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# Farm Household Income and On- and Off-Farm Diversification

Kevin T. McNamara and Christoph Weiss

The paper analyzes the relationship between off-farm labor allocation and on-farm enterprise diversification as farm household income stabilization strategies with census data from the federal state of Upper Austria, Austria. The results suggest that both on-farm diversification and off-farm labor allocation are related to farm and household characteristics. Larger farms tend to be more diversified. Younger farmers are more likely to work off-farm. Larger farm households tend to allocate more labor to off-farm income activities.

*Key Words:* enterprise diversification, farm income risk, off-farm income

**JEL Classifications:** J20, O13, Q12, Q19, R19

Farming is a risky business. Farm operators face a number of uncertain factors, including weather and market conditions, that affect household income risk. The effects of recent policy changes (in particular the liberalization and globalization of agricultural markets) on the further risk associated with farming are open to question. Historically, government market intervention has sheltered domestic markets from international prices (Hazell, Jaramillo, and Williamson). If policy changes so that domestic prices actually track international price signals, farmers, as well as those involved in agriculture policy formulation, will be forced to consider the implications of larger fluctuations in commodity prices on income risk.<sup>1</sup>

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<sup>1</sup> Recent studies on the effects of agricultural market liberalization on domestic market price instability include Thompson, Herrmann, and Gohout and Chavas and Kim. Fraser (2000) examined the implications for producer compensation in the Agenda 2000 Cereal Reforms.

On-farm enterprise diversification can be an efficient risk management mechanism by stabilizing expected returns in an uncertain environment. Although the importance of this strategy has long been recognized (Heady), few studies have examined the relationship between farm enterprise diversification and farm household income variability with microdata (Mishra and El-Osta; Pope and Prescott; Purdy, Langemeier, and Featherstone; Sun, Jenkins, and El-Osta; White and Irwin).

Changes in risk associated with specific activities causes fundamental structural changes in an economy. If producers are risk averse and perceive the variance of income to be greater in one enterprise than another, they will allocate less time to the higher risk enterprise. The reallocation of labor from agricultural to nonagricultural income activities has been an important farm household income management strategy of the postwar prosperity in most industrialized countries. Following Huffman's seminal work, the last two centuries have seen considerable empirical research on farm household labor allocation. However, as Mishra and Goodwin stressed, limited attention has been devoted to assessing how

farm enterprise risk influences farm household labor allocation across farm enterprises and off-farm earnings. Referring to a U.S. farmer attitudes survey, Mishra and Goodwin point out that farmers reported the primary reason they worked off-farm was to stabilize household income given the variability of their farm income. Analysis of off-farm labor supply decisions among Kansas farmers revealed a positive relationship between the coefficient of variation for farm income and off-farm work (Mishra and Goodwin). That is, the greater the variability of farm income, the higher the off-farm labor participation.

In this paper, we combined two strands of literature by analyzing the interrelationship between on-farm enterprise diversification and off-farm labor allocation as farm household income stabilization strategies, both theoretically and empirically.<sup>2</sup> A model was developed to examine the relationship between on-farm enterprise diversification and off-farm labor allocation and farm household income stabilization strategies. The data and econometric results are presented and discussed, and we present conclusions and implications.

## Theory

Theoretical models offer different arguments about farm household on-farm and off-farm diversification. These arguments can be divided into two groups: efficiency gains and risk reduction.<sup>3</sup> The standard theoretical framework for modeling efficiency issues related to off-farm diversification decisions, the farm household model, emphasizes the role of technologies and costs by focusing on the marginal productivity of labor both on and off the

farm. The marginal income of farm labor declines with the amount of time spent working on the farm. If farm income falls below the farm household reservation wage, household members will allocate time to off-farm labor if they can.<sup>4</sup> With respect to on-farm diversification, economies of scale and scope of the agricultural enterprise mix are important. If it is less costly to produce goods jointly instead of separately, the cost function exhibits "economies of scope." Although there is general acceptance of the synergy concept,<sup>5</sup> the sources of economies of scope are not easy to identify. Fernandez-Cornejo et al. explored causes of scope economies for German farms in detail.

Income risk arguments for nonfarm enterprise diversification stress the importance of risk associated with agricultural production as the key motivation. Farm households (farm firms) benefit from diversification strategies that generate a more stable income stream. This argument, however, is not convincing for manufacturers. Jovanovic argued that, without bankruptcy risk and liquidity constraints, firms need not diversify to avoid risk—shareholders should.<sup>6</sup> And, there is ample evidence that shareholders typically diversify their portfolios. In the agricultural sector, however, the argument for enterprise diversification has more appeal. The role of the owner and the manager coincide in family farms (the "manager" receives all the rewards of his efforts). Farm operators, therefore, might have less incentive to diversify their investment portfolio off the farm. Although research suggests the off-farm investment of U.S. farmers has increased in recent years (Mishra et al.), farm operators have a strong incentive to spread personal risks associated with farm investment through diversification of farm production enterprises.

The effects of price risk on farm operators' diversification decisions on and off the farm can best be studied in an expected value var-

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<sup>2</sup> Different definitions of farm diversification are used in the literature. For an extensive discussion, see Evans and Ilbery.

<sup>3</sup> In addition to these arguments, the industrial organization literature also mentions market power arguments, as well as the principal-agent relationship between corporate managers and shareholders (Montgomery). Given that these arguments have limited relevance for the agricultural sector, they were not discussed.

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<sup>4</sup> A survey of this literature is available in Lass, Findeis, and Hallberg.

<sup>5</sup> Baumol formalized this concept in an extensive treatise.

<sup>6</sup> Jovanovic reviewed arguments as well as the available empirical evidence.

iance (EV) approach.<sup>7</sup> Suppose a farm family allocates total available labor,  $L$ , across  $n$  different farm enterprises ( $l_i$ , with  $i = 1, \dots, n$ ) and off-farm work  $l_0$ :  $L = \sum_{i=1}^n l_i + l_0$ . Farm output is produced according to the production function  $q_i = l_i^\alpha$ , which, for simplicity is assumed to be identical for all farm products.<sup>8</sup> The only form of risk considered here are price fluctuations in the agricultural product market. For simplicity, assume the expected prices of all farm products  $p_i$  and the variances and covariances of  $p_i$  to be identical ( $p_i = p$ , and  $\sigma_{ii} = \sigma_k^2$ ,  $\forall i = 1, \dots, n$ , and  $\sigma_{ij} = \rho\sigma_k^2$ ,  $\forall i \neq j = 1, \dots, n$ ; with  $-1 \leq \rho \leq 1$ ). Expected income can be written as

$$(1) \quad E(y) = \sum_{i=1}^n p_i l_i^\alpha + w l_0 - cn$$

$$= np \left( \frac{L - l_0}{n} \right)^\alpha + w l_0 - cn,$$

where  $w$  is the wage rate in the off-farm labor market. In Equation (1), the acquisition of each farming enterprise involves a fixed fee,  $c$ , that represents the cost of learning to manage or supervise the enterprise.<sup>9</sup> The certainty equivalent income is<sup>10</sup>

$$(2) \quad y_{CE} = E(y) - \frac{\lambda}{2} \sigma^2(y)$$

$$= np \left( \frac{L - l_0}{n} \right)^\alpha + w l_0 - cn$$

$$- \frac{\lambda}{2} (L - l_0)^2 \left[ \frac{1 + (n-1)\rho}{n} \right] \sigma_k^2,$$

where  $\lambda > 0$  represents the degree of risk aversion.

What are the optimal levels of farm diversification (the number of farm enterprises,  $n$ ) and the optimal time spent on off-farm work ( $l_0$ )? Maximizing  $y_{CE}$  with respect to  $l_0$  and  $n$  gives

$$(3) \quad \frac{\partial y_{CE}}{\partial l_0} = -\alpha \left( \frac{L - l_0}{n} \right)^{\alpha-1} p + w$$

$$+ \frac{\lambda(L - l_0)[1 + (n-1)\rho]\sigma_k^2}{n} = 0,$$

$$\frac{\partial y_{CE}}{\partial n} = (1 - \alpha) \left( \frac{L - l_0}{n} \right)^\alpha p - c$$

$$+ \frac{\lambda(L - l_0)^2(1 - \rho)\sigma_k^2}{2n^2} = 0.$$

The optimal  $n$  and  $l_0$  is easy to compute for the simple case of a linear farm production function ( $\alpha = 1$ ). Here we find

$$l_0^* = \frac{n(w - \alpha p)}{\lambda[1 + \rho(n-1)]\sigma_k^2} + L \quad \text{and}$$

$$n^* = \left[ \frac{\lambda}{2c}(1 - \rho) \right]^{1/2} (L - l_0)\sigma_k.$$

<sup>7</sup> The following model draws heavily on Robison and Barry. The EV approach has had widespread use in economic analysis. It can be derived from expected utility maximization (a) if an individual's utility function is assumed quadratic, reflecting preferences for expected values and variances only, or (b) if the distribution of returns are fully characterized by expected values and variances. For a detailed discussion see Robison and Barry.

<sup>8</sup> This (restrictive) assumption allows us to represent the degree of diversification with a single variable, the number of different farm enterprises ( $n$ ). Robison and Barry point to the problems of deriving clear predictions when relaxing this assumption by allowing different production technologies.

<sup>9</sup> We do not consider product complementarity between the different activities here. For an analysis of the product diversification problem that features both producer risk aversion and product complementarity see Fraser (1990).

<sup>10</sup> Robison and Barry show that  $\sigma^2 = (L - l_0)^2 \{ [1 + (n-1)\rho]/n \} \sigma_k^2$ .

For the more general case of  $\alpha \neq 1$ , the comparative static results of this model are reported in the Appendix.

Similar to farm household models, we find the amount of off-farm labor increases with off-farm wages ( $\partial l_0^*/\partial w > 0$ ). The model also suggests that off-farm work is more attractive for risk-averse individuals ( $\partial l_0^*/\partial \lambda > 0$ ) and in situations in which risk associated with farming increases ( $\partial l_0^*/\partial \sigma_k^2 > 0$ ), as long as  $\rho$  is not "too small" ( $\rho > -1/[n-1]$ ). If  $\rho$  is very small (close to  $-1$ ), however, perfect risk reduction is possible on-farm and no off-farm work will be chosen. Finally, off-farm labor increases with the total amount of family labor

$L(\partial l_0^*/\partial L > 0)$  and declines with farm size  $\partial l_0^*/\partial p < 0$ .<sup>11</sup>

With respect to the optimal degree of diversification, three terms determine the optimal  $n$  in Equation (4). The third term,  $[\lambda(L - l_0)^2(1 - \rho)\sigma_k^2]/2n^2$ , which is always positive for  $\rho < 1$ , represents the gains in  $y_{CE}$  from risk reduction. This gain has to be set against the losses from the cost of learning to manage or supervise the additional enterprise ( $-c$ ). The smaller the costs of including an additional product into the farm production mix, the larger diversification will be. Finally, the first term,  $(1 - \alpha)[(L - l_0)/n]^\alpha p$ , represents the consequences of increasing  $n$  for farm productivity. Increasing (decreasing) returns,  $\alpha > 1$  ( $\alpha < 1$ ), implies additional gains from specialization (diversification) of farm production, *ceteris paribus*. As expected, we find that diversification is more attractive for risk-averse individuals ( $\partial n^*/\partial \lambda > 0$ ) and in situations in which risk associated with farming is substantial ( $\partial n^*/\partial \sigma_k > 0$ ). Diversification increases as the correlation between the different returns from farming declines ( $\partial n^*/\partial \rho < 0$ ). With respect to the relationship between the total amount of farm household labor available ( $L$ ), as well as farm size ( $p$ ) and diversification, we find  $\partial n^*/\partial L > 0$  and  $\partial n^*/\partial p > 0$  for  $\alpha < 1$  and  $\partial n^*/\partial p < 0$  for  $\alpha > 1$ . The effect of farm size on farm diversification thus provides information on the form of the underlying production technology.<sup>12</sup>

Finally, this model suggests on-farm and off-farm diversification are interrelated. In the optimum, we expect part-time farmers to have a lower level of on-farm diversification ( $\partial n^*/\partial l_0^* < 0$ ). Given that off-farm employment is not associated with the risk of agricultural production, part-time farmers, *ceteris paribus*,

will have more stable total income, reducing their incentive for on-farm diversification. Similarly, farmers with more on-farm enterprise diversification have lower probabilities of participating in off-farm employment activity, *ceteris paribus* ( $\partial l_0^* < 0$ ). Empirical tests of these hypotheses are presented and discussed in the next section.

## Data

The estimated model used panel data from 39,621 farm households in the federal state of Upper Austria, Austria. The data were collected by the Census Bureau in Upper Austria in 1985 and 1990 as part of the farm census. The farm census collects information on farm operations and farm household characteristics (e.g., age, sex, schooling of various family members, off-farm employment status).

Given the importance of dairy farming in Upper Austria, the size and on-farm diversification measures were based on the number and type of livestock (median large animal units). The aggregate measure of farm size is broken down into nine subcategories (calves, fattened cattle, cattle, piglets, sheep and goats, chicken, cows, fattened pigs, and brood sow). Indices of these nine farm production enterprises were used to measure the degree of on-farm enterprise diversification.

Three indices are commonly used to measure diversification:

- (1) a modified concentration ratio  $D_C = (Q - q^{\max})/Q$ ,
- (2) the Berry index (Berry)  $D_B = 1 - \sum_{j=1}^n s_j^2$ , and
- (3) the entropy measure (Jacquemin and Berry)  $D_E = \sum_{j=1}^n s_j \log(1/s_j)$ ,

where  $s_j = q_j/Q$ . Here,  $q_j$  denotes the quantity of product  $j$ , with  $Q = \sum_{j=1}^n (q_j, q^{\max})$  the quantity of the most important product in the group of all nine products [ $q^{\max} = \max(q_1, q_2, \dots, q_n)$ ] and  $n$  is the number of products ( $n = 9$ ). Note that complete specialization implies  $D_C = D_B = D_E = 0$ , whereas the maximum level of diversification is given by  $D_C = D_B = 1$  and  $D_E = \log n$ . The properties of these di-

<sup>11</sup> Most of the comparative static results on off-farm labor supply correspond to those derived from "standard" farm household models. For attempts to introduce risk and uncertainty into farm household models, see Finkelshtain and Chalfant and Roe and Graham-Tomasi.

<sup>12</sup> Recent work by Gomes and Livdan focuses explicitly on the role of technologies and costs for diversification of production, without, however, considering individual preferences with respect to risk.

**Table 1.** Definition and Descriptive Statistics of Variables

Variable	Symbol	Farm Mean (SD)		
		Part-Time	Full-Time	All
No. of Observations	$N$	21,146	18,670	39,621
Modified Concentration Index of Diversification	$D_C$	0.2777 (0.199)	0.413 (0.174)	0.341 (0.199)
Berry Index of Diversification	$D_B$	0.373 (0.231)	0.526 (0.187)	0.445 (0.225)
Entropy Measure of Diversification	$TD_E$	0.375 (0.234)	0.544 (0.208)	0.455 (0.237)
Part-Time Farming <sup>a</sup>	PT	1.000 (0.000)	0.000 (0.000)	0.529 (0.499)
Farm size <sup>b</sup>	$\ln(S)$	3.952 (1.267)	5.223 (0.884)	4.552 (1.271)
No. of Family Members				
<6 Years Old	$\#FAM_{<6}$	0.302 (0.633)	0.403 (0.733)	0.349 (0.683)
Between 6 and 15 Years	$\#FAM_{6<15}$	0.545 (0.898)	0.753 (1.040)	0.643 (0.973)
15–65 Years	$\#FAM_{15<65}$	3.596 (1.428)	3.745 (1.475)	3.668 (1.452)
Married State in 1990 <sup>c</sup>	MARR	0.846 (0.361)	0.769 (0.421)	0.809 (0.392)
Farm Operator Age in 1990	AGE	48.061 (12.735)	43.339 (10.401)	45.832 (11.928)
Agriculture-Specific Schooling <sup>d</sup>	SCHOOL	0.593 (0.491)	0.607 (0.488)	0.599 (0.489)

<sup>a</sup> Married couple spends more than 50% of total working time on off-farm employment.

<sup>b</sup> Log of livestock (median large animal units).

<sup>c</sup> Dummy variable; =1 is married, =0 otherwise.

<sup>d</sup> Dummy variable; =1 if farm operator has a "farm master" degree, =0 otherwise.

versification measures are discussed in Gollop and Monahan. In the following empirical model, we use  $TD_E = D_E/D_E^{\max}$  (with  $0 \leq TD_E \leq 1$ , where  $D_E^{\max}$  is the maximum level of diversification over all farms) as the dependent variable; the results when using alternative diversification measures are very similar and are reported in the Appendix.

The census data report farm household off-farm work participation in one of three groups: (a) 90% or more on-farm, (b) less than 90% but 50% or more on-farm, or (c) 50% or less on-farm. Farm households were classified as full-time farmers if more than 50% of household time was allocated to farm activities (PT

= 0). Farm households with 50% or less time allocated to on-farm activities were classified as part-time farmers (PT = 1).

To guarantee a homogeneous database, the analysis used only farms included in both years and having all relevant data. A total of 39,621 farm households satisfied these criteria. Descriptions and summary statistics for each variable used in the empirical model are reported in Table 1.

## Results

Results of the econometric analysis are shown in Table 2. Parameter estimates of probit mod-

**Table 2.** Results of Instrumental Variable Probit Models on Farm Production Diversification ( $TD_E$ ) and Off-Farm Diversification (Part-Time Farming)

Independent Variable Estimation Method		Dependent Variable	
		$TD_E$ ( $t$ Value)	PT ( $t$ Value)
Constant		-1.869*** (-18.94)	6.149*** (51.89)
Farm Size	$\ln(S)$	0.378*** (58.45)	-0.642*** (-73.22)
Agricultural Schooling	SCHOOL	-0.014 (-1.04)	-0.034** (-2.33)
Age of Farm Operator/40	AGE	-0.342** (2.12)	-6.769*** (-31.68)
(Age of Farm Operator/40) <sup>2</sup>	AGE <sup>2</sup>	0.143** (2.06)	3.171*** (33.18)
No. of Family Members (<6)	#FAM <sub>&lt;6</sub>	0.005 (0.51)	-0.101*** (-8.62)
No. of Family Member (6 to <15)	#FAM <sub>6&lt;15</sub>	0.002 (0.25)	-0.033*** (-3.98)
No. of Family Member (15-65)	#FAM <sub>15&lt;65</sub>	0.019*** (4.08)	0.011** (2.11)
Married State	MARR	-0.034* (-1.69)	0.698*** (31.18)
Hardship Zone 1	HZ <sub>1</sub>		0.138*** (7.21)
Hardship Zone 2	HZ <sub>2</sub>		0.156*** (6.73)
Hardship Zone 3	HZ <sub>3</sub>		0.079*** (3.24)
Hardship Zone 4	HZ <sub>4</sub>	0.209* (1.66)	0.353*** (2.25)
Region 1	R <sub>1</sub>		-0.879*** (-18.42)
Region 2	R <sub>2</sub>	0.159*** (3.56)	-0.283*** (-12.56)
Region 3	R <sub>3</sub>	0.110** (2.37)	0.080*** (3.17)
Region 4	R <sub>4</sub>	0.087** (1.99)	-0.100*** (-4.99)
Region 5	R <sub>5</sub>	0.192*** (4.44)	
Region 6	R <sub>6</sub>	0.217*** (5.01)	
Diversification (Entropy)	$TD_E$		-0.514*** (-12.55)
LL(0)		-27,302.99	-27,391.84
LL( $\beta$ )		-25,013.69	-19,755.37
LRT(DF)		4,578.61 (14)	15,272.94 (17)
R <sup>2</sup> McFadden (Veall/Zimmerman)		0.084	0.278 (0.479)

Notes: LL( $\beta$ ) and LL(0) are the log likelihood and restricted log likelihood functions, respectively, and LRT refers to the likelihood ratio test statistic. The parameter estimates are significantly different from zero at the \*\*\* 99%, \*\* 95%, and \* 90% levels.

els on diversification ( $TD_E$ ) and the probability of part-time farming (PT) are shown. All variables refer to observations from the 1990 farm census; we used lagged observations (from the 1985 farm census) as instruments for the independent variable  $TD_E$  in the PT diversification model. The estimation models are statistically significant at the 1% level, as measured by the likelihood ratio test. The PT diversification model correctly classifies 77.7% of all observations, whereas 75.1% of all cases with the farm operator working off the farm ( $PT = 1$ ) are predicted correctly. The percentage of correctly classified families reporting no off-farm work is somewhat higher, at 80.6%.<sup>13</sup> The

results reported for the PT diversification model are consistent with detailed empirical analysis of off-farm employment conducted by Weiss with these data. Discussion of the results focused on the determinants of diversification and the interaction between on- and off-farm diversification.

Empirical literature offers conflicting results as to the effect of farm size on farm enterprise diversification. White and Irwin, using aggregate U.S. Census Data, compared diversification across farm size classes and concluded that larger farms were more specialized. The opposite finding was reported in Pope and Prescott. Our results support the Pope and Prescott findings. The transformed Entropy measure ( $TD_E$ ) increased with farm size ( $\ln S$ ) and larger farms tended to be more

<sup>13</sup> Because  $TD_E$  is not binary, this statistic cannot be calculated here.

diversified.<sup>14</sup> This is consistent with the prediction of Robison and Barry's model outlined earlier and to more recent theoretical work on diversification that emphasizes the role of technologies and costs (Gomes and Livdan). According to the authors, decreasing returns to scale imply that the returns to capital accumulation decline as the farm enterprises expand until there is no further incentive for expansion of the current activity. This generates a powerful motivation for larger farms to diversify into new activities to obtain higher returns to capital accumulation. An increase in farm size also reduces the probability of entering into the off-farm labor market (Table 2, PT diversification model), which corresponds to the existing empirical literature.

The results suggest personal characteristics of the farm operator, as well as farm family influence on diversification decisions on and off the farm (Table 2, PT diversification model). The probability of off-farm work significantly decreases with the farm operators' farm-specific schooling (SCHOOL). No such relationship can be observed with respect to the degree of diversification on the farm. The parameter estimates for nonfarm-specific schooling were found to be insignificant in both models and are thus not reported here. The effect of the farm operator's age (AGE), is significantly different from zero in both models. Different arguments for a relationship between age and diversification have been offered. Pope and Prescott speculated that younger farmers are less risk averse, which would reduce the level of on-farm diversification (positive relationship between age and diversification). On the other hand, the age of the farm operator might be positively correlated with wealth (which is not observed in this dataset). Given a decreasing absolute risk aversion as wealth increases, there would be an inverse relationship between age and diversification. Similarly, sociological studies from

direct interviews frequently indicate the farmers' intention to reduce working load and make life easier as they grow older. This could be achieved through specialization or by reducing the number of farm enterprises. In Table 2 there is a nonlinear age-diversification relationship in the TD<sub>E</sub> diversification model. On-farm diversification first declines with the farm operator's age, reaches its minimum at 48 years of age, and then increases. A similar nonlinear pattern is reported in the PT diversification model, which is consistent with other research (Lass, Findeis, Hallberg).

Farm family size also appears to be an important determining variable of both on- and off-farm diversification. An increase in the number of family members living on the farm in the age category between 16 and 65 years (#FAM<sub>15-65</sub>) is associated with a higher farm enterprise diversification. This result is consistent with the predictions derived from the theoretical model, given that a larger number of family members implies an increase in the total amount of family labor available on the farm. No significant effect is observed with respect to the number of younger family members (#FAM<sub><6</sub>, and #FAM<sub>6<15</sub>). Similarly, we find that additional family members below 16 years of age impede the acceptance of additional off-farm work for the married couple but later on provide the necessary labor resources on the farm and thereby facilitate entering the off-farm labor market. If the farm operator is married (MARR = 1), diversification on the farm is lower and the probability of off-farm employment is higher. The effect of this variable for the TD<sub>E</sub> diversification model is significantly different only at the 10% level, however.

Dummy variables for regional differences (R<sub>1</sub>-R<sub>6</sub> and HZ<sub>1</sub>-HZ<sub>4</sub>) were included when they contributed significantly to the explanatory power of the models. Farms located in less productive areas (HZ<sub>*i*</sub> = 1 with *i* = 1, 2, 3, 4) report a significantly higher probability of participating in the off-farm labor market. A significant positive effect on farm diversification can only be observed for farms located in the most unfavorable production conditions (HZ<sub>4</sub> = 1).

<sup>14</sup> The size distribution of farms is skewed to the right, with a skewness coefficient of 1.3 (Greene, p. 879). Given this skewed distribution, the natural logarithm of farm size is used in the empirical analysis.



To evaluate the relationship between the two forms of diversification ( $TD_E$  and  $PT$ ), we carried out a number of estimation experiments along the lines suggested in Maddala and in Greene.<sup>15</sup> Unfortunately, in none of the numerous specifications tested did the bivariate probit model converge. The results of independently estimated probit models are thus discussed in Table 2. We used the lagged diversification and part-time variable for instrumentation. The results suggest on-farm and off-farm diversification decisions are closely related. The probability of off-farm diversification is found to decline significantly as the farm enterprise mix becomes more diversified. This corresponds to our predictions derived from a simple mean variance model. Different estimation experiments indicate that  $PT$  does not contribute significantly to on-farm diversification.

## Summary and Conclusions

The purpose of this paper was to examine the effect of various farm and household characteristics on farm household income diversification. Two forms of diversification (and their interaction) were considered: farm production and off-farm diversification (off-farm employment). In contrast to the existing literature, we did not examine off-farm employment in a

farm household model, but derived testable predictions from an optimal portfolio selection framework.

With linked census data for Upper Austria from 1985 and 1990, we found that the degree of on-farm diversification, as well as the probability of off-farm diversification, was significantly related to farm and family characteristics. In particular, we provided evidence that larger farms are more diversified, whereas off-farm diversification is found to be less likely. A significant effect on the degree of on- and off-farm diversification is also reported for farm operator age and the number of family members living on the farm.

These results have important policy implications. Historically, government market intervention has sheltered domestic prices from international market price fluctuation. In the new economy of the European Union (EU), domestic prices will be more closely tied to international price signals. A similar tendency to shift a larger portion of risk-bearing function from the public sector back to the private sector can also be observed in non-EU countries. Our results imply that these changes will result in more off-farm diversification, more on-farm diversification, or both. Which of the two strategies is actually chosen by a farm operator will not only have important consequences for the performance of individual farms but will also influence the structure of the farm sector in the future.

<sup>15</sup> Maddala discusses alternative simultaneous equations models with discrete endogenous variables. A general specification for a two-equation model would be:  $y_1 = \gamma_1 y_2 + \beta_1' X_1 + \varepsilon_1$  and  $y_2^* = \gamma_2 y_1 + \beta_2' X_2 + \varepsilon_2$ , with  $E[\varepsilon_1] = E[\varepsilon_2] = 0$ ,  $\text{Var}[\varepsilon_1] = \text{Var}[\varepsilon_2] = 1$ , and  $\text{Cov}[\varepsilon_1, \varepsilon_2] = \rho$ . The unobservable variables  $y_2^*$  are related to the observable variables  $y_2$  as follows:  $y_2 = 1$  if  $y_2^* > 0$  and  $= 0$  otherwise. Maddala (p. 117f) shows that this model is logically consistent if and only if  $\gamma_1$  or  $\gamma_2 = 0$ . To find the appropriate specification for a model with two endogenous variables  $TD_E$  ( $\equiv y_1$ ) and  $PT$  ( $\equiv y_2$ ), we first estimate three different models.

In model 1, we assume  $\gamma_1 = \gamma_2 = 0$  and thus no direct relationship exists. Model 2 assumes  $\gamma_1 = 0$ , and model 3 has  $\gamma_2 = 0$ . A likelihood ratio test does not reject model 1 against model 2. However, model 1 is rejected against model 3. We thus consider model 3 the most appropriate specification, the results of which are reported in Table 2 ( $TD_E$  and  $PT$  diversification models).

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### Appendix: Comparative Static Results of the Model for $\alpha \neq 1$

From the first-order condition for the optimal  $l_0$  reported in Equation (3) in the text, we define

$$F \equiv -\alpha \left( \frac{L - l_0}{n} \right)^{\alpha-1} p + w + \frac{\lambda(L - l_0)[1 + (n - 1)\rho]\sigma_k^2}{n} = 0.$$

Applying the implicit function theorem with the second-order condition,

$$\begin{aligned} \frac{\partial^2 y_{CE}}{\partial l_0^2} \equiv A &= \alpha(\alpha - 1) \left( \frac{L - l_0}{n} \right)^{\alpha-1} \frac{p}{L - l_0} \\ &\quad - \frac{\lambda[1 + (n - 1)\rho]\sigma_k^2}{n} < 0, \end{aligned}$$

we find:

$$\begin{aligned} \frac{\partial l_0}{\partial w} &= -\frac{\partial F / \partial w}{\partial F / \partial l_0} = \frac{-1}{A} > 0; \\ \frac{\partial l_0}{\partial L} &= -\frac{\partial F / \partial L}{\partial F / \partial l_0} = 1 > 0; \\ \frac{\partial l_0}{\partial p} &= -\frac{\partial F / \partial p}{\partial F / \partial l_0} = \frac{\alpha(L - l_0)^{\alpha-1}}{n^{\alpha-1}A} < 0; \\ \frac{\partial l_0}{\partial \rho} &= -\frac{\partial F / \partial \rho}{\partial F / \partial l_0} = \frac{-\lambda(L - l_0)(n - 1)\sigma_k^2}{nA} > 0; \\ \frac{\partial l_0}{\partial c} &= 0; \\ \frac{\partial l_0}{\partial \lambda} &= -\frac{\partial F / \partial \lambda}{\partial F / \partial l_0} \\ &= \frac{-\lambda(L - l_0)[1 + (n - 1)\rho]\sigma_k^2}{nA} > 0 \\ &\quad \text{for } \rho > \frac{-1}{(n - 1)}; \end{aligned}$$

$$\begin{aligned} \frac{\partial l_0}{\partial \sigma_k^2} &= -\frac{\partial F / \partial \sigma_k^2}{\partial F / \partial l_0} \\ &= \frac{-\lambda(L - l_0)[1 + (n - 1)\rho]}{nA} > 0 \\ &\quad \text{for } \rho > \frac{-1}{(n - 1)}. \end{aligned}$$

Similarly, from Equation (4) we define

$$\begin{aligned} F &\equiv (1 - \alpha) \left( \frac{L - l_0}{n} \right)^{\alpha} p - c \\ &\quad + \frac{\lambda(L - l_0)^2(1 - \rho)\sigma_k^2}{2n^2} = 0. \end{aligned}$$

The second-order condition for the optimal number of products  $n$  is

$$\begin{aligned} \frac{\partial^2 y_{CE}}{\partial n^2} \equiv B &= -\alpha(1 - \alpha) \left( \frac{L - l_0}{n} \right)^{\alpha} \frac{p}{n} \\ &\quad - \frac{\lambda(L - l_0)^2(1 - \rho)\sigma_k^2}{2n^4} < 0. \end{aligned}$$

With the use of this, we find

$$\begin{aligned} \frac{\partial n}{\partial c} &= -\frac{\partial F / \partial c}{\partial F / \partial n} = \frac{1}{B} < 0; \\ \frac{\partial n}{\partial \rho} &= -\frac{\partial F / \partial \rho}{\partial F / \partial n} = \frac{\lambda(L - l_0)^2\sigma_k^2}{2n^2B} < 0; \\ \frac{\partial n}{\partial p} &= -\frac{\partial F / \partial p}{\partial F / \partial n} = \frac{-(1 - \alpha)(L - l_0)^{\alpha}}{n^{\alpha}B} \geq 0 \\ &\quad \text{if } \alpha \leq 1; \\ \frac{\partial n}{\partial \lambda} &= -\frac{\partial F / \partial \lambda}{\partial F / \partial n} = \frac{-(L - l_0)^2(1 - \rho)\sigma_k^2}{2n^2B} > 0; \\ \frac{\partial n}{\partial \sigma_k^2} &= -\frac{\partial F / \partial \sigma_k^2}{\partial F / \partial n} = \frac{-\lambda(L - l_0)^2(1 - \rho)}{2n^2B} > 0; \\ \frac{\partial n}{\partial w} &= 0; \\ \frac{\partial n}{\partial L} &= -\frac{\partial F / \partial L}{\partial F / \partial n} \\ &= \{-[\alpha(1 - \alpha)p(L - l_0)^{\alpha-1}n^{-\alpha+2}] \\ &\quad + \lambda(L - l_0)(1 - \rho)\sigma_k^2\} / (n^2B) \geq 0 \\ &\quad \text{if } \alpha \leq 1. \end{aligned}$$

**Table A1.** Results of Instrumental Variable Probit Models on Farm Production Diversification ( $D_B$ ) and Off-Farm Diversification (Part-Time Farming)

Independent Variable Estimation Method		Dependent Variable	
		$D_B$ ( $t$ Value)	PT ( $t$ Value)
Constant		-1.694*** (-17.35)	6.152*** (52.03)
Farm Size	$\ln(S)$	0.343*** (54.50)	-0.646*** (-74.31)
Agricultural Schooling	SCHOOL	-0.011 (-0.84)	-0.035** (-2.40)
Age of Farm Operator/40	AGE	-0.304* (1.90)	-6.742*** (-31.65)
(Age of Farm Operator/40) <sup>2</sup>	AGE <sup>2</sup>	0.125* (1.82)	3.159*** (33.17)
No of Family Members (<6)	#FAM <sub>&lt;6</sub>	0.001 (0.08)	-0.102*** (-8.65)
No. of Family Members (6 to <15)	#FAM <sub>6&lt;15</sub>	0.004 (0.48)	-0.033*** (-4.00)
No of Family Members (15–65)	#FAM <sub>15&lt;65</sub>	0.012** (2.55)	0.010* (1.89)
Married State	MARR	-0.028 (-1.41)	0.701*** (31.36)
Hardship Zone 1	HZ <sub>1</sub>		0.139*** (7.29)
Hardship Zone 2	HZ <sub>2</sub>		0.159*** (6.89)
Hardship Zone 3	HZ <sub>3</sub>		0.082*** (3.36)
Hardship Zone 4	HZ <sub>4</sub>	0.189 (1.51)	0.355** (2.25)
Region 1	R <sub>1</sub>		-0.871*** (-18.31)
Region 2	R <sub>2</sub>	0.129*** (2.92)	-0.278*** (-12.38)
Region 3	R <sub>2</sub>	0.085* (1.86)	0.084*** (3.35)
Region 4	R <sub>4</sub>	0.058 (1.36)	-0.096*** (-4.79)
Region 5	R <sub>5</sub>	0.137*** (3.20)	
Region 6	R <sub>6</sub>	0.178*** (4.18)	
Diversification (Berry)	$D_B$		-0.523*** (-11.97)
LL(0)		-27,354.95	-27,521.31
LL( $\beta$ )		-25,421.23	-19,837.46
LRT(DF)		3,867.44 (14)	15,367.70 (17)
R <sup>2</sup> McFadden (Veall/Zim.)		0.071	0.279 (0.479)

Notes: See Table 2 Notes.

**Table A2.** Results of Instrumental Variable Probit Models on Farm Production Diversification ( $D_C$ ) and Off-Farm Diversification (Part-Time Farming)

Independent Variable Estimation Method		Dependent Variable	
		$D_C$ ( $t$ Value)	PT ( $t$ Value)
Constant		-1.898*** (-18.78)	6.105*** (51.73)
Farm Size	$\ln(S)$	0.330*** (49.23)	-0.639*** (-73.99)
Agricultural Schooling	SCHOOL	-0.101 (-0.74)	-0.036** (-2.41)
Age of Farm Operator/40	AGE	-0.284* (1.72)	-6.733*** (-31.61)
(Age of Farm Operator/40) <sup>2</sup>	AGE <sup>2</sup>	0.117* (1.64)	3.155*** (33.13)
No. of Family Members (<6)	#FAM <sub>&lt;6</sub>	0.001 (0.10)	-0.101*** (-8.62)
No. of Family Members (6 to <15)	#FAM <sub>6&lt;15</sub>	0.002 (0.31)	-0.033*** (-4.01)
No. of Family Members (15-65)	#FAM <sub>15&lt;65</sub>	0.008* (1.75)	0.010* (1.89)
Married State	MARR	-0.027 (-1.35)	0.699*** (31.32)
Hardship Zone 1	HZ <sub>1</sub>		0.135*** (7.08)
Hardship Zone 2	HZ <sub>2</sub>		0.156*** (6.74)
Hardship Zone 3	HZ <sub>3</sub>		0.079*** (3.23)
Hardship Zone 4	HZ <sub>4</sub>	0.185 (1.41)	0.356** (2.27)
Region 1	R <sub>1</sub>		-0.866*** (-18.22)
Region 2	R <sub>2</sub>	0.115*** (2.49)	-0.275*** (-12.22)
Region 3	R <sub>3</sub>	0.061 (1.27)	0.082*** (3.24)
Region 4	R <sub>4</sub>	0.042 (0.93)	-0.097*** (-4.86)
Region 5	R <sub>5</sub>	0.113** (2.54)	
Region 6	R <sub>6</sub>	0.150*** (3.38)	
Diversification (concentration)	$D_C$		-0.643*** (-13.69)
LL(0)		-25,547.69	-27,521.31
LL( $\beta$ )		-23,960.23	-19,815.64
LRT(DF)		3,174.91 (14)	15,411.34 (17)
$R^2$ McFadden (Veall/Zimmerman)		0.062	0.279 (0.481)

Notes: \* See Table 2 Notes.