

Technical efficiency and farm size in the context of sustainable agriculture

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Electronic supplementary material

Supplementary Tables S1–S4

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Table S1. Economies of scale resulting from the relationship between measures SE_{VRS} and SE_{NIRS}

1. scale efficiency (SE_{VRS})			
$SE_{VRS} = 1$		$SE_{VRS} < 1$	
object efficient in relation to the scale of production		object inefficient in relation to the scale of production	
2. scale efficiency (SE_{NIRS})			
$SE_{NIRS} = 1$		$SE_{NIRS} < 1$	
object operates in the advantages of scale		object operates in the disadvantages of scale	
$SE_{NIRS} = 1$		$SE_{NIRS} < 1$	
object operates in the advantages of scale		object operates in the disadvantages of scale	

Source: Own elaboration based on Aldeseit (2013)

Table S2. Description of the dataset used

Variable	Description	Unit
OUTPUT		
Total output	Total value of output of crops and crop products, livestock and livestock products and of other output, including that of other gainful activities (OGA) of the farms.	current EUR
INPUT		
Total utilised agriculture area	Area of holding, it consists of land in owner occupation, rented land, land in share-cropping (remuneration linked to output from land made available). It includes agricultural land temporarily not under cultivation for agricultural reasons or being withdrawn from production as part of agricultural policy measures.	ha
Fertilizers	Purchased fertilisers and soil improvers (excluding those used for forests).	current EUR
Crop protection	Plant protection products, traps and baits, bird scarers, anti-hail shells, frost protection, etc. (excluding those used for forests).	current EUR
Total livestock units	Number of equidae, cattle, sheep, goats, pigs, and poultry and rabbits present on holding (annual average), converted into livestock units (LU). Animals which do not belong to the holder but are held under a production contract are taken into account according to their annual presence.	LU
Feed for grazing livestock	Concentrated feeding stuffs (including mineral licks and preservatives), coarse fodder, expenditure on the use of common grazing land, expenditure on agistment, cost of renting forage land not included in the UAA for equines, cattle, sheep and goats.	current EUR
Labour input	Time worked in hours by total labour input on holding.	hrs
Machinery and equipment	Tractors, motor cultivators, lorries, vans, cars, major and minor farming equipment – closing valuation.	current EUR
Gross investment on fixed assets	Adjusted value of purchases of fixed assets, i.e. reduced by their sale and increased by the purchase of breeding livestock – change of revaluation.	current EUR

Source: Own elaboration based on FADN database (FADN 2023b)

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Table S3. Statistical description of the dataset used in EU countries (2004–2020)

Variable in total		Country				
Mean (SD) Min. Max	EL	CY	SL	BG*	EE	HR**
Total output	22 468.2	36 315.1	23 924.5	45 873.6	97 551.2	24 569.9
	(1 014.9)	(3 478.9)	(4 401.3)	(18 900.9)	(29805.8)	(2 140.7)
	20 045.0	30 729.0	14 848.0	18 159.0	51617.0	21 013.0
	24 451.0	41 758.0	30 698.0	74 073.0	145840.0	28 959.0
Total utilised agriculture area	8.9	9.5	10.6	44.8	125.7	15.0
	(1.0)	(1.1)	(0.4)	(16.2)	(13.9)	(0.4)
	7.5	7.6	9.8	21.4	96.2	14.4
	10.3	11.4	11.4	69.7	139.8	15.7
Fertilizers	1 370.5	1 524.3	854.0	4 122.5	8 438.2	1 941.3
	(145.6)	(255.8)	(199.8)	(1 998.4)	(3 201.3)	(121.8)
	1 071.0	1 071.0	499.0	928.0	2 874.0	1 767.0
	1 574.0	2 249.0	1 273.0	7 115.0	12 388.0	2 153.0
Crop protection	909.5	952.3	506.2	2 492.4	3 030.8	1 053.0
	(86.6)	(114.3)	(105.4)	(1 313.9)	(1 151.7)	(106.5)
	763.0	764.0	326.0	598.0	1 225.0	943.0
	1 038.0	1 168.0	640.0	4 387.0	4 942.0	1 197.0
Total livestock units	6.2	12.5	11.4	13.8	36.5	8.6
	(0.3)	(2.8)	(1.0)	(4.3)	(2.9)	(0.5)
	5.7	8.0	9.9	9.1	30.0	7.9
	6.7	21.9	12.7	20.7	41.7	9.4
Feed for grazing livestock	2 561.5	8 271.7	5 305.9	3 120.8	19 508.3	3 969.9
	(278.6)	(1 722.1)	(1 790.0)	(777.0)	(5 436.35)	(269.2)
	1 985.0	5 291.0	1 606.0	2 188.0	9 581.0	3 520.0
	3 004.0	11 431.0	7 124.0	4 351.0	26 710.0	4 408.0
Labour input	2 738.8	3 006.8	2 803.4	4 825.6	4 778.1	2 982.1
	(253.7)	(238.8)	(531.8)	(369.0)	(822.5)	(162.8)
	2 387.7	2 763.9	2 109.1	4 377.0	3 820.0	2 785.9
	3 150.2	3 650.0	3 747.1	5 552.2	6 522.1	3 314.1
Machinery and equipment	18 024.6	15 426.1	26 761.1	20 862.0	60 604.5	21 253.9
	(4 225.0)	(1 949.6)	(6 308.5)	(8 593.9)	(19 408.1)	(1 792.7)
	11 079.0	12 244.0	4 863.0	5 908.0	21 369.0	19 350.0
	23 115.0	19 838.0	13 319.0	33 639.0	83 464.0	24 257.0
Gross investment on fixed assets	866.1	1 948.3	8 623.5	8 396.6	24 677.5	2 999.1
	(355.3)	(1 949.5)	(2 099.5)	(3 171.0)	(7 514.4)	(1 061.4)
	405.0	1 887.0	4 863.0	2 422.0	13 660.0	1 817.0
	1 567.0	7 228.0	13 319.0	13 472.0	40 172.0	5 269.0

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Table S3 to be continued

Variable in total		Country				
Mean (SD) Min. Max	LV	LT	HU	MT	PL	PT
Total output	53 007.5	32 731.2	66 711.8	38 286.0	27 675.5	30 087.8
	(14 700.5)	(9 218.7)	(11 541.0)	(3 245.1)	(4 349.0)	(5 165.3)
	30 824.0	14 105.0	43 752.0	32 619.0	18 872.0	22 221.0
	81 862.0	44 588.0	83 167.0	43 626.0	34 037.0	39 436.0
Total utilised agriculture area	66.4	44.1	48.6	2.8	18.6	24.5
	(4.5)	(6.6)	(3.4)	(0.2)	(1.1)	(1.3)
	56.1	28.9	44.4	2.6	15.7	22.5
	71.8	49.5	56.1	3.3	19.9	26.8
Fertilizers	4 381.8	3 859.2	4 255.8	777.7	2 470.4	1 414.5
	(1 519.0)	(1 467.1)	(968.4)	(121.1)	(525.3)	(195.3)
	1 442.0	1 088.00	2 489.0	537.0	1 372.0	1 039.0
	6 348.0	5 417.0	5 829.0	1 050.0	3 049.0	1 662.0
Crop protection	2 013.6	1 539.2	3 394.6	639.4	1 069.6	1 066.2
	(769.2)	(625.6)	(435.9)	(75.8)	(170.4)	(232.7)
	784.0	454.0	2 452.0	525.0	652.0	6 998.0
	2 981.0	2 256.0	4 099.0	789.0	1 234.0	1 527.0
Total livestock units	22.0	12.4	18.5	15.7	12.4	14.2
	(1.9)	(1.5)	(1.3)	(3.4)	(0.6)	(0.7)
	19.4	10.0	16.7	11.0	11.6	13.0
	27.1	15.9	20.9	21.4	13.4	15.3
Feed for grazing livestock	7 341.5	4 496.6	4 974.9	7 151.9	1 964.9	4 034.9
	(1 163.0)	(263.5)	(723.1)	(1 027.7)	(421.6)	(396.8)
	4 578.0	3 181.9	3 424.0	4 835.0	1 085.0	3 468.0
	8 441.0	4 164.1	6 152.0	9 989.0	2 458.0	4 876.0
Labour input	4 294.7	3 731.4	3 589.4	3 289.9	3 720.4	3 140.2
	(571.8)	(263.5)	(294.1)	(408.8)	(171.3)	(194.0)
	3 741.7	3 181.9	3 133.3	2 768.8	3 368.5	2 828.7
	5 481.6	4 164.1	4 190.0	3 868.9	3 928.5	3 808.7
Machinery and equipment	28 561.6	29 332.8	30 389.2	25 471.5	22 838.2	14 613.5
	(7 579.9)	(8 558.6)	(5 299.5)	(1 921.5)	(3 971.2)	(1 267.2)
	12 437.0	9 344.0	19 545.0	22 202.0	15 604.0	12 716.0
	40 654.0	39 492.0	39 505.0	28 349.0	27 664.0	17 137.0
Gross investment on fixed assets	15 192.5	10 763.4	7 933.4	3 337.5	4 079.4	4 188.3
	(4 577.9)	(3 592.1)	(1 991.3)	(1 435.9)	(858.0)	(1 238.0)
	5 671.0	2 551.0	4 631.0	1 227.0	2 672.0	2 686.0
	21 907.0	16 177.0	11 567.0	6 296.0	6 594.0	7 466.0

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Table S3 to be continued

Variable in total		Country					
Mean (SD) Min Max	RO*	AT	CZ	FI	SE	UK	
Total output	13 902.9	75 132.8	291 387.1	9 3267.2	173 203.6	226 901.8	
	(3 889.7)	(16 355.6)	(43 678.5)	(22 229.2)	(39 990.0)	(35 191.9)	
	10 405.0	52 658.0	232 735.0	57 839.0	111 782.0	158 841.0	
	21 754.0	102 280.0	420 470.0	129 212.0	218 695.0	268 855.0	
Total utilised agriculture area	11.1	31.3	213.0	57.5	99.0	155.5	
	(3.5)	(1.4)	(18.0)	(6.7)	(7.2)	(5.9)	
	8.2	28.6	188.3	46.4	87.4	143.1	
	17.8	33.3	247.0	68.2	106.8	164.5	
Fertilizers	812.9	1 958.2	18 482.1	6 320.2	9 634.0	14 504.5	
	(322.4)	(398.3)	(3 494.6)	(1 330.3)	(2 155.1)	(2 562.9)	
	382.0	1 259.0	11 097.0	3 969.0	5 840.0	10 178.0	
	1 417.0	2 420.0	24 274.0	7 752.0	12 584.0	18 585.0	
Crop protection	489.1	1 358.1	16 987.4	1 740.4	3 738.8	9 119.8	
	(230.2)	(307.9)	(2 422.8)	(279.5)	(986.5)	(1 387.1)	
	236.0	919.0	12 315.0	1 322.0	2 247.0	7 229.0	
	953.0	1 873.0	22 861.0	2 091.0	5 455.0	11 249.0	
Total livestock units	6.1	26.2	103.1	28.3	62.1	127.6	
	(1.3)	(2.3)	(15.5)	(1.2)	(4.9)	(3.2)	
	4.3	24.0	83.6	26.6	54.7	121.7	
	8.0	30.5	131.4	30.2	70.9	132.0	
Feed for grazing livestock	1 790.1	5 553.4	37 764.4	15 827.0	38 922.9	38 997.7	
	(983.2)	(1 465.7)	(4 478.5)	(6 334.5)	(10 814.5)	(9 644.1)	
	923.0	3 444.0	32 310.0	8 117.0	23 403.0	20 834.0	
	3 778.0	8 462.0	52 877.0	23 335.0	55 292.0	49 972.0	
Labour input	3 336.7	3 386.0	13 062.3	2 662.1	3 127.5	5 068.3	
	(655.3)	(144.0)	(2 094.4)	(204.6)	(87.3)	(121.1)	
	2 632.6	3 158.8	10 572.5	2 456.5	3 003.0	4 883.5	
	5 036.5	3 752.9	16 955.4	3 125.7	3 303.5	5 260.9	
Machinery and equipment	6 327.6	71 701.9	163 466.2	71 711.9	120 543.8	106 130.6	
	(2 257.2)	(13 991.4)	(41 908.3)	(8 070.0)	(41 455.6)	(18 144.0)	
	4 452.0	52 343.0	105 571.0	54 223.0	61 482.0	76 837.0	
	10 841.0	93 945.0	225 947.0	83 091.0	179 269.0	136 527.0	
Gross investment on fixed assets	765.6	20 859.2	44 207.7	27 257.6	38 039.9	39 018.2	
	(464.0)	(3 260.0)	(12 871.9)	(4 576.2)	(7 321.3)	(7 113.4)	
	31.0	14 387.0	18 968.0	17 357.0	24 273.0	24 509.0	
	1 827.0	26 879.0	65 394.0	35 643.0	48 553.0	47 632.0	

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Table S3 to be continued

Variable in total		Country					
Mean (SD)							
Min	ES	FR	IT	DK	BE	GE	
Max							
Total output	61 107.9	180 469.5	59 869.0	396 465.0	236 347.2	228 654.1	
	(18 054.9)	(25 859.2)	(10 780.7)	(98 358.4)	(42 587.5)	(41 966.6)	
	40 256.0	134 606.0	46 405.0	215 951.0	167 043.0	159 626.0	
	98 500.0	208 124.0	74 035.0	610 056.0	312 003.0	283 378.0	
Total utilised agriculture area	40.4	86.1	18.0	98.7	48.0	85.6	
	(5.0)	(2.8)	(2.6)	(13.3)	(4.1)	(6.0)	
	33.7	80.3	14.8	78.0	40.8	75.8	
	47.1	90.2	21.6	132.4	53.5	94.9	
Fertilizers	3 389.2	11 746.7	2 370.3	11 220.1	7 979.8	11 118.0	
	(942.6)	(2 159.4)	(663.7)	(3 239.3)	(1 346.3)	(2 353.7)	
	2 022.0	8 152.0	1 428.0	5 732.0	5 545.0	6 773.0	
	5 001.0	14 979.0	3 351.0	16 871.0	9 563.0	14 926.0	
Crop protection	2 199.7	9 362.3	1 829.1	8 500.7	7 160.8	8 524.2	
	(746.0)	(1 139.0)	(433.8)	(2 207.6)	(1 375.4)	(1 379.8)	
	1 238.0	7 392.0	1 263.0	5 077.0	4 967.0	5 888.0	
	3 519.0	11 107.0	2 375.0	13 182.0	8 883.0	10 639.0	
Total livestock units	26.4	72.6	15.3	150.6	124.7	87.3	
	(6.0)	(1.8)	(2.9)	(15.7)	(11.5)	(4.4)	
	19.2	69.2	10.8	124.7	105.8	78.9	
	38.8	75.4	19.9	198.1	139.8	92.1	
Feed for grazing livestock	6 445.1	13 095.0	5 670.4	43 228.1	22 304.5	21 920.2	
	(1 645.6)	(2 069.2)	(1 086.5)	(13 852.8)	(5 972.4)	(5 633.0)	
	3 869.0	9 048.0	3 969.0	14 106.0	12 514.0	12 695.0	
	9 184.0	15 632.0	7 348.0	67 283.0	31 534.0	32 175.0	
Labour input	2 981.7	3 263.9	2 897.4	3 359.6	4 927.6	4 875.3	
	(246.0)	(46.2)	(104.1)	(264.7)	(136.8)	(73.0)	
	2 655.1	3 194.5	2 716.7	3 067.4	4 654.6	4 767.0	
	3 496.3	3 337.5	3 021.1	4 182.0	5 148.9	4 991.4	
Machinery and equipment	13 657.6	73 691.2	22 090.2	179 631.6	69 834.7	103 179.4	
	(2 618.1)	(6 409.9)	(3 865.8)	(32 156.1)	(11 557.3)	(19 181.9)	
	9 456.0	63 040.0	16 871.0	108 889.0	47 684.0	73 766.0	
	18 160.0	85 558.0	26 905.0	234 993.0	88 532.0	130 692.0	
Gross investment on fixed assets	2 908.3	29 710.5	3 572.4	66 876.6	42 493.7	37 749.1	
	(857.8)	(4 061.2)	(2 120.5)	(18 522.9)	(9 093.4)	(8 419.6)	
	1 685.0	22 820.0	1 228.0	49 430.0	22 914.0	22 197.0	
	4 359.0	36 768.0	9 160.0	108 701.0	55 072.0	51 405.0	

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Table S3 to be continued

Variable in total		Country					
Mean (SD)		SK	LU	IE	NL	–	–
Min							
Max							
Total output		522 026.6	185 181.4	56 783.3	450 667.3		
		(91 194.8)	(35470.5)	(15 725.6)	(97 832.6)		
		362 440.0	12 231.0	34 418.0	281 549.0	–	–
		678 534.0	239 091.0	76 766.0	589 598.0		
Total utilised agriculture area		519.2	80.3	46.3	36.3		
		(64.1)	(5.4)	(2.6)	(3.0)		
		430.9	67.8	41.6	30.4	–	–
		615.3	87.8	50.1	40.6		
Fertilizers		36 241.7	8 714.7	5 179.8	6 651.4		
		(8 665.7)	(1 727.9)	(1 198.0)	(1 488.3)		
		22 521.0	6 013.0	3 306.0	3 962.0	–	–
		50 145.0	11 708.0	7 240.0	8 607.0		
Crop protection		32 856.2	4 725.4	823.4	8 185.7		
		(4 603.8)	(664.2)	(169.0)	(1 952.2)		
		26 333.0	3 201.0	566.0	5 043.0	–	–
		41 779.0	5 543.0	1 083.0	10 637.0		
Total livestock units		156.3	106.9	56.7	132.4		
		(29.6)	(12.5)	(6.3)	(14.8)		
		118.6	86.7	48.1	105.3	–	–
		214.1	128.6	65.8	148.3		
Feed for grazing livestock		76 369.7	29 207.4	14 312.4	33 737.6		
		(20 721.0)	(10 059.3)	(4 978.4)	(14 022.8)		
		35 333.0	14 220.0	6 253.0	12 709.0	–	–
		105 505.0	51 981.0	22 133.0	51 403.0		
Labour input		26 696.3	3 752.0	2 423.6	5 918.4		
		(7 613.4)	(210.2)	(70.6)	(314.4)		
		18 187.7	3 295.6	2 328.7	5 390.4	–	–
		209 294.0	4 043.7	2 556.9	6 439.7		
Machinery and equipment		153 735.4	190 485.0	28 389.2	148 845.5		
		(29 218.9)	(28 084.4)	(5 016.1)	(25 132.1)		
		103 617.0	142 278.0	17 003.0	97 524.0	–	–
		209 294.0	235 230.0	34 589.0	188 366.0		
Gross investment on fixed assets		86 528.4	73 872.6	8 678.0	72 289.9		
		(25 466.7)	(19 518.0)	(5 185.0)	(12 538.5)		
		39 844.0	51 837.0	3 105.0	51 303.0	–	–
		678 534.0	113 061.0	15 625.0	90 263.0		

*2007–2020; **2013–2020; EL – Greece; CY – Cyprus; SL – Slovenia; BG – Bulgaria; EE – Estonia; HR – Croatia; LV – Latvia; LT – Lithuania; HU – Hungary; MT – Malta; PL – Poland; PT – Portugal; RO – Romania; AT – Austria; CZ – Czechia; FI – Finland; SE – Sweden; UK – United Kingdom; IE – Ireland; ES – Spain; FR – France; IT – Italy; DK – Denmark; BE – Belgium; GE – Germany; NL – Netherlands; SK – Slovakia; LU – Luxembourg

Source: Own elaboration based on FADN database (FADN 2023b)

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Table S4. The structure of farms in the EU countries in selected years

Year	Structure of farm size	Number of countries	Countries
2020 (<i>N</i> = 28*)	from very small farms to very large	10	Estonia, Croatia, Latvia, Lithuania, Hungary, Matla, Poland, Portugal, Bulgaria, Romania
	from very small farms to large	3	Greece, Cyprus, Slovenia
	from small farms to very large	8	Czechia, Finland, Sweden, UK, Ireland, Spain, France, Italy
	from small farms to large	1	Austria
	from medium-small farms to very large	6	Belgium, Germany, Luxembourg, Netherlands, Slovakia, Denmark
	from medium-large farms to very large	0	–
2019 (<i>N</i> = 28)	from very small farms to very large	10	Estonia, Croatia, Latvia, Lithuania, Hungary, Matla, Poland, Portugal, Bulgaria, Romania
	from very small farms to large	3	Greece, Cyprus, Slovenia
	from small farms to very large	9	Czechia, Finland, Sweden, UK, Ireland, Spain, France, Italy, Denmark
	from small farms to large	1	Austria
	from medium-small farms to very large	3	Germany, Netherlands, Slovakia
	from medium-large farms to very large	2	Belgium, Luxembourg
2018 (<i>N</i> = 28)	from very small farms to very large	10	Estonia, Croatia, Latvia, Lithuania, Hungary, Matla, Poland, Portugal, Bulgaria, Romania
	from very small farms to large	3	Greece, Cyprus, Slovenia
	from small farms to very large	9	Czechia, Finland, Sweden, UK, Ireland, Spain, France, Italy, Denmark
	from small farms to large	1	Austria
	from medium-small farms to very large	3	Germany, Netherlands, Slovakia
	from medium-large farms to very large	2	Belgium, Luxembourg
2008 (<i>N</i> = 27**)	from very small farms to very large	10	Estonia, Latvia, Lithuania, Hungary, Bulgaria, Poland, Romania, UK, France, Italy
	from very small farms to large	5	Greece, Cyprus, Slovenia, Portugal, Ireland
	from small farms to very large	5	Czechia, Sweden, Denmark, Spain, Slovakia
	from small farms to large	3	Malta, Austria, Finland
	from medium-small farms to very large	3	Belgium, Germany, Netherlands
	from medium-large farms to very large	–	–
	from medium-small farms to very large	1	Luxembourg

*with UK; **without Croatia

Source: Own elaboration based on FADN database (FADN 2023b)

REFERENCES

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