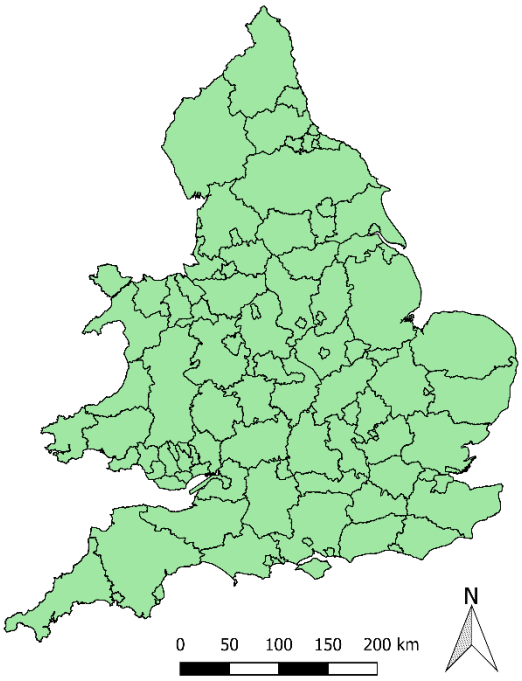
Stability of farm income: the role of agricultural diversity and agri-environment scheme payments - Supplementary material

1. County and Unitary Authority boundaries used in the analysis



Supplementary Figure 1 – County and Unitary Authority boundaries of England and Wales, used in the multilevel model analysis.

2. Population of farms included in the Farm Business Survey

The Farm Business Survey (FBS) is an annual survey conducted in England and Wales, collecting business information for approximately 2,500 farms each year (Department for Environment Food and Rural Affairs, 2020). The FBS population includes farms which meet a minimum size criteria: from 2005 to 2009 it includes full-time farms and part-time farms which occupy a farmer for half their time or more (>0.5 standard labour requirements) and from 2010 it includes farms with at least €25,000 of output (Department for Environment

Food and Rural Affairs, 2020). Small farms excluded from the survey only account for approximately 4% of agricultural production (Rural Business Research, 2020).

3. Overview of changes in common agricultural policy during study period, in England and Wales

Pillar 1 of the CAP provides direct payments to farmers, based on area farmed. Pillar 2 "Rural Development Regulation" (RDR) includes support for agri-environment schemes (AES) and the wider rural economy. Agri-environment schemes represent a significant proportion of pillar 2 Rural Development Regulation (RDR) in the UK (Reed et al., 2014). The key AES in England operating during the period of this study was Environmental Stewardship (Natural England, 2009), which either paid farmers a flat rate for straightforward environmental management across the entire farm landscape (Entry Level Stewardship) or followed a more demanding level (Higher level stewardship) requiring more complex and targeted environmental management in return for larger payments. In Wales, a similar tiered agri-environment scheme, namely Tir Cynnal (entry level scheme) and Tir Gofal (higher level), was in operation until 2012. In 2012 these schemes were merged into a single scheme called Glastir (National Assembly for Wales, 2011) which, similar to Environmental Stewardship, paid farmers a flat rate per hectare under the 'All Wales' element of the scheme. The upper level element of the scheme targets specific areas of environmental concern and pays farmers depending on the specific management taken.

Part of pillar 2 also provides additional dedicated support for farms in Less Favoured Areas (LFAs), for example those in mountainous or upland areas, to support these farms whilst preserving the environment and cultural landscape in Europe's rural areas (Bonn et al., 2008; DEFRA, 2006). From 2001, farmers in the English LFAs could receive area-based payments (under the Hill Farm Allowance) and optional payments for environmental

enhancement (DEFRA, 2006). The HFA scheme closed in 2010 and farmers were offered Upland Entry Level Stewardship agreements as part of the Environmental Stewardship scheme, with an elevated standard payment rate (Natural England, 2013). Until 2012, Farms in the Welsh LFAs could also receive area-based payments (under "Tir Mynydd" hill support scheme). In 2012, LFA farmers receiving Tir Mynydd were offered Glastir agreements with elevated standard payment rates for LFAs (National Assembly for Wales, 2011).

4. Correlation between the four measures of the stability of farm income

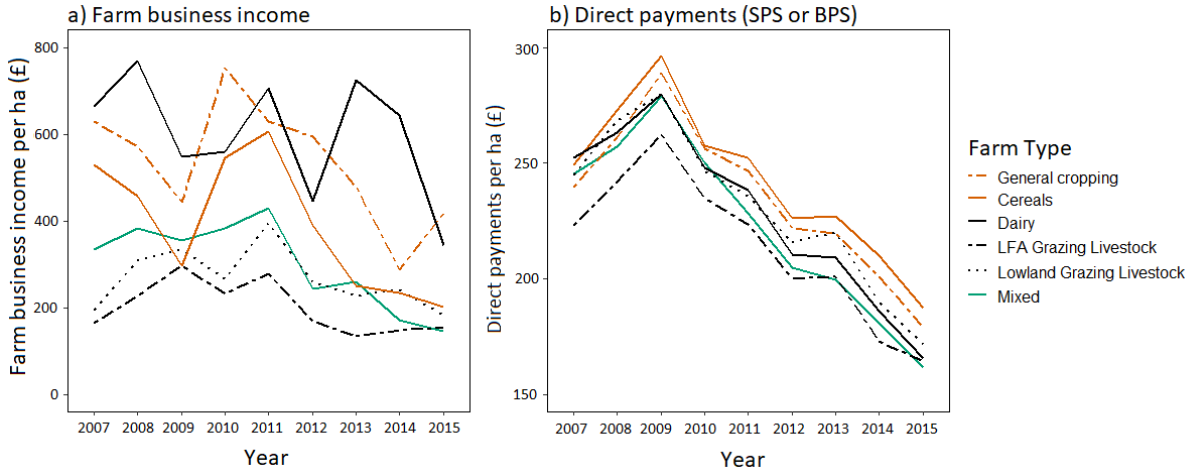
Commonalities in their calculation leads to the annual measures of stability, absolute and relative anomaly, being strongly positively correlated (Supplementary Table 1). Equally, medium-term stability measures, the standard deviation and relative standard deviation of farm income are also strongly positively correlated (r>0.7). Both absolute measures (absolute anomaly and standard deviation) and relative measures (relative anomaly and relative standard deviation) are moderately correlated with one another (Supplementary Table 1), therefore farms with larger variability in the annual terms are more likely to show larger variability over several years. Similar results are seen when calculating the Pearson's correlation coefficients for each farm type separately.

	Relative anomaly	**Standard deviation**	**Relative SD**
Absolute anomaly	0.830	0.689	0.480
Relative anomaly		0.509	0.655
Standard deviation			0.738

Supplementary Table 1 - Pearson's correlation coefficient (r) of dependent variables used in the analysis

5. Changes in Farm business income and direct payments over time

Between 2007 and 2015 farm business income (a net figure incorporating all income, government payments, as well as, all fixed and variable costs) in England and Wales was highly changeable for all farm types, with large variability in mean income over time (Supplementary Figure 1). Since 2011, mean farm income has shown a downward trend across most farm types (Supplementary Figure 1Supplementary Figure). Over the same period, direct payments (primarily Single Payment Scheme (SPS) and Basic Payment Scheme (BPS)) show a downward trend since 2009 across all farm types. Since direct payments are calculated in Euros, strengthening of the pound between 2009 and 2015 led to a reduction in the pound equivalent paid to farmers during this period. In addition, the value of single farm payments has not kept up with the rate of inflation, causing a reduction subsidies per ha in 'real' monetary terms.



Supplementary Figure 2 - Farm business income and direct payments (primarily Single Payment Scheme or Basic Payment Scheme) per ha (2007-2015). Figures use data from the Farm Business Survey; values deflated using UK Consumer Price Index (2015=100; ONS, 2020)

6. Correlation between input and output intensity and farm business income (FBI) per hectare

There is a strong positive correlation (r>0.7) between the intensity of inputs (Cost of fertiliser, crop protection and concentrated animal feed divided by the area farmed in hectares) and output intensity (economic value of agricultural products produced per hectare). However, there is only a weak positive correlation (r<0.3) between input intensity and farm business income per hectare. Similar results are seen when calculating the Pearson's correlation coefficients for each farm type separately.

	Input intensity	**Output intensity**
FBI per ha	0.298	0.535
Input intensity		0.856

Supplementary Table 2 - Pearson's correlation coefficient (r) of farm business income (FBI) and intensity variables used in the analysis

7. Multilevel model, all farm types combined

Using the same methods outlined in the main text, we ran multilevel models for the effect of farming practices and government payments on the stability of farm income with all farm types included in each model. Model were run using the two relative measures of income stability to account for the variation in mean income for each farm type. An interaction was included between each farm type and the independent variables to examine if the effect of farming practices and government payments differ between farm types.

The models indicate the effects of independent variables show relationships which are consistent with the farm type models included in the paper; for most farm types size and agri-environment payments decrease the variability of income, while increasing input intensity, specialisation of farming activities, direct payments and greater reliance on income from on-farm diversification increases the variability of income. The effects observed for each farm type are, in many cases, significantly different from the effects seen in dairy farms (used as the reference level). As seen in the paper, the effect of agri-environment payments for LFA

grazing farms is significantly different from dairy farms and increases the variability of income. This same effect is found for lowland grazing farms in the model results below.

	All farms		
Random effects			
County SD	0.029		
Farm SD	0.298		
Level-1 residual	1.117		
Fixed effects			Standard error
Intercept	-1.895	***	(0.079)
LFA Grazing Livestock	0.067		(0.100)
Cereals	0.607	***	(0.113)
Mixed	0.138		(0.140)
General cropping	0.680	***	(0.140)
Lowland Grazing Livestock	0.568	***	(0.116)
Area farmed	-0.121	***	(0.027)
Input intensity	0.184	***	(0.029)
Specialisation (agricultural)	0.118	***	(0.027)
On-farm diversification	0.041		(0.025)
Direct payments per ha	0.227	***	(0.067)
Year	0.049	***	(0.011)
Agri-environment payments per ha	-0.050	*	(0.026)
Direct payments per ha × year	-0.033	***	(0.010)
Area farmed × LFA Grazing Livestock	-0.118	***	(0.037)
Area farmed × Cereals	0.064	*	(0.038)
Area farmed × Mixed	-0.005		(0.048)
Area farmed × General cropping	0.125	**	(0.050)
Area farmed × Lowland Grazing Livestock	-0.071	*	(0.042)
Input intensity × LFA Grazing Livestock	0.027		(0.038)
Input intensity × Cereals	-0.128	***	(0.040)
Input intensity × Mixed	0.079		(0.050)
Input intensity × General cropping	0.000		(0.049)
Input intensity × Lowland Grazing Livestock	0.019		(0.044)
Specialisation × LFA Grazing Livestock	-0.094	***	(0.035)
Specialisation × Cereals	-0.090	**	(0.038)
Specialisation × Mixed	-0.048		(0.049)
Specialisation × General cropping	0.085	*	(0.049)
Specialisation × Lowland Grazing Livestock	-0.109	***	(0.042)
On-farm diversification × LFA Grazing Livestock	0.041		(0.033)
On-farm diversification × Cereals	0.000		(0.038)
On-farm diversification × Mixed	0.008		(0.046)
On-farm diversification × General cropping	0.008		(0.047)
On-farm diversification × Lowland Grazing Livestock	0.039		(0.040)
Direct payments per ha × LFA Grazing Livestock	0.065		(0.088)

Direct payments per ha × Cereals	-0.115		(0.096)
Direct payments per ha × Mixed	-0.215		(0.134)
Direct payments per ha × General cropping	-0.373	***	(0.130)
Direct payments per ha × Lowland Grazing Livestock	-0.081		(0.099)
Year × LFA Grazing Livestock	0.008		(0.013)
Year × Cereals	-0.054	***	(0.015)
Year × Mixed	0.004		(0.019)
Year × General cropping	-0.072	***	(0.019)
Year × Lowland Grazing Livestock	-0.046	***	(0.016)
Agri-environment payments per ha × LFA Grazing Livestock	0.110	***	(0.034)
Agri-environment payments per ha × Cereals	0.023		(0.039)
Agri-environment payments per ha × Mixed	-0.019		(0.046)
Agri-environment payments per ha × General cropping	-0.029		(0.048)
Agri-environment payments per ha × Lowland Grazing Livestock	0.077	*	(0.041)
Direct payments per ha × year × LFA Grazing Livestock	0.010		(0.013)
Direct payments per ha × year × Cereals	0.030	**	(0.014)
Direct payments per ha × year × Mixed	0.034	*	(0.019)
Direct payments per ha × year × General cropping	0.048	**	(0.019)
Direct payments per ha × year × Lowland Grazing Livestock	0.011	***	(0.016)
Observations (n)	12,628		
County (n)	78		
Farm (n)	2,333		
AIC	39,727		
BIC	40,151		
logLik	-19,807		
R^2	0.091		

Supplementary Table 3 - Multilevel model results for the effect of farming practices and government payments on the stability of farm income, including all farm types, using (log) relative anomaly of farm business income per hectare as dependent variable. Significant at: *10, **5 and ***1 percent levels.

	All farms		
Random effects			
County SD	0.074		
Farm SD	0.000		
Level-1 residual	0.525		
Fixed effects			Standard error
Intercept	-1.140	***	(0.046)
LFA Grazing Livestock	0.192	***	(0.056)

Cereals	0.233	***	(0.061)
Mixed	0.129	*	(0.070)
General cropping	0.256	***	(0.072)
Lowland Grazing Livestock	0.543	***	(0.063)
Area farmed	-0.118	***	(0.017)
Input intensity	0.205	***	(0.020)
Specialisation (agricultural)	0.091	***	(0.017)
On-farm diversification	0.048	***	(0.016)
Direct payments per ha	0.181	***	(0.035)
Year	0.037	***	(0.006)
Agri-environment payments per ha	-0.047	***	(0.017)
Direct payments per ha × year	-0.024	***	(0.005)
Area farmed × LFA Grazing Livestock	-0.087	***	(0.025)
Area farmed × Cereals	0.079	***	(0.023)
Area farmed × Mixed	0.025		(0.026)
Area farmed × General cropping	0.089	***	(0.031)
Area farmed × Lowland Grazing Livestock	-0.044	*	(0.026)
Input intensity × LFA Grazing Livestock	-0.007		(0.024)
Input intensity × Cereals	-0.145	***	(0.024)
Input intensity × Mixed	0.072	**	(0.032)
Input intensity × General cropping	-0.081	***	(0.029)
Input intensity × Lowland Grazing Livestock	-0.028		(0.027)
Specialisation × LFA Grazing Livestock	-0.077	***	(0.022)
Specialisation × Cereals	-0.045	*	(0.023)
Specialisation × Mixed	-0.106	***	(0.027)
Specialisation × General cropping	0.102	***	(0.030)
Specialisation × Lowland Grazing Livestock	-0.097	***	(0.025)
On-farm diversification × LFA Grazing Livestock	0.011		(0.021)
On-farm diversification × Cereals	0.045	**	(0.023)
On-farm diversification × Mixed	-0.046	*	(0.025)
On-farm diversification × General cropping	-0.012		(0.024)
On-farm diversification × Lowland Grazing Livestock	0.030		(0.023)
Direct payments per ha × LFA Grazing Livestock	0.021		(0.048)
Direct payments per ha × Cereals	-0.090	*	(0.048)
Direct payments per ha × Mixed	-0.172	***	(0.058)
Direct payments per ha × General cropping	-0.141	**	(0.062)
Direct payments per ha × Lowland Grazing Livestock	-0.116	**	(0.049)
Year × LFA Grazing Livestock	0.004		(0.007)
Year × Cereals	0.000		(0.008)
Year × Mixed	0.020	**	(0.009)
Year × General cropping	-0.043	***	(0.009)
Year × Lowland Grazing Livestock	-0.028	***	(0.008)
Agri-environment payments per ha × LFA Grazing Livestock	0.105	***	(0.023)
Agri-environment payments per ha × Cereals	0.020		(0.025)
Agri-environment payments per ha × Mixed	-0.001		(0.024)

Agri-environment payments per ha × General cropping	-0.031		(0.027)
Agri-environment payments per ha × Lowland Grazing Livestock	0.055	**	(0.026)
Direct payments per ha × year × LFA Grazing Livestock	0.017	**	(0.007)
Direct payments per ha × year × Cereals	0.018	***	(0.007)
Direct payments per ha × year × Mixed	0.034	***	(0.008)
Direct payments per ha × year × General cropping	0.015	*	(0.009)
Direct payments per ha × year × Lowland Grazing Livestock	0.022	***	(0.008)
Observations (n)	12,628		
County (n)	78		
Farm (n)	2,333		
AIC	10,838		
BIC	11,269		
logLik	-5,361		
R^2	0.309		

Supplementary Table 4 - Multilevel model results for the effect of farming practices and government payments on the stability of farm income, including all farm types, using (log) relative standard deviation of farm business income per hectare as dependent variable. Significant at: *10, **5 and ***1 percent levels.

8. Sensitivity analysis of multilevel model

A small proportion of farms (n=283) change farm type across the time series, and therefore appeared in more than one model, albeit in different years. To consider how this may have affected the results we repeated the model analysis using farms classified as only one farm type across the data series (n=2049). The results of these models showed very little change to the models presented in this paper; the direction and relationships of the independent variables remained consistent and there was little change in the significance of variables in the models. Therefore, we can conclude a small subset of farms changing farm type across the time series does not impact the conclusions drawn from the study.

We also examined the model results using alternative measures of intensity and on-farm diversification. We ran the models using output intensity (economic value of agricultural products produced per hectare (£)) as a measure of agricultural intensity. Output

intensity was strongly positively correlated with input intensity (r>0.7; Supplementary Table 2). The effect of output intensity on the stability of income revealed the same relationship as input intensity, increasing the variability of farm income across all models, with little change in the magnitude or significance of coefficients. We also examined the effect of on-farm diversification using different independent variables, including the total value of revenue from diversified activities per hectare (£) and a dummy variable capturing farms which do not engage in on-farm diversification (1) versus those who do (0), which was included in the model alongside the ratio of revenue from on-farm diversification. All variables showed similar relationships; farms who engage in on-farm diversification or increase revenue from diversified activities have more variable income.

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