

**Supplementary Material** for “Linking Entrepreneurship to Productivity: Developing a Composite Indicator for Farm-Level Innovation in UK Agriculture with Secondary Data”

**Supplementary Material**

**Section S1. Non-parametric Data Envelopment Analysis (DEA)**

**Section S1.1. The set of inputs and outputs in a production system**

A farm is considered a Decision-Making Unit (DMU) that decides over the selection of the production plan (i.e., the set of inputs to produce a set of outputs). Consequently, the farm serves as the system that transforms inputs into outputs.

To formalise the above, let us assume that we observe a set of  $n$  farms and each farm  $i = \{1, \dots, n\}$  has a set of  $j$  inputs and  $s$  outputs representing multiple performance measures. For the  $i^{th}$  farm then the  $j - vector$  of inputs and the  $s - vector$  of outputs are defined as  $x^i = (x_1^i, \dots, x_j^i) \in \mathbb{R}_+^j$  and  $y^i = (y_1^i, \dots, y_s^i) \in \mathbb{R}_+^s$ , respectively<sup>1</sup>. The production plan for the  $i^{th}$  farm is thus defined as a pair of input and output vectors:

$$(x^i, y^i) \in \mathbb{R}_+^j \times \mathbb{R}_+^s$$

Note that  $\mathbb{R}_+ = \{\alpha \in \mathbb{R} | \alpha \geq 0\}$  and it is therefore presumed that both inputs and outputs for the  $i^{th}$  farm are non-negative numbers, i.e., they are positive or zero.

For a set of  $n$  farms the input data matrix  $X$  and the output data matrix  $Y$  can be arranged as follows:

$$X = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_j^1 \\ x_1^2 & x_2^2 & \cdots & x_j^2 \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ x_1^n & x_2^n & \cdots & x_j^n \end{bmatrix}$$

$$Y = \begin{bmatrix} y_1^1 & y_2^1 & \cdots & y_s^1 \\ y_1^2 & y_2^2 & \cdots & y_s^2 \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ y_1^n & y_2^n & \cdots & y_s^n \end{bmatrix}$$

In benchmarking theory, the basic assumption is that a set of DMUs have a common and homogenous underlying technology defined by the technology or production possibility set  $P$ ,

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<sup>1</sup> Superscripts are used to denote the different farms and subscripts to denote the different types of inputs and outputs. Note that in the absence of subscripts we consider all inputs and outputs in a vector format.

$$P = \{(x, y) \in \mathbb{R}_+^j \times \mathbb{R}_+^s \mid x \text{ can produce } y\}$$

The production possibility set (PPS) is denoted by the social, technical, mechanical, chemical, and biological environment in which the production process takes place. Conceptually, the PPS is defined as the minimum technology that satisfies the assumptions of feasibility of the observed input and output combinations, that the PPS is convex, the free disposability of inputs and outputs and that if  $(x, y)$  is feasible, then for any  $\beta \geq 0$ ,  $(\beta x, \beta y)$  is also feasible without specifying any functional form.

### Section S1.2. Estimating the Malmquist Index (MI) of Total Factor Productivity (TFP)

According to Färe, Grosskopf, Norris, et al. [21], the distance functions required for the calculation of the MI of TFP, i.e.,

$$D_i^t(x^t, y^t), D_i^{t+1}(x^{t+1}, y^{t+1}), D_i^t(x^{t+1}, y^{t+1}) \text{ and } D_i^{t+1}(x^t, y^t)$$

are computed with the use of DEA techniques. Specifically, four different linear programs must be solved. Suppose that for each period  $t = 1, 2, \dots, T$  there is  $i = \{1, \dots, n\}$  set of farms which use a set of inputs and outputs representing multiple performance measures. Considering then that each farm  $i$  uses  $J$  ( $j = 1, \dots, J$ ) inputs,  $x_j$  to produce  $s$  outputs  $y_r$  ( $r = 1, \dots, s$ ).

The first Shephard input distance function  $D_i^t(x^t, y^t)$  is estimated as follows:

$$\begin{aligned} [D_i^t(x^t, y^t)]^{-1} &= F_i^t(x_{ij}^t, y_{is}^t) = \min_{\kappa, \lambda^1, \dots, \lambda^i} \kappa \\ \text{st. } \kappa x_{ij}^t &\geq \sum_{i=1}^n \lambda_i x_{ij}^t \\ y_{is}^t &\leq \sum_{i=1}^n \lambda_i y_{is}^t \\ \lambda &\in \Lambda^i(\text{crs}) \end{aligned}$$

Where  $j$  and  $s$  are the  $j - \text{vector}$  of inputs and the  $s - \text{vector}$  of outputs defined as above as  $x^i = (x_1^i, \dots, x_J^i) \in \mathbb{R}_+^J$  and  $y^i = (y_1^i, \dots, y_s^i) \in \mathbb{R}_+^s$ , respectively. Further, note that the notation has changed and that farms and input or outputs are indicated as subscripts. The value of  $\kappa$  is the technical efficiency for the  $i - \text{th}$  farm. Also note that  $D$  stands for the Shephard distance function and  $F$  for the Farrell distance function. The second input distance function  $D_i^{t+1}(x^{t+1}, y^{t+1})$  is estimated as follows:

$$\begin{aligned} [D_i^{t+1}(x^{t+1}, y^{t+1})]^{-1} &= F_i^{t+1}(x_{ij}^{t+1}, y_{is}^{t+1}) = \min_{\kappa, \lambda^1, \dots, \lambda^i} \kappa \\ \text{st. } \kappa x_{ij}^{t+1} &\geq \sum_{i=1}^n \lambda_i x_{ij}^{t+1} \end{aligned}$$

$$y_{is}^{t+1} \leq \sum_{i=1}^n \lambda_i y_{is}^{t+1}$$

$$\lambda \in \Lambda^i(crs)$$

The third input distance function required for the MI of TFP  $D_I^t(x^{t+1}, y^{t+1})$  considers data from the period  $t + 1$  relative to technology based on data from period  $t$ . Specifically,

$$[D_I^t(x^{t+1}, y^{t+1})]^{-1} = F_I^t(x_{ij}^{t+1}, y_{is}^{t+1}) = \min_{\kappa, \lambda^1, \dots, \lambda^i} \kappa$$

$$st. \kappa x_{ij}^{t+1} \geq \sum_{i=1}^n \lambda_i x_{ij}^t$$

$$y_{is}^{t+1} \leq \sum_{i=1}^n \lambda_i y_{is}^t$$

$$\lambda \in \Lambda^i(crs)$$

Finally, the third input distance function required for the MI of TFP  $D_I^{t+1}(x^t, y^t)$  considers data from period  $t$  relative to technology based on data from period  $t + 1$ . Specifically,

$$[D_I^{t+1}(x^t, y^t)]^{-1} = F_I^{t+1}(x_{ij}^t, y_{is}^t) = \min_{\kappa, \lambda^1, \dots, \lambda^n} \kappa$$

$$st. \kappa x_{ij}^t \geq \sum_{i=1}^n \lambda_i x_{ij}^{t+1}$$

$$y_{is}^t \leq \sum_{i=1}^n \lambda_i y_{is}^{t+1}$$

$$\lambda \in \Lambda^i(crs)$$

Note that each distance function must be calculated for each farm in each period.

### Section S1.3. Statistical inference for MI of TFP and their components

Despite the significant advantages of DEA for the calculation of the MI of TFP, we need to consider the fact that the estimates of productivity may be affected by sampling variation. In other words, it is possible to underestimate the distance functions to the frontier if the best performing farms in the population are excluded from the sample since DEA is a Benchmarking technique and it only considers the farms in the sample [8, 72]. To overcome this shortcoming, Simar & Wilson [74] and Simar & Wilson [75] proposed a bootstrapping method for the construction of confidence intervals for the DEA efficiency estimates relying on smoothing the empirical distribution. The rationale behind bootstrapping is to simulate the true sampling distribution by mimicking the data generation process (DGP) [8]. Through the DGP, a pseudo-data set is constructed which is then used for the re-estimation of the DEA distance functions. Increasing the bootstrapped replicates (more than 2000. See [71]) allows for a good approximation of the true distribution of the sample.

Simar and Wilson [72] adapted the bootstrapped procedure for the estimation of the MI of TFP in order to account for possible temporal correlation arising from the panel data characteristics [8]. Specifically, they proposed a consistent method using a bivariate kernel density estimate that accounts for the temporal correlation via the covariance matrix of data from adjustment years. The bootstrapped estimates of the distance functions allow the calculation of a set of MI of TFP which accounts for the bias and enables the estimation of confidence intervals. The latter are used for statistical inference of the MI of the TFP and its components.

MI values exceeding unity indicate an enhancement, while values below unity suggest a decline in productivity. Additionally, the significance of these changes is reported for each individual farm, with confidence intervals (CIs) calculated for 5% and 1% levels of significance (for a comprehensive discussion on statistical inference for MI of TFP and their components, refer to Supplementary Material,

section, section A.2). The majority of MI estimates show statistically significant differences from unity at the 99% or 95% confidence level. A farm is deemed to have made significant progress between the two time periods if the lower bound of its confidence interval surpasses unity. Conversely, a farm is considered to have significantly regressed during the period if its upper bound is below unity. If unity falls within its confidence interval, there is no statistically significant change.

## Supplementary tables

**Table S1. Statistical inference of the MI of TFP over the 11 periods for cereal farms**

FARM ID	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014
1	1.203***	0.814***	0.607***	0.832***	1.195***	0.898***	0.818***	1.257***	1.163***	0.896***	0.750***
2	0.715***	0.840***	0.992	1.040	0.990	0.766***	1.208***	0.973	0.948	0.955	1.484***
3	1.214***	0.879***	0.830***	0.794***	1.089**	1.014	0.885***	1.064	1.270***	0.988	1.164
4	0.928**	1.056**	0.856***	0.742***	0.811***	1.343***	0.729***	0.927***	1.254***	1.371***	0.926***
5	1.243***	0.954**	0.869***	0.807***	0.878***	1.284***	0.777***	0.974	1.297***	0.681***	1.755***
6	1.448***	0.833***	0.979	0.674***	1.018	1.026	0.686***	1.013	1.115***	0.849***	1.190***
7	0.843***	0.879***	1.011	0.884***	0.816***	0.999	0.796***	0.847***	2.331***	0.717***	0.804***
8	1.101***	0.924***	0.819***	0.611***	1.230***	1.657***	0.578***	0.792***	1.501***	1.091***	0.959
9	1.186***	0.630***	1.345***	0.909***	0.858***	1.292***	0.657***	1.135***	1.483***	0.660***	0.912***
10	1.148***	0.551***	1.113***	1.298***	0.773***	0.857***	1.006	0.777***	1.581***	1.392***	0.886***
11	1.460***	0.769***	1.090**	0.775***	0.816***	1.554***	0.737***	0.886***	1.180***	0.987	1.256***
12	1.145***	0.848***	0.893***	0.670***	0.871***	1.805***	0.688***	0.886***	1.346***	1.300***	1.169***
13	0.774***	0.728***	0.761***	0.876***	1.390***	1.132***	1.064	0.703***	1.109**	1.139***	0.545***
14	1.416***	1.069	0.788***	0.903**	0.685***	2.072***	0.906***	1.079***	0.814***	0.849***	1.231***
15	1.091***	0.928***	0.927***	0.622***	1.344***	1.178***	0.638***	0.862***	1.330***	1.161***	0.871**
16	1.196***	1.066***	0.909***	0.792***	0.882***	0.962	0.738***	0.819***	1.329***	1.193***	0.974
17	1.427***	0.949***	0.781***	0.647***	0.880***	1.283***	0.726***	0.902***	1.141***	1.017	1.203***
18	1.163***	0.912**	0.730***	0.799***	0.888***	1.303***	0.909***	0.911	1.082**	1.209***	1.128
19	1.267***	0.990	0.820***	0.724***	1.234***	1.059	0.889***	0.740***	1.209***	1.589***	1.098***
20	1.094***	0.818***	0.966***	0.870***	0.795***	1.111***	0.976	0.808***	1.324***	0.750***	1.307***
21	1.177***	0.586***	1.130	0.992	0.571***	1.846***	0.552***	0.650***	2.371***	1.187	1.199

FARM ID	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014
22	1.228***	0.817***	0.898***	0.729***	0.768***	1.738***	0.621***	0.929***	1.425***	0.981	1.094***
23	1.000	0.310***	1.891***	0.539***	1.332***	1.698***	0.771***	0.722***	1.029	1.788***	0.768***
24	1.329***	0.978	0.885***	0.775***	0.672***	1.758***	0.616***	1.020	1.565***	1.047	1.037
25	1.289***	0.824***	0.926	0.810***	0.470***	1.919***	0.902**	0.808***	1.722***	0.813***	0.974
26	1.208***	1.018**	0.601***	0.938**	1.463***	0.837***	0.920	1.573***	1.981***	0.538***	0.827***
27	1.179***	0.950***	1.013	0.629***	0.959	1.590***	0.625***	0.919***	1.312***	1.174***	1.099***
28	0.921	0.988	0.829***	0.698***	1.221***	1.477***	0.661***	1.069***	0.970	0.909	1.775***
29	0.945	1.063	0.750***	1.433***	0.875	1.721***	0.892***	0.910***	0.858***	1.086***	1.141***
30	0.730***	0.953	0.836***	0.875***	0.884***	1.276***	0.810***	0.690***	2.096***	0.847***	1.195***
31	1.201**	0.614***	0.714***	1.142***	1.728***	0.543***	1.107	0.886**	1.099***	1.110***	2.036***
32	1.162	0.797***	0.839***	0.785***	1.430***	0.836**	1.182***	0.774***	1.602***	0.942**	1.147***
33	1.184***	0.536***	1.548***	0.371***	1.556***	1.087***	0.409***	1.154***	1.606***	0.912	1.185***
34	1.519***	1.278***	0.781***	0.573***	0.672***	1.904***	0.815***	0.885***	0.778	1.220***	1.186***
35	1.072***	0.965	1.095***	0.779***	0.473***	1.991***	0.847***	1.092***	0.781	1.154***	0.919***
36	0.993	0.943***	0.776***	0.818***	0.721***	1.431***	0.713***	1.309***	1.045	1.261***	1.095***
37	0.815***	1.533***	0.640***	1.110	0.884***	1.228***	0.659***	0.723***	1.564***	0.791***	1.174***
38	1.128	0.845***	0.953**	0.743***	1.317***	1.105	0.375***	1.504***	1.625***	0.812***	0.971
39	1.252***	0.848***	0.981	0.863***	0.603***	1.512***	0.756***	0.805***	1.031	1.206	1.147***
40	1.608**	0.816***	0.577***	1.686***	0.576***	1.304***	1.053***	0.647***	1.225***	1.195***	0.731***
41	1.139***	0.747***	1.005	0.871***	0.647***	1.961***	1.171***	0.900**	1.079***	1.174***	1.037
42	1.114***	0.677***	0.813***	1.059	1.059	1.410***	0.479***	1.445***	0.935	0.870***	1.245***
43	0.840	1.011	0.829***	0.775***	1.553***	0.788***	0.957	1.041	1.182***	1.031	0.950
44	0.871	1.044	0.952**	0.747***	1.166***	1.106***	0.689***	1.155***	0.793***	0.952***	1.105***

FARM ID	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014
45	1.363***	0.798***	0.787***	0.624***	1.200***	1.213***	0.790***	0.862***	1.317***	1.330***	0.958***
46	1.197**	0.907***	0.897***	0.663***	1.155***	0.871***	1.157**	0.770***	1.287***	0.615***	1.731***
47	1.320***	0.856***	0.744***	0.954**	0.768***	1.324***	0.813***	0.816***	1.341***	1.224***	0.793***
48	0.920	0.817***	1.240***	1.314***	0.886***	1.009	0.823***	0.762***	1.102	1.519***	0.898***
49	1.294***	0.875***	0.966**	0.773***	0.869***	1.181***	0.875***	0.833***	1.220***	1.187***	0.958
50	1.110	1.048***	0.810***	0.700***	1.026	1.003	0.952	0.672***	1.426***	1.091***	1.132***
51	0.984	0.626***	1.013	1.070	0.910***	1.395***	0.725***	0.835***	1.362***	1.179***	0.844***
52	0.925***	0.987**	0.879***	0.549***	1.262***	0.915**	0.615***	1.747***	0.851***	0.932**	1.460***
53	0.770***	0.801***	1.250**	1.444***	0.846**	1.173***	0.862***	0.673***	1.261***	1.201***	0.927***
54	0.970	0.668***	0.730***	0.924***	1.228***	1.512***	0.481***	1.044	1.261***	1.545***	0.849***
55	1.082	0.782***	0.822***	0.810***	0.854***	1.335***	0.780***	0.914***	0.918***	1.402***	1.308***
56	1.084***	0.894**	0.738***	0.741***	0.919***	1.045	1.801***	0.587***	2.031***	0.643***	1.275***
57	0.736***	1.035	0.899***	0.695***	0.885	1.022	1.319***	0.612***	1.688**	0.929***	0.895***
58	0.849	1.072***	0.907***	0.728***	0.826***	1.708***	0.541**	0.932***	1.753***	0.673***	1.521***
59	1.198***	0.945***	0.925***	0.900***	0.825***	1.295***	0.725***	0.986	1.188**	0.987	1.080**
60	1.098***	0.846***	1.059**	0.766***	0.875***	1.095***	1.087***	0.735***	1.308***	0.974	1.150***

\*\* Significantly different from unity at 0.05 level

\*\*\* Significantly different from unity at 0.01 level

**Table S2. Detailed presentation of the pure efficiency change factor for each individual farm in the sample over the 11-year period**

FARM ID	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.65***	1.07	1.03	1.24***	0.76***	0.92	1.09	1.08	0.85***	1.17	1.27***
3	0.81***	0.97	1.05	1.00	0.87***	0.97	1.00	0.95	1.28***	1.00	0.94
4	0.81***	1.09**	1.08**	0.94	0.72***	1.27***	0.77***	1.11	0.95	1.34***	1.00
5	1.056	1.07	1.03	0.88**	0.74***	1.57***	0.88**	0.95	0.86***	0.96	1.44***
6	1.22***	1.08	1.11	0.85***	0.97	0.91	0.99	1.06	0.91	0.80***	1.18***
7	0.64***	1.55***	0.94	1.07	0.94	0.84***	1.05	0.90**	1.21***	0.94	0.88
8	1.13	1.03	0.93	0.92	1.27***	0.92	1.18**	0.77***	1.20***	0.88**	1.17**
9	1.00	1.00	1.32***	1.00	0.91	1.01	0.83***	1.16***	1.10**	0.87**	0.90
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.19***	0.85***	1.44***	0.90	0.82***	1.25***	0.98	0.94	0.99	0.86***	1.25***
12	0.91	1.29***	0.88	0.88	1.04	1.14**	0.93	1.00	0.97	1.21***	1.00
13	0.82**	1.00	1.00	1.00	1.09	0.92	1.16	0.86	1.00	1.00	1.00
14	1.00	1.03	0.97	1.00	1.00	1.00	1.02	1.05	0.93	1.00	1.00
15	0.84***	1.01	1.16***	0.84***	1.19***	1.25***	0.83***	0.84***	1.06	1.10**	0.66***
16	1.04	1.13**	0.95	1.13	0.98	0.77***	1.00	1.00	1.00	1.00	1.00
17	1.15***	0.96	1.06	0.79***	1.03	1.06	1.08	0.83**	0.92	1.00	1.17***
18	1.00	1.00	1.00	1.00	1.00	1.00	1.08	0.93	1.00	1.00	1.18
19	1.00	1.12**	0.96	0.93	1.05	0.95	1.20**	0.84**	1.00	1.08	1.15**
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	0.93	0.86***	1.23***	0.88**	0.85**	1.17**	0.85	1.00	1.11	0.90	1.17
23	0.87***	0.92	1.28**	0.78**	1.10	1.39***	1.05	0.76***	0.83***	1.62***	0.66
24	1.41***	1.02	1.12	0.88	0.79***	1.26***	0.89	1.17***	1.16***	0.99	0.99
25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.30***	0.77***	1.00
27	1.09	1.09	1.08	0.87***	0.99	1.08**	0.90	0.97	1.08	1.06	1.08
28	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
29	1.00	1.01	0.99	1.00	1.43***	1.08	0.95	0.97	0.98	1.16**	0.94
30	0.78***	1.05	0.96	1.14	1.05	0.84	1.00	1.00	1.20	0.83	1.09
31	1.05	0.95	1.00	1.01	1.23***	0.80***	1.00	1.00	1.00	1.09	1.22**
32	1.22	0.82	1.00	1.00	1.00	1.00	1.27***	0.79**	1.10	1.13	1.18**

FARM ID	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014
33	0.76***	0.93	1.26***	0.79***	1.20	0.95	0.88	1.00	1.02	0.98	1.00
34	1.00	1.39**	0.72***	1.00	1.04	0.96	1.12	0.89	1.00	1.00	1.00
35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.02
37	1.00	1.26***	0.79***	1.33***	0.88***	1.08	0.95	0.84**	1.11	0.90	1.21**
38	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
39	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
40	1.00	1.05	0.96	1.32***	0.83***	0.98	1.12	0.83***	1.09	1.21***	0.76***
41	1.16	0.86	1.01	1.27**	0.78**	1.00	1.11	1.27	0.87	1.03	1.04
42	0.93	0.97	0.92	1.12	1.03	1.20***	0.72***	1.42***	0.70***	1.00	1.25
43	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
44	0.83***	1.11**	1.17**	0.90	0.94	1.28***	0.89**	1.05	0.75***	0.97	1.26**
45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
46	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
47	1.11**	0.97	0.99	1.16**	0.80***	1.19***	1.01	0.90**	1.18***	1.37***	0.68***
48	0.93	1.00	1.08	1.10	0.99	0.88	1.23***	0.78***	1.12	1.13	0.80***
49	1.01	1.08	1.11	0.95	0.88**	1.00	1.19	0.85***	0.99	1.12	1.04
50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
52	0.84***	1.08	0.97	0.93	0.89**	1.00	0.94	1.07	0.93	1.13	1.08
53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
54	0.77***	0.98	0.89	1.09	1.22***	1.39***	0.65***	1.08	0.92	1.10	0.95
55	1.00	1.00	1.00	1.00	1.02	0.98	1.04	0.96	1.00	1.00	1.00
56	1.05	1.16***	0.93	0.86***	0.82***	1.00	1.93***	0.72***	1.47***	0.66***	1.28***
57	0.61***	1.00	1.00	1.00	1.00	1.00	1.71***	0.70***	1.18***	0.99	0.96
58	0.65***	1.49***	1.14***	0.82***	0.75***	1.61***	0.59***	1.08	1.34***	0.86	1.23***
59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
60	0.87***	0.91**	1.19***	1.02	0.81***	1.00	1.00	1.00	1.04	1.16***	1.03

\*\* Significantly different from unity at 0.05 level

\*\*\* Significantly different from unity at 0.01 level

**Table S3. Detailed presentation of the scale efficiency change factor for each individual farm in the sample over the 11-year period**

FARM_ID	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014
1	0.97	0.99	0.78***	1.06	1.31**	0.72***	1.00	1.26***	1.08	0.79	0.93
2	0.96	0.99	1.04	1.04	0.99	1.01	1.25	0.86	0.86***	1.01	1.23**
3	1.23***	0.93	0.96	1.01	0.99	1.17	0.79**	1.34***	0.71***	1.06	1.24**
4	0.99	1.07**	0.94***	1.00	1.01	0.99	1.15**	0.88**	1.00	1.08**	1.09
5	1.12**	1.06	1.01	1.12	0.80***	0.99	1.12	0.90	1.13	0.89	1.42***
6	1.02	1.03	0.95	1.00	1.01	1.03	0.96**	1.05**	0.96**	1.15***	1.26
7	1.35***	0.78	1.16***	0.99	0.94	0.86***	1.00	1.05**	1.65***	0.62***	0.95
8	0.82	1.13**	0.98	0.84**	0.90	1.58***	0.63***	1.07	1.14**	1.06	1.09
9	1.00	1.00	1.00	1.13**	0.89**	1.17**	0.85***	1.18***	1.04	0.82***	1.39**
10	1.02	0.72***	1.20**	1.81***	0.64***	0.99	0.90	0.80	1.20**	2.00***	0.73
11	1.02	1.17***	0.89**	1.06	0.95	1.06	0.99	1.01	0.98	0.93	1.32***
12	0.91	0.98	0.99	1.11	0.90	1.24***	0.81***	1.12**	1.06	1.12	1.09
13	0.80**	0.90	1.00	1.00	1.29***	0.91	0.91	0.96**	0.99	0.99	1.00
14	1.00	1.09**	0.92***	1.20	0.83	1.33***	0.92	1.33***	0.65***	1.20**	1.22
15	1.10	1.00	1.02	0.88**	1.03	1.03	0.96	0.96	0.99	1.01	1.76***
16	1.13***	1.18**	1.10	0.93	1.07	0.81	0.94	0.93	1.10**	1.10**	1.02
17	1.09***	0.99	0.97	0.95**	1.03	1.04	0.93	1.07	1.00	0.98	1.10
18	1.00	1.07	0.94	1.00	1.00	1.00	1.02	0.98	1.00	1.00	1.07**
19	1.04***	1.05	1.03	0.89***	1.25***	0.91	0.92	1.00	1.04	1.45***	1.05
20	0.84***	0.90	1.52***	1.00	0.66***	1.17	0.94	0.91	1.18	0.85**	1.14**
21	0.98	0.95	1.04	1.23***	0.78***	1.00	1.00	1.00	1.00	1.00	1.07
22	1.14***	0.93	0.99	0.98	0.97***	1.06***	0.94***	1.00	1.05	0.95	1.06
23	0.94	0.97	1.00	1.00	1.25***	0.98	0.91	1.04	0.97	0.99	1.42***
24	1.07	1.02	0.91***	1.11**	0.95	1.02	0.98	1.01	1.10	0.89	1.27***
25	1.03	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.24	0.81**	1.01
26	1.00	1.02	0.98	1.00	1.00	1.00	1.00	1.43***	1.28	0.56***	0.97
27	1.05	0.96	1.19***	0.83***	1.07**	1.05	0.89**	1.03	1.10	0.91	1.15***
28	1.00	1.00	1.05	0.95	1.12	1.21	0.82**	1.17	0.79**	0.97	1.66***
29	1.00	1.09**	0.92**	1.52***	0.71***	1.11	1.06	1.11	0.72***	1.09**	0.90***
30	0.88***	1.06	0.95	1.06	1.01	0.93***	1.00	1.00	1.18***	0.85***	1.52***
31	1.21	0.69***	1.00	1.12**	1.20	0.74***	1.35**	0.74***	1.00	1.01	2.20***
32	1.11**	0.90**	1.00**	1.00	1.00	1.00	1.01	0.99	1.04	0.98	1.07**
33	1.42***	0.56***	1.38***	0.72***	1.07	1.22	0.76***	1.00	1.01	0.99	1.00

FARM_ID	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014
34	1.20	0.87	1.07	0.89	1.27***	0.79***	1.14**	1.16	0.76**	1.00	1.00
35	0.81***	1.05	1.72***	0.89	0.63***	1.32	0.88	1.23**	0.70***	1.16***	0.86***
36	0.84**	1.17	0.85	1.19	0.93	0.91	1.02	1.45***	0.74**	1.07	1.25**
37	1.00	1.09***	0.92***	1.02**	1.01	1.01	0.97	0.99	1.07**	0.93**	1.24***
38	1.00	1.06	1.17	0.82	1.63***	0.73***	0.82	1.00	1.37***	0.73**	1.01
39	1.00	1.00	1.00	1.21	0.82	1.00	1.00	1.00	1.00	1.00	1.00
40	1.43***	0.91	0.72***	1.66***	0.67***	1.17	0.98	0.99	0.89	1.00	0.89
41	1.25**	0.95	1.20**	0.83	0.91	1.08	1.66***	0.73	0.99	1.37***	1.05
42	1.23***	0.82**	0.98**	1.06***	0.94***	1.16***	0.86***	1.01	0.99	1.00	1.03
43	0.98	1.00***	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
44	1.06	0.95	0.97	1.01	1.09	0.94	0.99	1.17***	0.85***	0.99	1.18***
45	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.11	0.97
46	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.03
47	1.04	0.94	0.94	1.02	1.08	0.86***	1.07	1.01	0.95	0.93***	1.22***
48	0.77	1.17	1.33**	1.50***	0.80***	1.09	0.67***	1.21	0.78**	1.15	1.38**
49	1.06	0.95	1.02	1.01	1.24***	0.80***	1.04	1.06	0.97	1.02	1.19
50	0.89***	1.21***	1.21	0.83**	0.87	1.00	0.99	0.76***	1.24***	1.10	1.01
51	1.00***	1.00	1.00	1.00	1.00***	1.00***	1.00	1.00	1.00	1.00	1.00
52	1.13	0.89	1.11	0.82	1.11	1.10	0.63***	1.82***	0.72***	1.05	1.25
53	0.62***	1.02	1.19	1.20**	0.88	1.12	0.94	0.75***	1.09	1.22***	0.87
54	1.05	0.98	0.97	1.03***	0.99	1.18***	0.85**	0.99	1.09	1.24***	1.43
55	1.04	1.00	0.90***	1.09***	0.99	0.92***	1.03	1.02	0.95	1.00	1.45***
56	1.03	0.84	0.91**	1.06**	0.93***	1.07**	1.04	0.90***	1.11***	0.91***	1.27***
57	1.01	1.21***	1.17	0.89	0.82**	0.85***	0.99	1.03	1.20***	0.82***	0.99
58	1.14	0.93	0.90***	1.09***	1.09	1.00	0.91	1.12**	0.91	0.98	1.24***
59	0.97***	1.17***	1.12	0.99	0.77***	1.07	0.93	1.00	1.03	1.03	1.03
60	1.14	0.84**	1.09	0.94	0.85***	1.17	1.30**	0.70***	1.03	0.91**	1.36***

\*\* Significantly different from unity at 0.05 level

\*\*\* Significantly different from unity at 0.01 level