}$=1) for example increases tactical flexibility by 2.2%. These results are not surprising since family members provide the necessary labor resources on the farm and thereby facilitate the adjustment of both, aggregate output as well as the product mix to exogenous shocks. This is very clearly expressed in a response to a Reading University survey where a farmer's wife said that she had to "be prepared to do anything at any time at very short notice and regardless of what is in the oven" (quotation taken from Gasson and Errington, 1993, p. 126).[8]

If the farm operator is working off the farm besides running the farm business (*PT*=1), both measures of flexibility are significantly lower. Full-time farm operators (*PT*=0) may be better able to adjust family labor to changing needs, may be better equipped with modern and more flexible production technologies and may also be more experienced, which reduces uncertainty about their own managerial abilities and thereby reduces the variability of aggregate output (Jovanovic, 1982). In terms of Mills and Schuman's theoretical model, additional off-farm income would furthermore weaken the zero-expected-profit condition in the farm business in a long-run steady state. Part-time farms will then be represented in the steady state even if they are characterized by a lower static and dynamic efficiency.

Changes in the off-farm employment status between 1980 and 1990 (ΔPT) significantly increase tactical flexibility. Given that the long-run steady state farm size differs between full-time and part-time farms (Weiss, 1998), changes in the off-farm employment status will have to be followed by adjustments in aggregate output over time.

8 Gasson and Errington (1993) conclude: "The farm family business has certain strengths and weaknesses in comparison with the non-family farm. Its strength can be summed up in one word 'flexibility'" (p. 240).

Table 2 also reports the parameter estimates of various regional dummy variables (*HZ1* to *HZ4*, and *DR1* to *DR5*). Note that flexibility is significantly lower in less favorable agricultural areas as indicated by the monotonically increasing negative impact of the variables *HZ1* to *HZ4*.

So far, we have analyzed tactical and operational flexibility separately without considering their potential interrelationship. Following Ungern-Sternberg (1990), one could however argue that a firm unable to adjust its product mix to an exogenous shock (low operational flexibility) is forced to adjust aggregate output (high tactical flexibility). Similarly, if adjustment costs associated with changing aggregate output are very high (low tactical flexibility), a firm may be forced to significantly adjust its product mix (high operational flexibility). The results reported in Table 2 actually support these arguments. Models [1] and [2] suggest that firms reporting a low level of tactical (operational) flexibility are characterized by a high level of operational (tactical) flexibility.

3. Summary and Conclusions

This note investigates the determinants of - and the interrelationship between - two different dimensions of flexibility, tactical and operational flexibility. Utilizing a panel of 39.235 farm households for the period 1980-90 in Upper Austria, we find smaller, diversified, full-time farms operated by younger, better educated farm operators to be more flexible, ceteris paribus. The significant and negative interrelationship between the two aspects of flexibility also sheds a different light on the way to interpret the existing empirical literature on flexibility. According to Mills and Schumann (1985), firms with high output variability would be considered more flexible. But this is not necessarily the case when considering different dimensions of flexibility. Ungern-Sternberg (1990) notes that variability of aggregate output might also indicate that firms are unable to shift to the production of a different product in periods of low demand. This is an indicator of low (operational) flexibility. Our results underline the importance of taking into account different dimensions of flexibility (as well as their interaction) when investigating "flexibility (which) is widely recognized as one of the most important dimensions of a successful manufacturing strategy" (deGroote, 1994, p.933).

6. References

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Table 1: Definition and descriptive statistics of all variables used

Symbol	Definition	Mean (Std.-dev.)	Minimum	Maximum
T_FLEX	Tactical flexibility 1980-90, is defined in the text.	0.286 (1.009)	0.000	19.690
O_FLEX_MS	Michaely/Stoikov Index for operational flexibility for nine products, is defined in the text.	0.079 (0.147)	0.000	1.000
O_FLEX_L	Lilien Index for operational flexibility for nine products, is defined in the text.	1.230 (1.541)	0.000	11.513
$\overline{\log(Q_i)}$	Average of log. of livestock for the period 1980 to 1990	6.845 (1.147)	0.767	9.686
A	Age of the farm operator in 1980 in years, divided by 40.	1.141 (0.261)	0.375	2.325
SUCC	Farm succession between 1980 and 1990 is set equal to 1 if the difference between the farm operator's age in 1980 and 1990 is less than 9 years	0.371	0	1
DSA	Dummy variable for agricultural-specific schooling of the farm operator in 1980. Is set equal to 1 if the farm operator has a higher level of agricultural specific schooling ("Facharbeiter" or "Meister") and is equal to zero otherwise.	0.593	0	1
DSG	Dummy variable for general schooling of the farm operator in 1980. It is set equal to 1 if the farm operator has a higher level of general schooling ("Höhere Land- und Forstwirtschaftliche Lehranstalt" or "Land- und Forstwirtschaftliche Universität") and is zero otherwise.	0.019	0	1
$FAM_{<6}$	Number of family members living in the farm household in 1980 younger than 6 years.	0.385	0	6
$FAM_{<16}$	Number of family members living in the farm household in 1980 between 6 and 15 years of age.	0.756	0	8
$FAM_{\geq 16}$	Number of family members living in the farm household in 1980 older than 15 years.	4.215	0	16
MARR	Dummy for farm operators married state (1=married; 0=unmarried).	0.881	0	1
PT	Part time farming: married couple spends more than 50% of total working time (excluding household work) on off-farm employm. and less than 50% on farm work.	0.506	0	1
ΔPT	Changes in off-farm employment status betw. 1980 and 1990 (=0 no change; 5=maximum amount of changes).	0.765	0	5
$\overline{B}$	Average Berry index for the years 1980, 1985, and 1990 ($\overline{B} = (B_{80} + B_{85} + B_{90})/3$). The Berry index for year *t* is defined as 1 minus the the sum of the squared shares s_j of nine different products *J = 9*: $B_t = 1 - \sum_{j=1}^{J} s_j^2$.	0.470 (0.187)	0.000	1.000

Table 2: Results of tobit models

Dependent Variable: Independent Variable		*T_FLEX* Parameter [1]	(t-value)	*O_FLEX_L* Parameter [2]	(t-value)
Intercept		8.205	(62.69)	12.738	(47.99)
Farm Size	$\overline{\log(Q_i)}$	-0.859	(-76.19)	-1.341	(-46.67)
Berry Index	$\overline{B}$	-.-	(-.-)	0.319	(5.94)
Age of Operator	A	-2.096	(-17.62)	-3.194	(-15.99)
(Age of Operator)^2	A^2	0.756	(15.05)	1.175	(14.09)
Succession	*SUCC*	0.238	(19.81)	0.373	(18.29)
Agricultural Schooling	*DSA*	0.021	(2.33)	0.026	(1.83)
General Schooling	*DSG*	0.069	(2.22)	0.107	(2.11)
# of Family memb. <6	$FAM_{<6}$ *100	2.353	(3.41)	2.952	(2.61)
# of Family memb. 6<16	$FAM_{<16}$ *100	0.057	(0.12)	-0.353	(-0.47)
# of Family memb. ≥16	$FAM_{\geq 16}$ *100	0.639	(2.48)	0.664	(1.58)
Married	*MARR*	0.107	(7.18)	0.109	(4.35)
Part-time Farm	*PT*	-0.410	(-38.45)	-0.506	(-18.96)
Change in off-farm status	ΔPT*100	2.927	(7.24)	-.-	(-.-)
Hardshipzone 1	HZ_1	-0.217	(-17.55)	-0.323	(-15.37)
Hardshipzone 2	HZ_2	-0.307	(-21.33)	-0.442	(-16.93)
Hardshipzone 3	HZ_3	-0.378	(-25.11)	-0.525	(-18.03)
Hardshipzone 4	HZ_4	-0.494	(-6.05)	-0.709	(-5.25)
Region 1	DR_1	0.103	(3.58)	0.170	(3.62)
Region 2	DR_2	0.098	(6.37)	0.173	(6.97)
Region 3	DR_3	0.098	(5.79)	0.171	(6.24)
Region 4	DR_4	0.122	(8.39)	0.193	(7.98)
Region 5	DR_5	0.025	(1.86)	0.057	(2.64)
"operational" Flexib.*)	$\widehat{O\_FLEX\_L}$	-0.527	(-29.57)	-.-	(-.-)
"tactical" Flexib. *)	$\widehat{T\_FLEX}$	-.-	(-.-)	-1.347	(-29.35)
s		0.847	(281.27)	1.382	(278.86)
LRI(adj.)		0.128		0.063	
LRT (DF)		13,952.0 (39,715)		9,218.5 (39,715)	

Remarks: t-values are in parenthesis. *LRI(adj)* and *LRT* is the likelihood ratio index (Agresti, 1990) and the likelihood ratio test respectively. DF is the number of degrees of freedom. *) *T_FLEX* and *O_FLEX_L* have been instrumented using all exogenous variables in the empirical model. Hardship zones (HZ_1 to HZ_4) are regional classifications indicating unfavourable production conditions due to climate, transportation facilities, and mountainoues nature of the area. HZ_0 = 1 (HZ_4 = 1) indicates most favourable (most unfavourable) production conditions.