"Sources of measured agricultural yield difference"

Simone Pieralli

Department of Agricultural Economics, Humboldt University in Berlin, Unter den Linden 6, D-10115 Berlin, Germany
and
Department of Agricultural and Resource Economics, University of Maryland College Park, 2200 Symons Hall, College Park, MD 20742, USA

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Paper prepared for presentation at the Agricultural & Applied Economics Association's 2012 AAEA Annual Meeting, Seattle, Washington, August 12-14, 2012

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June 4, 2012

Abstract

We decompose yield difference relative to a reference level into components attributable to (1) efficiency difference, and movements along the frontier due to (2) land quality, to (3) land size, and to (4) other inputs. The production frontier is built using nonparametric methods requiring no specification of the functional form of the technology. We analyze the contributions to yield relative to a reference unit in terms of the quadripartite decomposition finding that results depend on the choice of the unit of reference. If the reference unit is chosen to be the mean, land size contributions are found to be negatively correlated to yield with usual finite moments regression methods. Also nonparamteric correlation confirms the negative sign of the relationship. If the reference unit is chosen to be the median instead, land size contributions are found to be negatively correlated to yield with usual finite moments regression methods. But nonparametric correlation is not statistically significant because many farmers have no contribution to production difference from their different land sizes. Integrated squared density difference tests show in both cases efficiency has a major role in shaping the distribution.

Key words: inverse land size-productivity relationship, productivity decomposition, efficiency, yield, Kenya

JEL classification: D20, C14, C43

Introduction

The introduction of new methodologies and new technologies has led to a sustained interest in the inverse farm size-productivity relationship. Since Chayanov (1926), the inverse relationship between land size and yield, as a crude measure of productivity, has been the topic of an extensive debate. Unlike older studies, recent empirical literature has revisited the long-standing relationship, focusing especially on the introduction of new data, available thanks to technologies applied innovatively to this old problem.

While recent studies have considerably improved our understanding of the problem, they have also revived the controversy by neglecting the importance of very critical agricultural physical factors such as land quality, even after including newly available data. After Chayanov (1926) who noticed it for the first time, empirical economists emphasized the importance of other factors, such as incomplete and imperfect markets, measurement error and omitted soil quality as the cuplrit of this relationship in developing countries settings. The latest contributions find little role for omitted soil quality (Barrett, Bellemare, and Hou 2010), and no role for measurement error (Carletto, Savastano, and Zezza 2011), while confirming a strong negative relationship between land size and yield.

Much of the existing empirical literature is summarized in the recent contributions (e.g. Barrett, Bellemare, and Hou (2010) and Carletto, Savastano, and Zezza (2011)). This literature has focused on explaining the relationship with new data but with available methods. One of the first explanations of this relationship in the past was the presence of imperfect labor markets. These imperfections caused, following this explanation, an over-usage of labor in small-holder fields making them appear more productive. Data restrictions have instead caused to formulate the omitted soil quality explanation and the size measurement error explanation. The first indicates soil quality as an omitted variable negatively correlated with land size. By virtue of regression methods, this could provoke the inverse relationship. The size measurement error explanation instead considers that the inverse relationship could be caused by measurement error attenuation bias (Lamb 2003). These explanations have sometimes caused the relationship to disappear but not unanimously.

Very recently the focus has been on introducing and using newly available data for explaining this old relationship with available methods. The availability of new satellite measurements for plot sizes have allowed Carletto, Savastano, and Zezza (2011) to show a stronger inverse relationship when taking into account the measurement error of plot size among Ugandan households with regression methods. The availability of new quantitative land characteristics measurements have allowed Barrett, Bellemare, and Hou (2010) to show the insignificance of land quality in explaining the inverse relationship with usual regression methods.

Modern data do not explain anything of this relationship when used with usual regression methods, with common functional form assumptions. The goal of this study is to separate spurious empirical relationships from truly significant ones. This inverse relationship is an important topic in development economics. Its truth or falsity has policy implications.

This issue is very important presently because the international agenda is mostly focused on smallholder African agriculture productivity. Smaller farms could be considered the most productive and efficient production units for a better development if the inverse relationship were confirmed using also more assumptions-free methods. If instead the relationship is proved just a result of applied statistical methods, other policies such as land consolidation or formation of aggregate groups of farmers should be investigated more closely.

This paper addresses this question directly. In particular, we decompose an index of yield, a crude measure of productivity difference, into components attributable to (1) efficiency difference, and movements along the frontier due to (2) land quality, to (3) land size, and to (4) other inputs. The first component reflects movements toward (or away from) the frontier as farmers adopt best practice technologies and reduce (or exacerbate) technical inefficiency. The second component reflects movements along the frontier due to land quality, keeping land size, and other inputs fixed. The third component reflects movements along the frontier due to land size, keeping land quality, and other inputs fixed. Finally, the fourth component measures movements along the frontier due to all other inputs, keeping land quality, and land size unchanged. This decomposition sheds light on which of these components is more important in explaining the difference in yield index.

The production frontier is constructed using nonparametric methods requiring no specification of the functional form for the technology and without specific assumptions on returns to scale or on market efficiency. We calculate the above four components of yield difference for a sample of Kenyan households.

These methods, already used by Färe et al. (1994) and Kumar and Russell (2002) to analyze changes in macroeconomic context, are here generalized. Moreover, these methods are here applied to Kenyan households to shed light on a long-standing issue in development and agricultural economics by innovating the methodology applied to already available data. This is done in the hope of obtaining more general results. Any procedure that produces estimates or approximations to the technology frontier (econometric estimation or Data Envelopment Analysis, DEA, approximation) could be used to obtain empirical versions of each of the theoretical measures developed in this study.

Studies based on standard linear regression methods focusing on the first and second moments of distributions have not provided until now satisfactory explanations of the inverse land size-productivity relationship. In the present case, for example, a crude standard regression of logarithm of yield on logarithm of land size provides an estimate of elasticity of -0.236 significant at 1% level. This means that yield decreases by around a fourth of each percentage increase in land size. Even when relaxing the parametric assumptions the results still show significant negative correlation around the mean of the logarithm of size. This can be seen in the nonparametric regression plot shown in figure 1. But we also see from the nonparametric regression that there are parts of the distribution that are not well described by this simple regression analysis. It is important to understand what is hidden inside the data around the mean. Moreover, we want to relax restrictive assumptions on form of production functions usually embedded in linear regression methods. For these reasons in this study we decide to adopt the DEA methodology.

Although the methods used in the analysis here are quite simple, it provides somewhat fundamentally different results than usually obtained with regression methods: (1) Results are shown to be relative to the reference unit considered. (2) If measured around the median (or the mean), while with usual regression methods there is a negative significant relationship between size and yield, in the present study there is substantial evidence of no important negative contributions of land size to difference in yield when considered with the proposed methods. (3) A lot of the difference in yield is due to efficiency differences.

A caveat on the results shown in this study is granted now. The measures of productivity difference developed here are measures developed for one cross-section of data. This means that there is no time dimension in the results; this is so because there are no land quality panel households data available in the context of developing world countries. Once these data were to become available a generalized version of this study would be in order. This would allow a less arbitrary and more natural choice of reference unit. For the moment we leave this for future research. Moreover these results are done only for one output so no consideration can be given to strategic behavior of the farmers. The methodology is easily generalizable to multiple outputs case. This could help in comparing better the results of this study to previous studies which might be, in this respect, more comprehensive than this.

We should also say that the analysis, because of the index number theory methods used, is not intended to provide causal explanations of the facts observed. It only is a generalized growth-accounting exercise applied to shed light on an important problem in a different field of analysis. The methodology is discussed next. Then data are presented. Finally, empirical results and conclusions are shown.

Methodology

If the inverse land size-productivity relationship reflects physical reality, land could potentially be more productive if large-scale operations were broken into smaller units. Hence the inverse relationship is often offered as an economic argument for land redistribution programs. The inverse land size-productivity relationship is often analyzed (e.g. Assunçao and Braido (2007) and Bardhan (1973)) assuming a Cobb-Douglas production function with constant returns to scale. But constant returns to scale implies that a proportional increase in all inputs leads to a corresponding proportional increase in all outputs. This is not necessarily true a priori. The use of a production function implies all agents operate in a technically efficient manner. But there are possibly many cases in which incentives are such that agents produce inefficient bundles. In addition, the use of a Cobb-Douglas functional form implies a unitary elasticity of substitution that can mask legitimate changes in the degree of input substitutability as allocative inefficiency.

The inverse land size-productivity problem is often studied by regressing yield (or the natural logarithm of yield) on land size (or on the natural logarithm of land size) while conditioning on other characteristics (among which input factors and, seldom, land quality characteristics). In particular, conditioning linearly on land quality characteristics implies that, in the evaluation of the performance of the farmer, substitution possibilities are not considered, even among land quality characteristics, and the inverse relationship is calculated as if these characteristics were given.

My research addresses the possibility that relaxing too restrictive assumptions and accounting quantitatively for land quality characteristics and land size could change the results obtained from more conventional regression methods on the inverse relationship. The typical measure of productivity used in the empirical literature on land size and productivity is yield. Yield is easily recognized as a partial productivity measure. Therefore, once yield is converted into index form by comparing it to some base-level yield it can be analyzed exactly as other partial productivity measures have been analyzed (Kumar and Russell 2002).

A simple method rooted in the theory of index numbers and productivity accounting can be used to isolate the contribution of different factors to differences in measured productivity.

DEA is the methodology used in this article because it allows to characterize the technology with minimal parametric assumptions (i.e. only piecewise linearity).

Let $y \in \mathbb{R}_+$ and $\mathbf{x} \in \mathbb{R}_+^U$ denote output and inputs respectively and let $l \in \mathbb{R}_+$ and $q \in \mathbb{R}_+$ denote land area devoted to production and land quality respectively. The following is developed in the case of one output to follow the empirical literature on the inverse yield-size relationship but could be extended to a multi-output case. The technology set T_t, where t represents time, is defined:

(1)

$$T_t = \left\{ (\mathbf{x}_t, l_t, q_t, y_t) \in \mathbb{R}_+^{U+1+1+1} : (\mathbf{x}_t, l_t, q_t) \text{ can be used by households to produce } y_t \text{ at time } t \right\}$$

T_t is assumed to satisfy:

A.1: $(\mathbf{x}_t, l_t, q_t, y_t) \notin T_t$ if $\mathbf{x}_t = \mathbf{0}, l_t = 0, q_t = 0, y_t > 0$.

A.2: If $(\mathbf{x}_{1t}, l_{1t}, q_{1t}, y_t) \in T_t$ and $(\mathbf{x}_{2t}, l_{2t}, q_{2t}, y_{2t}) \in T_t$, then $\forall \alpha \in [0,1] : (\mathbf{x}_t, l_t, q_t, y_t) = \alpha(\mathbf{x}_{1t}, l_{1t}, q_{1t}, y_{1t}) + (1-\alpha)(\mathbf{x}_{2t}, l_{2t}, q_{2t}, y_{2t}) \in T_t$.

A.3: T_t is assumed closed $\forall (\mathbf{x}_t, l_t, q_t, y_t) \in \mathbb{R}_+^{U+1+1+1}$.

A.4: T_t is bounded $\forall (\mathbf{x}_t, l_t, q_t) \in \mathbb{R}_+^{U+1+1}$.

A.5: Outputs are strongly disposable: if $y_t \in \mathbb{R}_+ \in T_t \subseteq \mathbb{R}_+^{U+1+1+1}$ then $0 \leqq y'_t \leqq y_t \Rightarrow y'_t \in T_t$.

A.6: Inputs $(\mathbf{x}_t, l_t, q_t)$ are strongly disposable: if $(\mathbf{x}_t, l_t, q_t) \in \mathbb{R}_+^{U+1+1} \in T_t \subseteq \mathbb{R}_+^{U+1+1+1}$

then $(\mathbf{x}'_t, l'_t, q'_t) \geqq (\mathbf{x}_t, l_t, q_t) \Rightarrow (\mathbf{x}'_t, l'_t, q'_t, y_t) \in T_t$

In the single output case, the Farrell output efficiency score is defined:

(2) $E(\mathbf{x}_t, l_t, q_t, y_t) = \max\{e_t \in \mathbb{R}_+ : (\mathbf{x}_t, l_t, q_t, e_t y_t) \in T_t\}$

if $\exists\, e_t$ s.t. $(\mathbf{x}_t, l_t, q_t, e_t y_t) \in T_t$ and $+\infty$ otherwise. By **A.5**

(3) $E(\mathbf{x}_t, l_t, q_t, y_t) \geq 1 \Leftrightarrow (\mathbf{x}_t, l_t, q_t, e_t y_t) \in T_t$

so that $E(\mathbf{x}_t, l_t, q_t, y_t)$ is a complete function representation of the technology. It is also positively homogeneous of degree minus one in y, that is,

(4) $E(\mathbf{x}_t, l_t, q_t, \mu y_t) = \mu^{-1} E(\mathbf{x}_t, l_t, q_t, y_t) \quad \mu > 0.$

The method of decomposition of the factors affecting yield difference allows for non constant returns to scale. In doing so, it adapts and generalizes what has been done in productivity studies, for example, by Henderson and Russell (2005) and by Kumar and Russell (2002). But especially it allows for a more general framework in which to study the inverse farm size-relationship. This is developed for one period in time only because we have data on land quality for only one period. But it could be easily generalized to include a technological change component.

We recognize a yield index as a ratio of partial productivity measures. A yield index for one unit (in the following, unit 1) can be defined relative to a base unit (in the following, the base unit will be unit 0) as:

$$(5) \qquad \frac{y_1/l_1}{y_0/l_0} = \frac{f(\mathbf{x}_1,l_1,q_1)/l_1}{f(\mathbf{x}_0,l_0,q_0)/l_0}\frac{E(\mathbf{x}_0,l_0,q_0,y_0)}{E(\mathbf{x}_1,l_1,q_1,y_1)}$$

Using the fact that the Farrell output efficiency is positively linearly homogeneous of degree minus 1 in its output argument, we can rewrite this expression as:

$$(6) \qquad \frac{y_1/l_1}{y_0/l_0} = \frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_0,l_0,q_0)}\frac{E(\mathbf{x}_0,l_0,q_0,y_0/l_0)}{E(\mathbf{x}_1,l_1,q_1,y_1/l_1)}$$

The second right hand term can be considered a usual relative efficiency index measured with inefficiency measures. The rest of the treatment here will concentrate on the first right hand term

$$(7) \qquad \frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_0,l_0,q_0)}$$

which can be recognized as a ratio of efficient points on the production function, without necessity of assuming specific returns to scale, nor functional forms a priori.

It is possible to obtain different decompositions of (7). To illustrate, first multiply and divide by $f(\mathbf{x}_1,l_1,q_0)f(\mathbf{x}_1,l_0,q_0)$ to obtain

$$(8) \qquad \frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_0,l_0,q_0)} = \frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_1,l_1,q_0)}\frac{f(\mathbf{x}_1,l_1,q_0)}{f(\mathbf{x}_1,l_0,q_0)}\frac{f(\mathbf{x}_1,l_0,q_0)}{f(\mathbf{x}_0,l_0,q_0)}.$$

Each of these three terms on the right-hand side:

$$\frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_1,l_1,q_0)},$$
$$\frac{f(\mathbf{x}_1,l_1,q_0)}{f(\mathbf{x}_1,l_0,q_0)},$$

and

$$\frac{f(\mathbf{x}_1, l_0, q_0)}{f(\mathbf{x}_0, l_0, q_0)}$$

are legitimate index numbers. That is, only one argument changes in every ratio and every ratio measures relative changes due to that argument. In particular the first of the right hand terms represents the vertical distance between the two frontier points given by a change in soil quality. The second of the right hand terms represents instead a distance between two frontier points given by a change in land size. The last of the right hand terms represents instead a change in the frontier points given by a change in the inputs other than land quality and land size.

But it is also possible to decompose (7) by multiplying and dividing by $f(\mathbf{x}_0, l_1, q_1) f(\mathbf{x}_0, l_0, q_1)$. This obtains:

$$\text{(9)} \quad \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_0)} = \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_1, q_1)} \frac{f(\mathbf{x}_0, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_1)} \frac{f(\mathbf{x}_0, l_0, q_1)}{f(\mathbf{x}_0, l_0, q_0)}$$

Also in this case every term represents a proper index. In this case the first term is associated with a change in inputs other than land quality and land size, the second term is associated with a change in land size and the last term is instead associated with a change in land quality. We can see that the corresponding terms of the decompositions are not the same. For example the land size component is not the same in the two decompositions:

$$\text{(10)} \quad \frac{f(\mathbf{x}_1, l_1, q_0)}{f(\mathbf{x}_1, l_0, q_0)} \neq \frac{f(\mathbf{x}_0, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_1)}$$

More generally, it is possible to show that

$$(11) \quad \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_0)}$$

can be decomposed in the following equivalent but different decompositions, in addition to the previous two:

$$(12) \quad \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_0)} = \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_1, l_0, q_1)} \frac{f(\mathbf{x}_1, l_0, q_1)}{f(\mathbf{x}_1, l_0, q_0)} \frac{f(\mathbf{x}_1, l_0, q_0)}{f(\mathbf{x}_0, l_0, q_0)}$$

$$(13) \quad \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_0)} = \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_1, q_1)} \frac{f(\mathbf{x}_0, l_1, q_1)}{f(\mathbf{x}_0, l_1, q_0)} \frac{f(\mathbf{x}_0, l_1, q_0)}{f(\mathbf{x}_0, l_0, q_0)}$$

$$(14) \quad \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_0)} = \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_1, l_1, q_0)} \frac{f(\mathbf{x}_1, l_1, q_0)}{f(\mathbf{x}_0, l_1, q_0)} \frac{f(\mathbf{x}_0, l_1, q_0)}{f(\mathbf{x}_0, l_0, q_0)}$$

$$(15) \quad \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_0)} = \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_1, l_0, q_1)} \frac{f(\mathbf{x}_1, l_0, q_1)}{f(\mathbf{x}_0, l_0, q_1)} \frac{f(\mathbf{x}_0, l_0, q_1)}{f(\mathbf{x}_0, l_0, q_0)}$$

Our proposed solution to resolve the ambiguity in the method of decomposition is to pursue the path followed by Fisher in creating his ideal index and by many others since. That is we take the geometric average of the different decompositions to obtain:

$$\frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_0, q_0)} =$$

$$\left(\frac{f(\mathbf{x}_1, l_0, q_0)}{f(\mathbf{x}_0, l_0, q_0)} \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_1, q_1)} \frac{f(\mathbf{x}_1, l_0, q_0)}{f(\mathbf{x}_0, l_0, q_0)} \frac{f(\mathbf{x}_1, l_1, q_1)}{f(\mathbf{x}_0, l_1, q_1)} \frac{f(\mathbf{x}_1, l_1, q_0)}{f(\mathbf{x}_0, l_1, q_0)} \frac{f(\mathbf{x}_1, l_0, q_1)}{f(\mathbf{x}_0, l_0, q_1)} \right)^{1/6}$$

$$\left(\frac{f(\mathbf{x}_1,l_1,q_0)}{f(\mathbf{x}_1,l_0,q_0)}\frac{f(\mathbf{x}_0,l_1,q_1)}{f(\mathbf{x}_0,l_0,q_1)}\frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_1,l_0,q_1)}\frac{f(\mathbf{x}_0,l_1,q_0)}{f(\mathbf{x}_0,l_0,q_0)}\frac{f(\mathbf{x}_0,l_1,q_0)}{f(\mathbf{x}_0,l_0,q_0)}\frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_1,l_0,q_1)}\right)^{1/6}$$

$$(16)\quad \left(\frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_1,l_1,q_0)}\frac{f(\mathbf{x}_0,l_0,q_1)}{f(\mathbf{x}_0,l_0,q_0)}\frac{f(\mathbf{x}_1,l_0,q_1)}{f(\mathbf{x}_1,l_0,q_0)}\frac{f(\mathbf{x}_0,l_1,q_1)}{f(\mathbf{x}_0,l_1,q_0)}\frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_1,l_1,q_0)}\frac{f(\mathbf{x}_0,l_0,q_1)}{f(\mathbf{x}_0,l_0,q_0)}\right)^{1/6}$$

The first term is a term that considers effects of changes in the inputs ($\mathbf{x}_i$) keeping quality of land and land size fixed (INPUTS). The second term measures effects of changes in the frontier due to a change in land size (SIZE), and the last term measures the changes in the frontier due to a change in soil quality (QUAL). For later purposes, let us express the decomposition in compact form as follows:

$$(17)\quad \frac{f(\mathbf{x}_1,l_1,q_1)}{f(\mathbf{x}_0,l_0,q_0)} = INPUTS * SIZE * QUAL$$

In this case yield index would be decomposed, following (16) and (6), into an efficiency component, a component due to land size, a component due to soil quality, and a component relative to the other inputs.

Because results are relative to the specific unit of reference ($\mathbf{x}_0,l_0,q_0$) and they change substantially we show in the results eight different possible scenarios. These different scenarios are useful to shed light on the possible importance of variables of interest such as size. The variables we vary in the scenarios are land quality, land size, and yield.

For each of these three variables we choose one unit with high and one with low value, resulting in eight possible scenarios. One scenario is taking as a reference unit a household with a low land size, low land quality, and low yield. Another scenario is taking as a reference unit a household with big land size, low land quality, and low yield and so on varying land quality and yield. We also conduct the same calculations by taking the mean of all inputs and outputs as a reference unit. But we recognize that the distributions might be skewed.

In search of an ideal unit of reference, we then calculate the measures taking as a reference the median value of inputs and outputs. For the median values reference scenario, we elaborate the results in more detail to study where the inverse yield-size relationship comes from and which variables are actually most important in the decomposition of productivity differences. The importance of this methodology is in its generality. It can accommodate decompositions of productivity in components related to each different input, if so desired.

To test statistically for the significance of the contribution of different components to productivity difference we look at the linear regression of each component on the observed yield. This is to see if there is any significant relationship to emphasize. But usually applied regression methods are only looking at the behavior around the mean of the distribution. On the other hand, the nonparametric productivity measurements used in this study allow to characterize the position of each point, and not only of the average, with respect to the production frontier, and with respect to the reference unit. This is much more general than focusing only on the first moment characterization proper of usual linear regression methods. To exploit the potential of such richer characterization, nonparametric tests of equality of distributions are used to investigate the importance of relevant contributions to productivity difference (Li, Maasoumi, and Racine 2009). We prefer a nonparametric test of the integrated squared density difference to test for 'any difference' among distributions (Li, Maasoumi, and Racine 2009). This test allows to see which of the components isolated has a decisive impact on shaping the observed yield distribution. Same test is repeated to show if there are any differences among different returns to scale assumptions.

In particular we can rewrite the decomposed productivity difference, using the decomposition in (17) as:

$$(18) \quad \frac{y_1/l_1}{y_0/l_0} = INPUTS * SIZE * QUAL * \frac{E(\mathbf{x}_0, l_0, q_0, y_0/l_0)}{E(\mathbf{x}_1, l_1, q_1, y_1/l_1)}$$

From this decomposition we can, following Kumar and Russell (2002) and adapting their intuition to our context, define different sets of counter factual distributions. In particular we can rewrite

$$(19) \quad y_1/l_1 = y_0/l_0 * INPUTS * \frac{E(\mathbf{x}_0, l_0, q_0, y_0/l_0)}{E(\mathbf{x}_1, l_1, q_1, y_1/l_1)} * SIZE * QUAL$$

This can be considered as an alternative decomposition. If we multiply each component on the right-hand side we obtain exactly the observed yield distribution on the left-hand side. To isolate the significance of the contributions of inefficiency, land size, and land quality, we can start from a counter factual distribution that would equal observed yield if there were no differences in land size, land quality, and inefficiency. In particular this can be written as:

$$(20) \quad y_1^I/l_1 = y_0/l_0 * INPUTS$$

We then successively introduce differences in inefficiency to have:

$$(21) \quad y_1^E/l_1 = y_0/l_0 * INPUTS * \frac{E(\mathbf{x}_0, l_0, q_0, y_0/l_0)}{E(\mathbf{x}_1, l_1, q_1, y_1/l_1)}$$

This is the counter factual distribution of yields if we were to ignore differences in land quality and land size. Then we introduce differences in land size to have

$$(22) \quad y_1^L/l_1 = y_0/l_0 * INPUTS * \frac{E(\mathbf{x}_0, l_0, q_0, y_0/l_0)}{E(\mathbf{x}_1, l_1, q_1, y_1/l_1)} * SIZE$$

This is a counter factual distribution of yields that does not take into account differences in land quality. Finally, we can introduce the land quality differences to obtain the previous decomposition (19).

But the last step, as the previous ones, could also be done in reverse order. In other words we could introduce the adjsutment for land quality, first, to obtain:

$$(23) \quad y_1^Q/l_1 = y_0/l_0 * INPUTS * \frac{E(\mathbf{x}_0, l_0, q_0, y_0/l_0)}{E(\mathbf{x}_1, l_1, q_1, y_1/l_1)} * QUAL$$

And then introduce the land size component to obtain the original decomposition (19).

For later reference, we can also introduce the efficiency component at last. In other words, we can define

$$(24) \quad y_1^{QL}/l_1 = y_0/l_0 * INPUTS * QUAL * SIZE$$

Of course to arrive to this decomposition other counterfactual distributions can be obtained. In particular we can introduce only the land quality component after (20):

$$(25) \quad y_1^{IQ}/l_1 = y_0/l_0 * INPUTS * QUAL$$

Or we can introduce only the land size component after (20) as follows:

$$(26) \quad y_1^{IL}/l_1 = y_0/l_0 * INPUTS * SIZE$$

At each subsequent step a test (Li, Maasoumi, and Racine 2009) will be done for equality of counter factual and observed yield distributions to see when the two distributions cannot be statistically distinguished. In this way we can test which component contributes to shape the observed yield distribution.

For example, if the distribution y_1^L/l_1 is not found statistically different than y_1/l_1, this would mean that land quality (in this case the last excluded factor) would not have a predominant effect in shaping the observed yield distribution. Moreover this would signal a significant impact of land size if, for instance, the previous test of equality of y_1^E/l_1 and y_1/l_1 were to be rejected in preceding comparisons.

Obviously the order of introduction of the subsequent differences is arbitrary. The underlying story behind does not seem to change from changing the order of introduction of different components.

Data

The data are drawn from a sample of households in 99 sub-locations in Kenya in early 2007 and they are relative to the long and short seasons 2005-2006. The survey is part of a panel named "Research on Poverty, Environment and Agricultural Technologies (REPEAT): Panel studies in Africa". Survey data were obtained from the National Graduate Institute for Policy Studies (21st century Center of Excellence Program) in Japan. The cross-section sample analyzed in this study initially includes 718 households, of which only 579 units are available for calculation. Of these, data on land quality are available for 452 families.

Measured output, representative for agriculture, is harvested dry maize. Faithful to the development economics literature on the topic of yield productivity we choose to take into account only the case of dry maize production. Selectivity of farmers in maize production might be considered as an issue but all households available for estimation produce maize. So this seems less of a concern considering also that the sample has maintained its random sample properties even after elimination of some units due to errors in sampling.

The measured inputs used in maize production directly are seeds, land area, organic and inorganic fertilizers, family worked hours, cost of temporary hired workers, hours worked by permanent and shared workers, and milking cows. Other variables measuring inputs available for household production are number of hand hoes, ploughs, sickles, spray pumps. Table 1 shows input and output summary statistics of the households. Data on physical characteristics of land for the largest maize plot for each household are available for mid-2003. The analysis focuses on two measures that are stable over time: soil carbon and soil clay content. These two variables are aggregated into a ordinal land quality measure, following the methodology developed in Pieralli (2011). In creating the land quality indicator, we will vary the percentiles of reference of the inputs and outputs to see how the results change. Table 1 shows summary statistics of these soil properties but more soil properties could be aggregated into a land quality indicator, if so desired.

Results

In development economics, it is an empirical regularity to encounter a negative relationship between yield and land size, either of the farm or of the plot farmed. Measurement errors seem to reinforce this negative relationship (Carletto, Savastano, and Zezza 2011).

Indeed, even in the present case, common regression methods and nonparametric regression methods show a negative and strongly significant relationship. This can be seen from figure 1. The figure represents the nonparametric regression of logarithm of yield on the logarithm of land size. The nonparametric regression (middle) line is contoured by the 95% confidence intervals to show significance. This figure shows a significant negative relationship between logarithm of land size and logarithm of yield of dry maize per acre. This conceptually means that the unconditional elasticity of yield with respect to land size is negative. This kind of evidence is usually brought forward to signal at first glance a significant negative relationship between yield and size per acre (Barrett, Bellemare, and Hou 2010). The nonparametric regression is significant, at least, around the average. We estimated the elasticity also with parametric methods. The parametric estimate of the elasticity at the average size is -0.236 and it is significant at less than 1% level. This means that per acre production decreases on average almost by one fourth of the percentage increase in acreage. Results are robust also when including inputs and remain qualitatively the same when including also a land quality measure. This is usually taken to signal the presence of a negative relationship between size and yield and the apparent insignificance of the land quality variable.

The problem is that this estimated relationship assumes a specific functional form and studies the relationship (at least usually in parametric cases) around the mean value. Moreover, usually, production efficiency and constant returns to scale in production are assumed. These assumptions are very stringent and possibly the cause of how the estimate results.

In this paper we relax these assumptions to see if the relationship persists. We consider a flexible nonparametric productivity accounting method, separating explicitly the efficiency component, and the influence of land size, land quality, and other inputs. In this way we do not assume a specific functional form, nor efficiency of production, or constance of returns to scale.

The productivity accounting method described in the preceding methodology section produces measures that are relative to the unit of reference considered. In the following we show how results change by changing the unit of reference. We do this by means of graphing the four percentage components of productivity against observed yield. As said in the methodology section we consider eight different cases to show how estimates change for a high and a low value of three characteristics: land quality, land size, and yield. We choose the units using the level of land quality calculated under variable returns to scale. Because the ranks can change, especially between constant returns and the other assumptions, we focus on studying the variable returns to scale as the most general assumption. The exercise can be replicated under different returns to scale and for different characteristics to see how measures change.

To place the units of reference in context of the present sample, we can show the different values on the cumulative distribution functions of yield, land size, and land quality with empirical cumulative distribution functions of the single variables and with joint bivariate histograms. While we tried hard to match this simple theoretical idea with finding the right units of reference for the analysis, we had to accommodate to approximately high and approximately low values to match these ideas with real units. In particular in figure 2 we can see the empirical cumulative distribution function of land size. We plotted on the graph lines in correspondence of 0.55 acres, 2.25 acres, 2.65 acres, and 4 acres. These lines are in correspondence of values from four units we have chosen as reference units for the analysis and that can help to see also where the other four units used for reference are placed. In figure 3 we show the empirical cumulative distribution function of yield. Corresponding to the previous four values are, respectively, the lines at 981 Kg acre^{-1}, at 240 Kg acre^{-1}, at 135 Kg acre^{-1}, and at 787.5 Kg acre^{-1}. Each of these households has an associated land quality. In particular, in figure 4 we report lines corresponding to previous values at 0.7199, at 0.99, at 0.42, and at 0.35. These four cases allow seeing the eight possibilities we designed for measurement. In particular, the first unit among the four will be the reference unit representative for little size, high yield, and relatively low land quality. The second unit will be one with a relatively big land size, a low yield, and a very high land quality. The third unit instead is an example of a unit with big land size, low yield, and low land quality. Finally the fourth unit is a unit with very big size, high yield, and very low land quality.

The other four units have respectively 0.5 acres of land size, yield of 270 Kg acre^{-1}, and 0.7453 of land quality index, 0.5 acres of land size, yield of 720 Kg acre^{-1}, and 0.95 of land quality index, 2.5 acres of land size, yield of 972 Kg acre^{-1}, and 0.98 of land quality index, and finally 0.6 acres of land size, yield of 250 Kg acre^{-1}, and 0.96 of land quality index. It is possible to visualize the position of these reference units approximately on the joint histogram of land quality and land area in figure 5, land area and yield in figure 6, and land quality and yield in figure 7.

In each of the eight cases we repeated the calculations of the quadripartite decomposition, for understanding what is the relation between yield and the four contributions. Figures from 8 to 15 plot the percentage contributions measures (dots) against the observed yield. Graphs also report a usual regression line (solid) for which the legend says if the relationship is significant or not at the 95% confidence level and a dashed line representing a smoothed Gaussian kernel. The kernel shows a smoothed local regression line.

Consider first the case of reference unit with small land size, low yield, and low land quality. This is shown in figure 8. We expect positive percentages of land size, land quality, and other inputs in contributing to the yield difference between other units and the reference unit. The regression lines show these significant relationships. It is not significant the contribution of efficiency to yield difference in this case. At first sight, these regression lines seem to suggest a completely opposite relationship between land size contribution and observed yield than usually seen in empirical applications. This result changes if we take as a reference unit a household with same characteristics (low yield and low land quality) but with a big land size as we do in figure 9. In this case we see that land size contribution is not correlated with observed yield almost at all, while contributions of land quality and efficiency are positively correlated to observed yield. If we do the same analysis passing from a little land size to a big land size but for a household with high yield as in figures 10 and 11, we can see the same trends in the changes of relationship between land size contributions and land quality. Land size contributions to yield difference are moderately positively significantly correlated to yield in the case of little land size but are negatively significantly correlated to yield in the case of big land size reference unit.

We then consider the cases when the household units of reference have high land quality. In particular, in figures 12 and 13 we consider the cases when the household reference unit has low yield and high land quality, passing from little land size in figure 12 to big land size in figure 13. We observe here the same relationship in the change of land size. In particular, in these cases, because the land quality of reference is high, most other households have negative contributions of land quality to yield difference. Moreover, these contributions are negatively correlated to observed yield if we follow the regression line plotted. But if we look empirically at the dots representing the different contributions we can see that the most negative contributions are for smaller yields. This would mean that actually the households more affected by a difference in land quality compared to a high land quality are the households with lower yields. This would open another branch of research that is not strictly the focus of this study but for sure of critical importance to assess vulnerability of households.

If we then consider the graph of the contributions of land size to yield difference, we can see that increasing size of the land makes insignificant the positively sloped significant regression line. So we go from evidence against most literature on the topic (positive correlation of percentage contributions of land size to yield) to a negative significant or insignificant relationship. In other words, going from a small to a big land size reference unit any relationship between land size contributions and yield, if significant, becomes negative or disappears.

We finally consider the case of a reference unit with high yield, high land quality and we move from a small land size in figure 14 to a big land size in figure 15. The same kind of positive relationship when considering a small land size unit of reference in figure 14 is inverted in a negative relationship when considering a big land size unit of reference in figure 15.

In some cases, finding a negative relationship of land size contributions with yield would seem to reassure the empirical studies on the topic. But these estimates are relative to a specific reference unit and change substantially. Moreover, the regression line seems particularly not informative of the variation among land size percentage contributions to yield difference.

Considering that these estimates could be misjudged depending on the reference unit used, we also produce the same graphs taking into account as a reference unit the average unit with average values of inputs and outputs. This case should, in principle, be a more meaningful balanced case than the extreme cases considered until now. Graphs to illustrate the average case are reproduced in figures 16, 17, and 18 for constant, non-increasing, and variable returns to scale respectively. These figures suggest that, independently of returns to scale assumptions, there is a significant negative linear relationship, on average, between contributions of land size to yield difference and observed yield. This negative slope is essentially what has led many to argue for the inverse land size-yield relationship. This result is consistent across returns to scale. Moreover, the figures show an insignificant relationship between contributions of land quality to yield difference and observed yield in the south-west quadrant.

Because in usual empirical cases, as in this one, the median is a much more informative statistic given the skewness of some of the distributions of the variables, we repeat the calculations taking into account as a reference unit the median values of inputs and outputs. We can see in tables from 2 to 13 summary statistics of the components of the quadripartite decomposition of yield. These calculations are done in correspondence of land quality measures calculated for different percentiles of reference levels of inputs and outputs as done in Pieralli (2011) and as adapted to the present case of a single product.

To facilitate the interpretation we report the reciprocal of the efficiency index. In this way we can see that the units were, on average, 45 to 60% as inefficient as the unit of reference. This is true under all returns to scale even though variable returns have slightly lower averages. Land quality contribution is between -10% and -1% for the constant and between -15% and -1% for the non-increasing returns to scale on average. Land quality, under variable returns, has instead a much higher negative contribution to yield difference on average from around -20% to -6%. Land size, on average, has a relativley small effect under constant returns to scale and it is increasing in importance with increasing the percentiles of reference of the land quality measure from around -2% to -3%. Same trend with similar figures is evidenced under non-increasing (-2% to -3%) and variable returns to scale (-2% to -5%). Other inputs instead account for a negative mean contribution of around 50%. In looking at these statistics we have to say that when the considered land quality measure is calculated at lower percentiles of reference of inputs and outputs the convergence of units presents more problems. This is why we concentrate the analysis of the results using the land quality measure originating from the highest percentile of reference of other inputs and outputs, i.e. the measures summarized in the last line of each of the tables. The results shown for the highest percentile of reference level of inputs and outputs (on which the treatment is concentrated here) are summarized from the results of 443 units because only 443 units have a strictly positive yield in this sample. The results at the highest percentile of reference level for constant and non-increasing returns to scale are from these 443 units. The results at the highest percentile of reference level for variable returns to scale are instead summarized from 403 families. This is because the land quality component of the productivity accounting measures proposed seems very sensitive to jumps among counter factual measures. The stability of the results across returns to scale assumptions reassures of the non arbitrariness of these results. Moreover we also repeated these calculations and the tests without the 9 units with zero yield and results are qualitatively the same, if not stronger.

As before, three graphs are used to illustrate the results of the calculations for the unit of reference with median values. Figures 19, 20, and 21 present the results in the same format as previously for constant, non-increasing, and variable returns to scale respectively. Across returns to scale assumptions, there is a significantly negative linear relationship between contributions of land size to yield difference and observed yield. This shows that for smaller yields differences in land sizes matter most for productivity differences. But results vary slightly for the land quality component across different returns to scale assumptions. While in the constant returns to scale case the relationship between land quality contributions to yield difference and observed yield is significantly negative, in both non-increasing and variable returns to scale the significance of this relationship disappears.

This is the reading that we could have if we wanted to stop at a characterization of the average behavior of the measures. We could emphasize that in the beginning part of north-east graph of figure 21, under most general returns to scale assumption, there are many contributions that are positive and then followed by negative contributions at higher levels of yields. But this would leave out a lot of the variation around the observations. In particular, we can see that observations, especially around the beginning of the distribution, are very spread, both on the negative and on the positive side, signaling the inadequacy of first moment parametric comparisons (Kumar and Russell 2002; Li, Maasoumi, and Racine 2009).

For example, a simple Spearman correlation coefficient between land contributions and observed yields is significantly negatively correlated for constant (-0.08) and non-increasing returns to scale (-0.079) only at 10% level. But in the case of variables returns to scale the test is not significant (-0.058 with p-value of 0.2443)[1].

The spread of the observations on the graphs, together with these tests, show that the characterization of the results by only looking at a first moment parametrically might be misleading. So we check more in detail what is hidden around the average in the estimates of land quality and land size contributions. To check which of the three components of the production function has a major role in a relative sense, we calculated the percentage average difference rates due to each of the three components of the decomposition of the production function: land quality, land size, and other inputs. While the percentage average difference rates due to other inputs is predominant in all returns to scale assumptions, we want to concentrate on land quality and land size. The percentages due to land quality and land size differ depending on the returns to scale assumptions. In particular, figure 22 plots mean percentage contribution rates in the last twenty percentiles of reference of inputs and outputs when obtaining land quality measure. In the constant and non-increasing returns to scale case (the upper and middle graphs respectively) land size contributes on average more to the percentage yield difference. In the variable returns to scale instead (the lower graph) land quality contributes almost the double than land size at each given percentile. This shows that depending on the assumptions the importance of contribution rates can be different. It also shows that land size and land quality contributions can be relatively very important, and in different proportion for different assumptions.

We start a more in depth explanantion of the results with median reference unit from the analysis of land quality contributions. We notice (figure 23) that land quality contributions at low levels of size (plotted on the horizontal axis) are more important and more variable for the variable returns to scale (the lower graph) than for constant (the upper graph), and non-increasing returns (the middle graph). This suggests that bigger sizes are less influenced by quality for production. We can see in figure 24 the land quality measure q plotted against size. This graph shows a non well defined relationship. But, especially for variable returns (the lower graph), some units with smaller size have a more variable land quality measure. This could play a role in showing a bigger contribution of land quality to yield difference.

For small farmers of very small sizes the land size percentage contribution is negative across all returns to scale assumptions (see figure 25). This figure shows also that when increasing size the percentage to contribution is increasing systematically at least up to a certain size. This level of size up to which the increase is systematic is around 0.8 acres. Even though this could seem an artifact of the methods presented here, this increase is not systematic along the whole distribution and it does not reflect in the portion higher than the median in the same way. Many farmers have land size contributions less negative on the left of the median and less positive on the right of the median level, respectively.

The negative contribution of land size for smaller farmers can be seen directly from the kernel smoothing distributions in figure 26. In particular we can notice, in aggregate, a shift of probability mass, even if not statistically significant, between the solid lines (before land size adjustment) and the dashed lines (yield distribution after land size adjustment). This shift is under the three returns to scale assumptions of the same direction: shifting mass to the left. This means more farmers have lower yield after the land size adjustment. These are the smaller farmers up to 0.8 acres but for the purpose of this study we want to see how this changes along the yield distribution if we disaggregate measures of land size contributions.

We divide non negative and negative land size contributions to see how land size contributions behave differently across the yield distribution. We replicate the same comparisons of kernel smoothing distributions between land size unadjusted and observed yields in figure 27. We can see that the presence of negative land size contributions to yield difference moves farmers towards lower yields (that are below the median yield level of 540 Kg acre^{-1} plotted as a vertical line). Figure 28 represents, in the same way, instead the non negative contributions of land size to yield difference. The non negative contributions to yield difference of land size move instead farmers towards higher yields (that are higher than the median level of yield).

To see if it is true that there is a differential impact of land size for higher yielding or lower yielding farmers, we divide precisely between the ones that are below the median or greater than or equal to the median level of 540 Kg acre^{-1}. Among lower yield farmers in figure 29 we see much less clear evidence of shifts of probability mass to the left signaling that not all lower yielding farmers are negatively affected by land size. In the same way when we analyze the higher yield farmers (as the median or higher) in figure 30 we see no particular evidence of shifts of probability mass to the right. A shift to the right would be expected if we were to think that higher yield farmers would be positively affected by land size. This counterintuitive result seems to be caused by the fact that many farmers that are both below and above the median level have a zero measured contribution of land size to yield difference. This is probably where this measurement differs from usual regression methods. While these farmers have differing land sizes, with the present methods, after taking into account land quality and efficiency explicitly, the contribution to yield difference of this difference in land sizes is null. To show this we isolate the farmers with zero contribution of land size to yield and we show their distribution of yields in figure 31. They are more on the lower side of the median. We show what is their distribution of land sizes in figure 32. More importantly we show how the sizes of these household farmers are distributed along the yield distribution in figure 33. In this figure we see that there is a negative relationship between land size and yield among the farmers that, in our measures, have no contribution of size to yield difference. This relationship is strongly significantly negative with nonparametric Spearman correlation tests (-0.3041 for constant returns, -0.3387 for non-increasing returns, and -0.3131 for variable returns all significant at less than 1% level). This is so because the efficiency index for these farmers is decreasing at the same time. This is shown by a strongly negative relationship between land size and the efficiency index. Nonparametric Spearman correlation tests (-0.4766 for constant returns, -0.5467 for non-increasing returns, and -0.6265 for variable returns) are all significant at less than 1% level. This negative relationship means that increasing land size increases the relative inefficiency of these families with respect to the median unit. There is not such a relationship at the level of the total sample.

This means that with usual methods their land measures are negatively correlated with yield and they are contributing to characterize the negative empirical regularity. But our methods instead predict that these sizes do not change the counter factual production measures if you separate contributions of land quality, efficiency, and other inputs. No changes in the counter factual production points are evidenced for these farmers if we take solely the effect of changes in land size into account as in our productivity accounting method. This fact means that these negative contributions to changes in the production measures are mistakenly thought to be caused by land size while instead are probably the outcome of inefficiency. This is evidence of the insignificance of the negative empirical relationship between land size contributions to yield difference and observed yield. But these are only descriptive methods. To discover if land size has actually a statistically significant effect we have to consider any difference on the whole distribution caused by the components of our quadripartite decomposition.

Exploiting the nonparametric nature of the productivity accounting measures used we explore the behavior of the distribution as a whole. In other words, we want to see in our method which component relevant to our research shapes the observed yield distribution more significantly. We do this in a more general way than correlation tests and in a more statistical way than visual inspection of density distributions by studying any deviations of two distributions, focusing on an integrated squared density difference test by Li, Maasoumi, and Racine (2009). This smoothing test is shown to have advantages on the non-smoothing tests of difference of two distributions, such as the Kolmogorov-Smirnov test (Li, Maasoumi, and Racine 2009).

As shown in the methodological section we ask ourselves which component actually brings the distribution of yields from the unit of reference (in this case the median value) to the observed yields distribution. This is equivalent to a shift from the counter factual distribution y_1^I/l_1 to the observed yields distribution as can be seen in figure 34. When the null hypothesis of the test by Li, Maasoumi, and Racine (2009) is not rejected anymore by successively testing counter factual distributions against observed yields, we would then have found the component that plays the major role in shaping observed yield distribution. We can also study the importance of the adjustment by studying the probability value. We can then qualify the nature of the change brought by this component on the counter factual yield distribution.

We show informally which component is most important comparing kernel smoothing density estimates of observed yields (dashed line) and of different counter factual distributions of the different yield components. In particular, we present the counter factual distributions y^L, y^Q, and y^{QL} as defined in the methodological section. We remind here that the counter factual distributions y^L and y^Q are the observed yield distributions without the final component of land quality and land size, respectively. So the difference between the counter factual distributions and the actual yield distribution is the contribution of those characteristics to yield. Analogously, the difference between y^{QL} and the observed yield distribution is the effect of efficiency. Figure 35 shows the difference between y^{Q} and observed yields with empirical cumulative distributions. Figure 36 shows the difference between y^{L} and observed yields with empirical cumulative distributions. In figure 37 finally we show instead the effect of efficiency adjustment. This effect seems to be really strong. The efficiency effect seems to be the responsible of a big portion of the shift between y^{I} and observed yields distribution. Considering the particular, almost bimodal shape of y^{I} we could ask what are the characteristics of these families, and why this happens, but this is not the focus here and is left for future research.

Exploiting new developments in the statistical nonparametric theory we can then test formally the most important contributor to shaping the observed yield distribution by means of a test by Li, Maasoumi, and Racine (2009). From table 14 we can notice that introducing the other inputs component to obtain y^{I} does not make the distribution statistically equal to the observed yield distribution. This is true across different returns to scale. We see instead that the efficiency component makes the distributions statistically equal. This is particularly true for constant returns to scale and for non-increasing returns to scale where the p-values reach levels well above 0.25. It is not the same in the case of variables returns to scale where the p-value is only 0.089. This means that still efficiency does not make the counter factual distribution statistically equal to observed yields, at least for a 10% level test. This also means that for the variable returns to scale case there is a stronger impact of the non introduced components of land quality and land size, compared to the case of constant and non-increasing returns. This is also confirmed by the mean percentage contirbution rates shown in figure 22. In particular, introducing land size component makes the p-value of the test jump to 0.947 in the case of variable returns. This high increase in p-value means that the effect of land size in the variable returns is relatively big compared to the other returns assumptions.

This also means, differentially that there is not much left for land quality to change the distribution if you include already land size. However if land quality were introduced instead of land size, the p-value would grow similarly up to 0.901. This means that, after efficiency, probably land size has a bigger impact than land quality in making the distributions equal. Different are instead the land size and land quality impacts in the constant and non-increasing returns case. The p-value becomes very high when including land size, but on the other hand it moves very little when introducing land quality after efficiency. The distributions move in a different way for different returns to scale. In particular, under variable returns the adjustment for land quality has a bigger impact than under the other assumptions. This means that land quality interacts differently especially for farmers who are on the increasing returns side of the production technology. For them in particular, land quality seems to be very important.

This analysis shows a strong decisive impact of efficiency in shaping the actual yield distribution, confirmed when studying qualitatively the kernel density estimates. This analysis also shows a differential impact of land quality in the variable returns to scale. Moreover, we show that land size assumes an importance in making the distributions equal only under variable returns to scale and only when introduced directly after y_1^E/l_1. If instead we introduce, after inputs, only land size or only land quality to create respectively y_1^{IL}/l_1 and y_1^{IQ}/l_1, there is no significant change. No change even when we include both in order to create y_1^{QL}/l_1, as can be seen from table 14. This confirms once again the qualitative evidence of the importance of efficiency component shifting the distribution from the counter factual y_1^I/l_1 to the distribution of observed yields as shown in figure 34.

We also test for difference among returns to scale of the productivity components. As we can see in table 15, there seems to be no particular difference among returns to scale apart for when introducing land size in y_1^L/l_1 and y_1^{IL}/l_1. This happens when testing equality of constant returns estimates with non-increasing (p-value of around 13%) and variable returns estimates (p-value less than 5%). The difference between returns to scale assumptions suggests that there are different ways land size interacts with farms on the upper and lower parts of the size distribution. This is where main differences among the two assumptions on scale play a role in a significant (variable returns case) or not so significant way (non-increasing returns case). The same qualitative results can be seen from studying the scenario of a mean value reference unit as can be seen in table 16.

Conclusions

The methods presented in this study allow knowing more on whether the long debated inverse land size-productivity relationship is true or false. Land quality is not taken usually into account quantitatively in the literature. When it is taken into account it is considered with very restrictive statistical assumptions. The hypothesis is that this, together with the other assumptions, among which production efficiency, cause the empirical regularity of the inverse land size-yield relationship. Ascertaining if this relationship is true is done in this study by taking into account land quality, land size, and efficiency explicitly, in productivity terms.

In particular, we decompose a yield index measure into four parts. We purge out the inefficiency and decompose the efficient production function difference into three components. Components are relative to land size, land quality, and other inputs. Many studies, with few exceptions, found land size empirically negatively correlated to measured yield. In this study many assumptions usually done are taken away. First, no efficiency assumption is done on household dry maize production. Secondly, no specific functional form of the technology is assumed. Thirdly, no returns to scale assumption is done a priori.

The fact of not assuming efficiency allows us to study the decomposition of the efficient points on the production function and not of the observed yields. This allows us to purge what is included in yield measurement but caused by inefficiency. The second assumption of no specific technological functional form comes together with the first and allows not imposing specific properties among inputs and outputs a priori. The third assumption of returns to scale is shown to bear some consequences when analyzing the statistical significance of results but these are not central features of this study.

We replicate usual regression methods and find a significant negative relationship between land size and observed yield. We decompose yield difference into efficiency, land quality, land size, and other inputs components relative to specific units for different returns to scale. Results are done for eight different reference units. We choose reference units with low and high values of respectively land size, land quality, and yield. Regression of percentage contributions of the quadripartite decomposition of observed yields shows different results depending on the reference unit.

Keeping the other characteristics the same and moving from a small land sized reference unit to a bigger farm transforms the relationship between land size contributions and yield from significantly positive to null or negatively sloped. Because we understand the relativity of these estimates, we repeat the calculations with mean values as reference unit. In this case the relationship between land size and yield is negative and significant. But we realize that, particularly in our case, mean statistics are less imformative than medians. We repeat the calculations against the median values taken as a reference unit. But also in this case the simple regression relationship between land size contributions and yield is negatively significantly sloped lending the side to what has usually been suggested as the regular negative yield-size relationship.

This is true when estimating the relationship with linear regressions. With nonparametric measures of correlation the negative relationship is not confirmed. More importantly, the view of the graph of contributions and yield suggests that a simple measure based on the average does not render a proper characterization of the variation of the contributions.

To understand how this works we study the distribution of the yields and land size contributions more closely isolating the families who have positive, zero, and negative contributions. When taking into account land quality, efficiency, size, and other inputs separately, we find that some farmers have zero contributions from land size to productivity. These farmers show evidence of an inverse significant relationship between yield and their land sizes, and at the same time a strong negative relationship of land size and the efficiency index. This is why many have registered the empirical relationship as a regularity when studying, in aggregate, parametric average behavior measures.

But these are just descriptive methods of the insignificance of the negative relationship between land size contributions to yield difference and observed yields. We follow the intent of exploring statistically more than the first and second moment of these distributions. We study any deviations among yield and several counter factual distributions with the integrated squared density difference test by Li, Maasoumi, and Racine (2009). In this way we want to see statistically which component is the one that shapes the observed yields distribution. From the results we see that there is a critical role of efficiency.

Land size under variable returns to scale, when applied after efficiency in the counter factual distributions, makes the counter factual yield distribution equal to observed yields for any statistically relevant level. But we acknowledge that this is not the case if land size component is applied before efficiency. Efficiency still plays the major role in shaping the distribution of yields. This means that neither land size nor land quality explain the shape of the yield distribution, even though they make up a comparable and, in some cases significant, percentage of yield difference rates. The same results are derived for the mean reference case.

The productivity accounting measures developed in this study show that with usual regression methods the yield-size negative relationship is present even when taking into account efficiency and land quality. With more general nonparametric measures the correlation is not present because a part of farmers with negative yield-size relationship is shown to have no contribution to yield differences when measured against the median. There is no critical role for land size in shaping the yield distribution also when we test the importance of contributions to yield difference statistically. Returns to scale assumptions do not interact critically with the importance land size and land quality have in shaping the yield distributions.

The last point we want to emphasize once more is the relativity of these measures. The findings on the shape of the distributions are robust to changes between the mean and the median reference choice. But the numeric values change when changing unit of reference. This means that a definitive answer to whether an inverse farm size-yield relationship is present or not could only come, once a less arbitrary reference unit choice would be available. But this is part of this contribution. We try to show that results from the methods proposed, and not solely, depend on the choice of the unit of reference.

Notes

[1]This test, if done in the case of not including the 9 zero yield units, shows a significantly negative relationship only under constant returns, while it is insignificant under non-increasing and variable returns to scale. The Spearman correlation coefficient between land contributions and observed yields, in the case of taking the mean as a reference point, is instead significantly negatively correlated for constant (-0.1913), non-increasing (-0.1859), and variable returns to scale (-0.1807) at 1% level.

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Figures

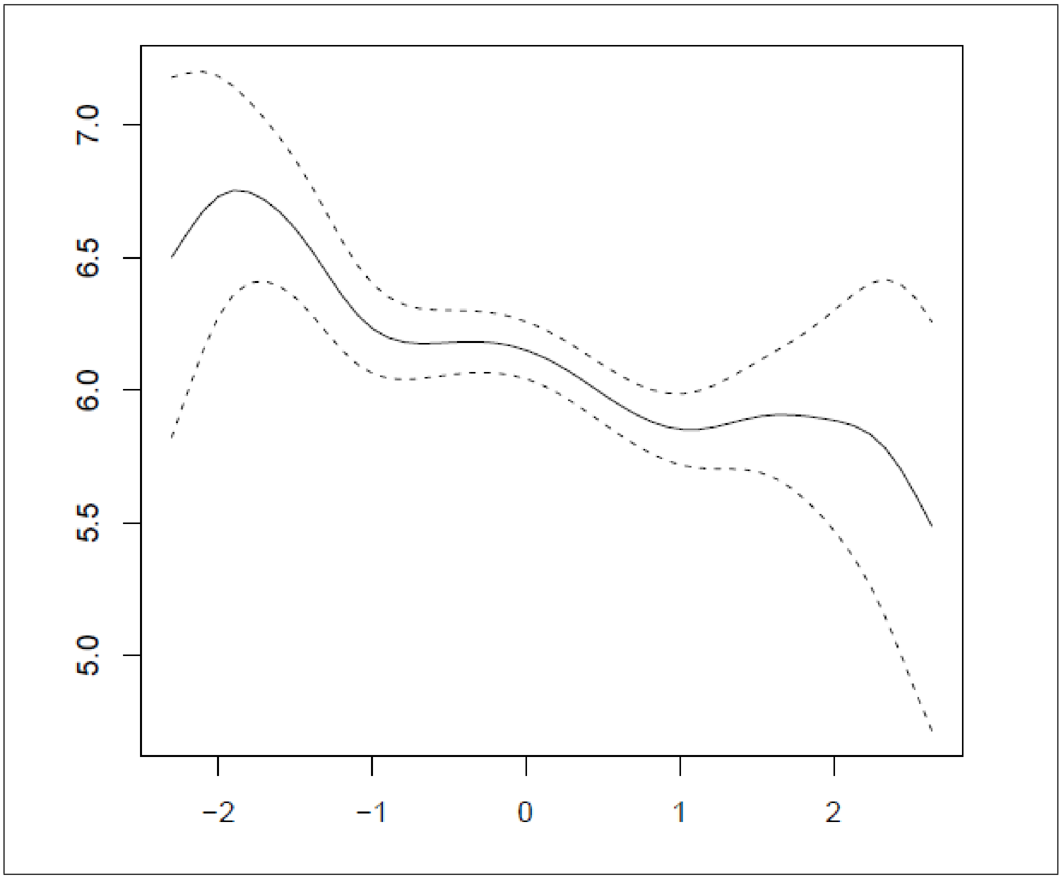

Figure 1. Negative empirical relationship between natural logarithm of yield of dry maize (on the vertical axis) and natural logarithm of land size (on the horizontal axis)

Note: There are only 443 observations considered in this graph because only 443 observations out of the 452 have a strictly positive yield.

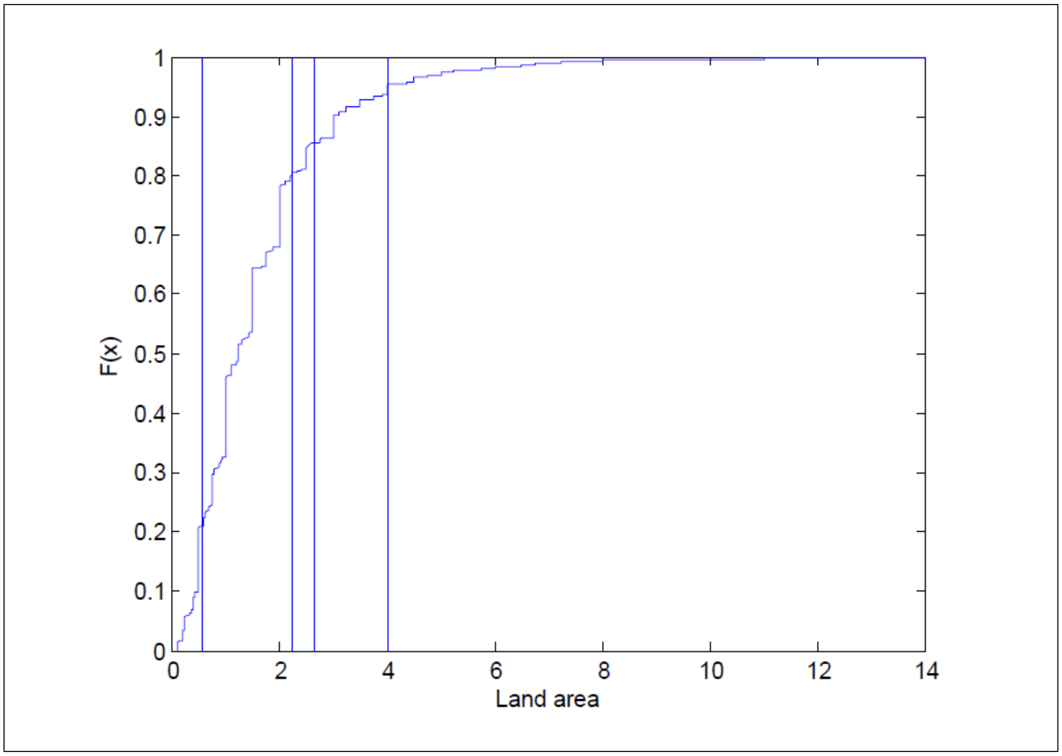

Figure 2. Empirical cumulative distribution of land size

Note: The lines plotted are in correspondence of 0.55 acres, 2.25 acres, 2.65 acres, and 4 acres.

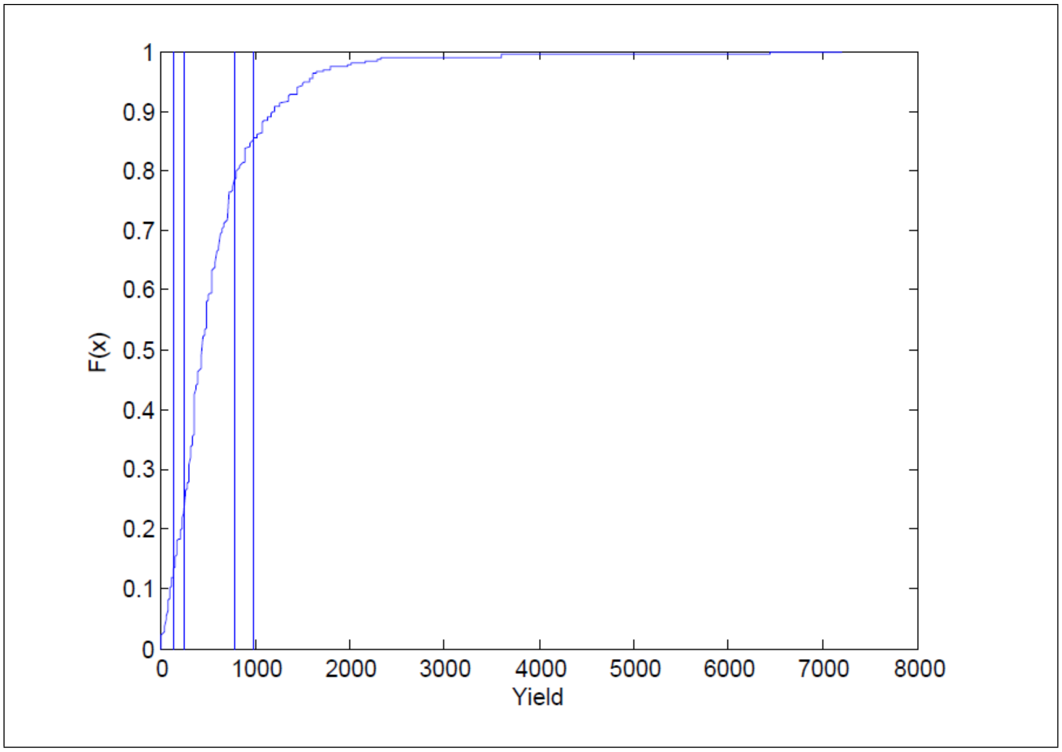

Figure 3. Empirical cumulative distribution of yield

Note: The lines plotted are in correspondence of values of yield of 135 Kg acre^{-1}, 240 Kg acre^{-1}, 787.5 Kg acre^{-1}, and 981 Kg acre^{-1}.

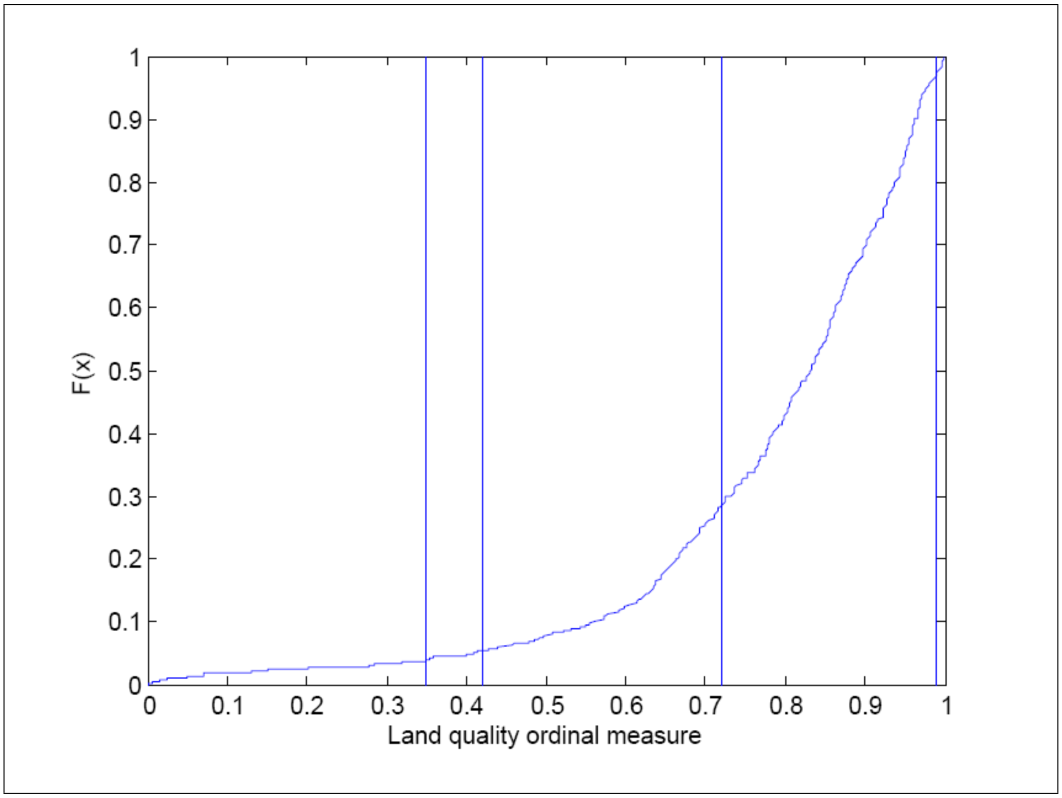

Figure 4. Empirical cumulative distribution of land quality under variable returns to scale

Note: The lines plotted are in correspondence of values of land quality index of 0.35, 0.42, 0.7199, and 0.99.

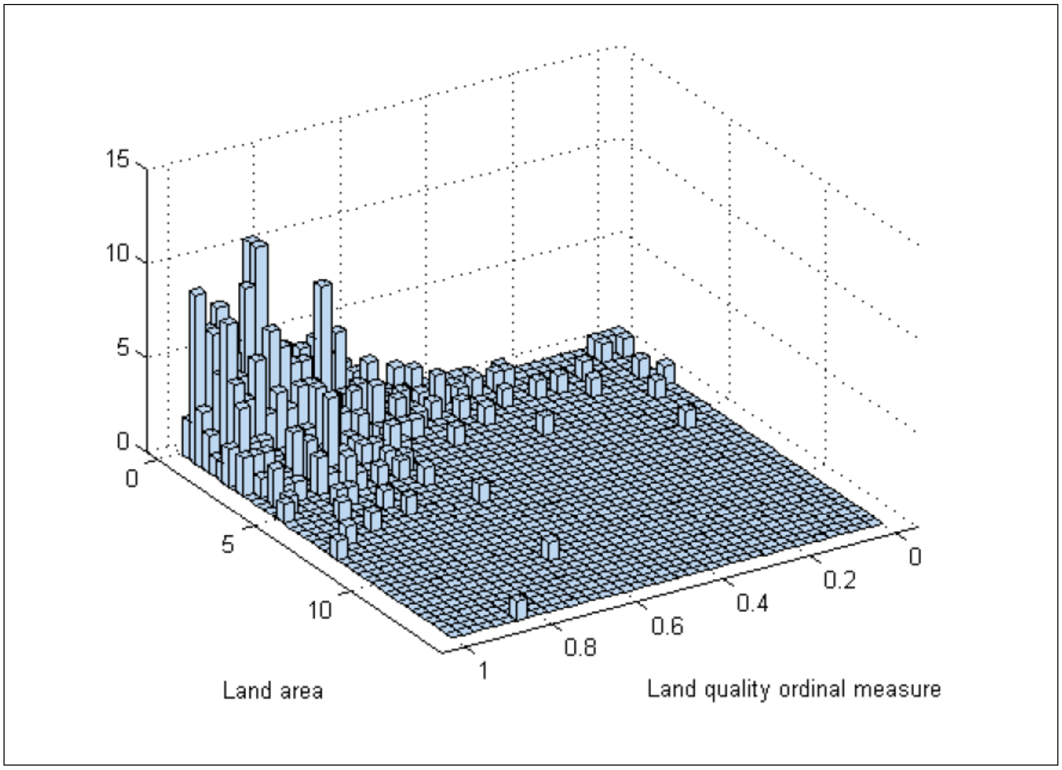

Figure 5. Empirical joint histogram of land area and land quality index under variable returns to scale

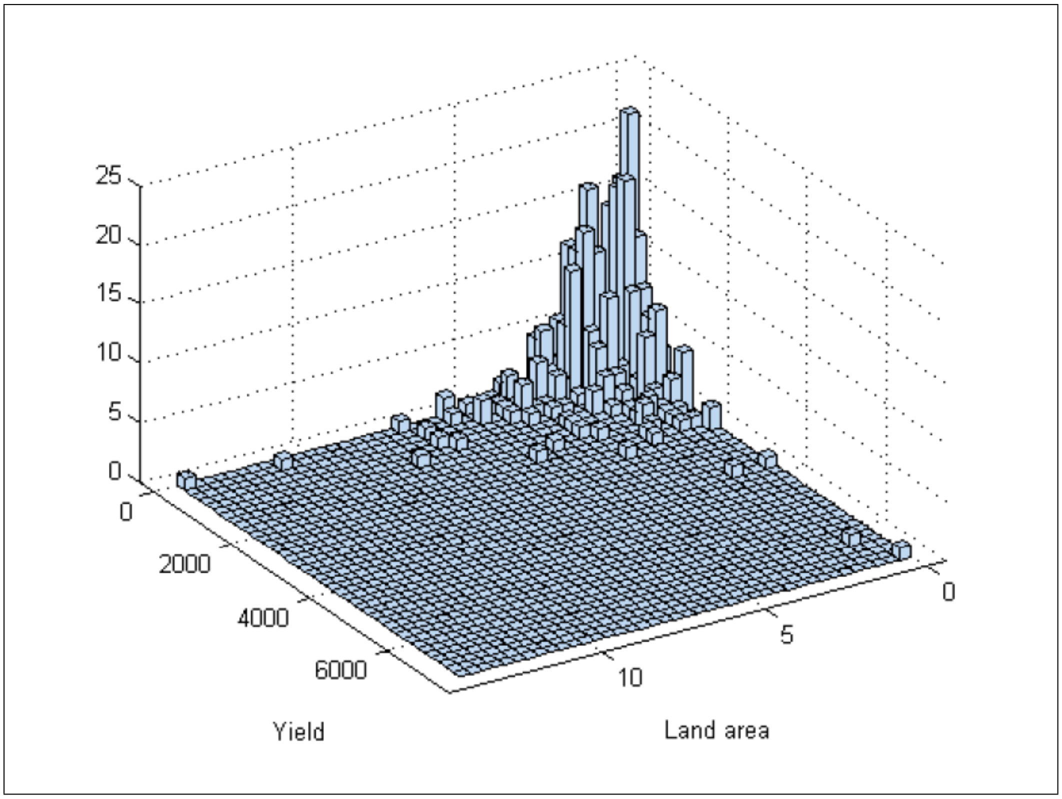

Figure 6. Empirical joint histogram of land area and observed yield

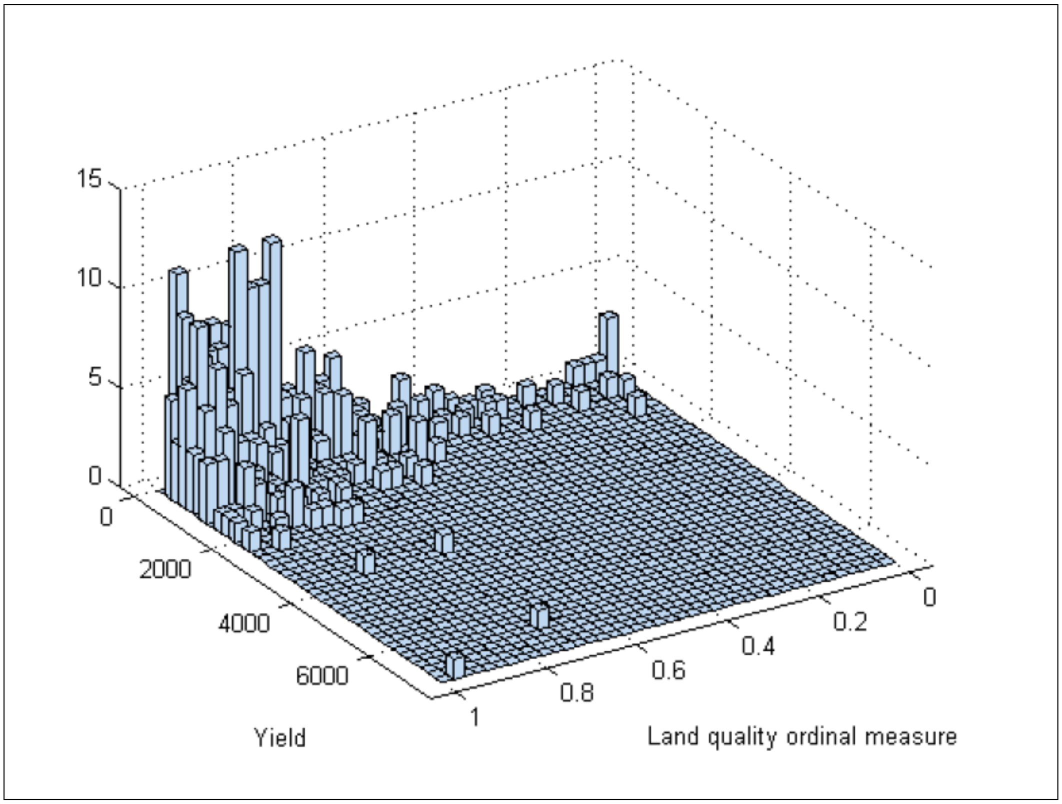

Figure 7. Empirical joint histogram of land quality under variable returns to scale and observed yield

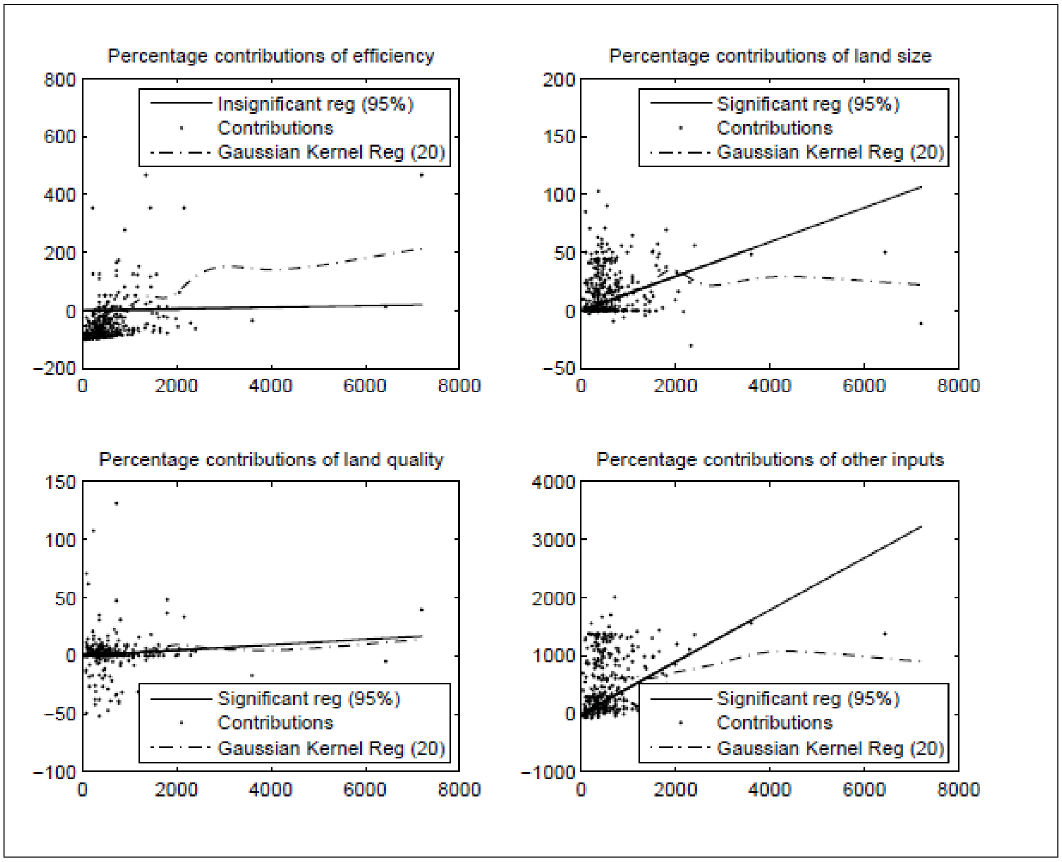

Figure 8. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with little land size, low yield, and low land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

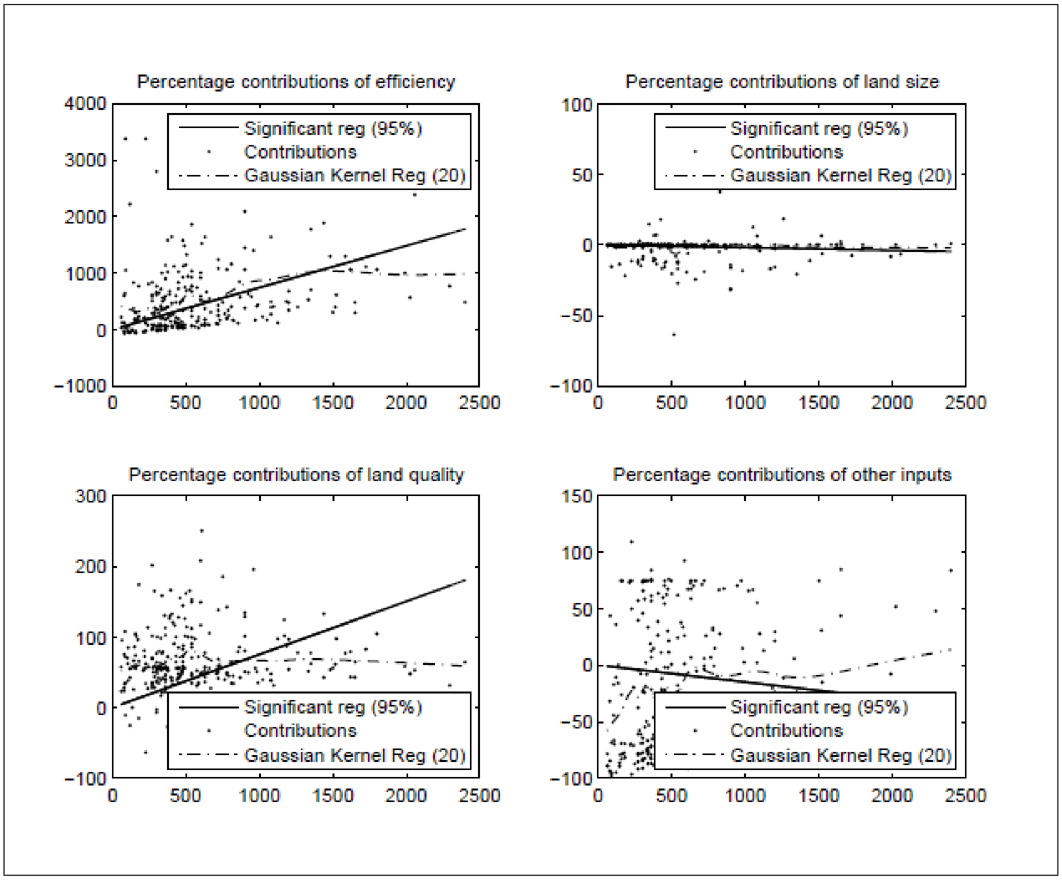

Figure 9. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with big land size, low yield, and low land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

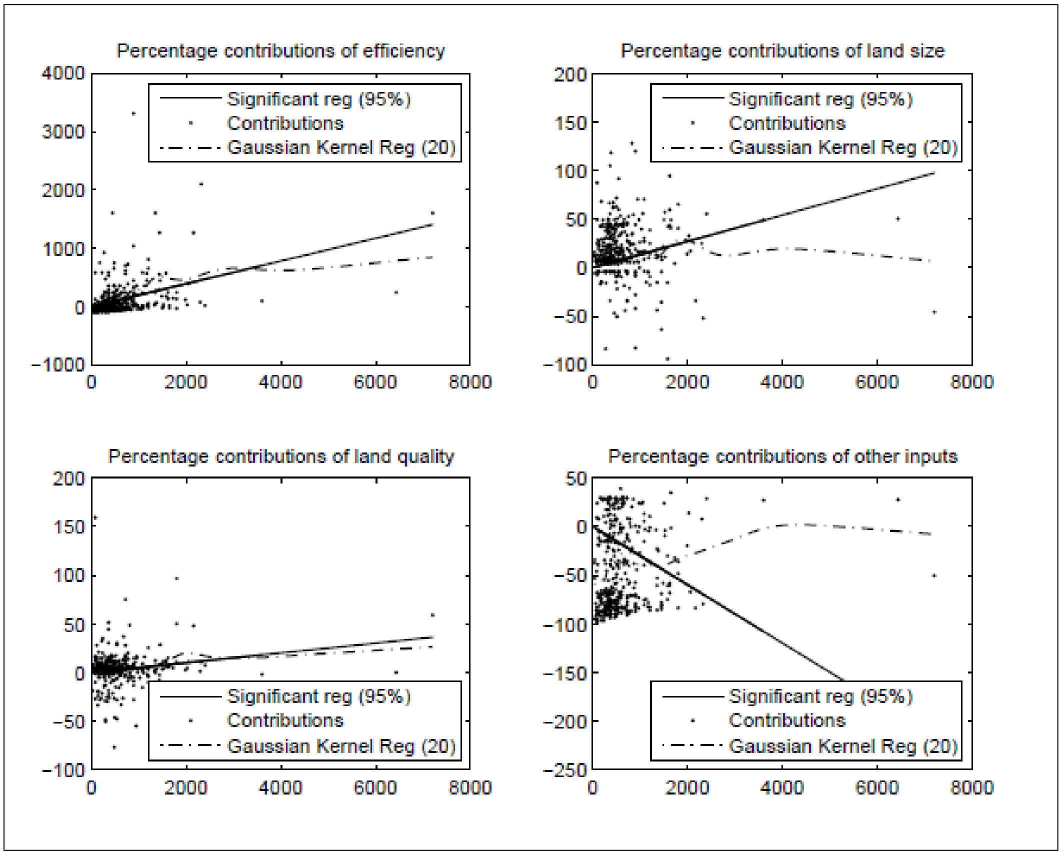

Figure 10. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with little land size, high yield, and low land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

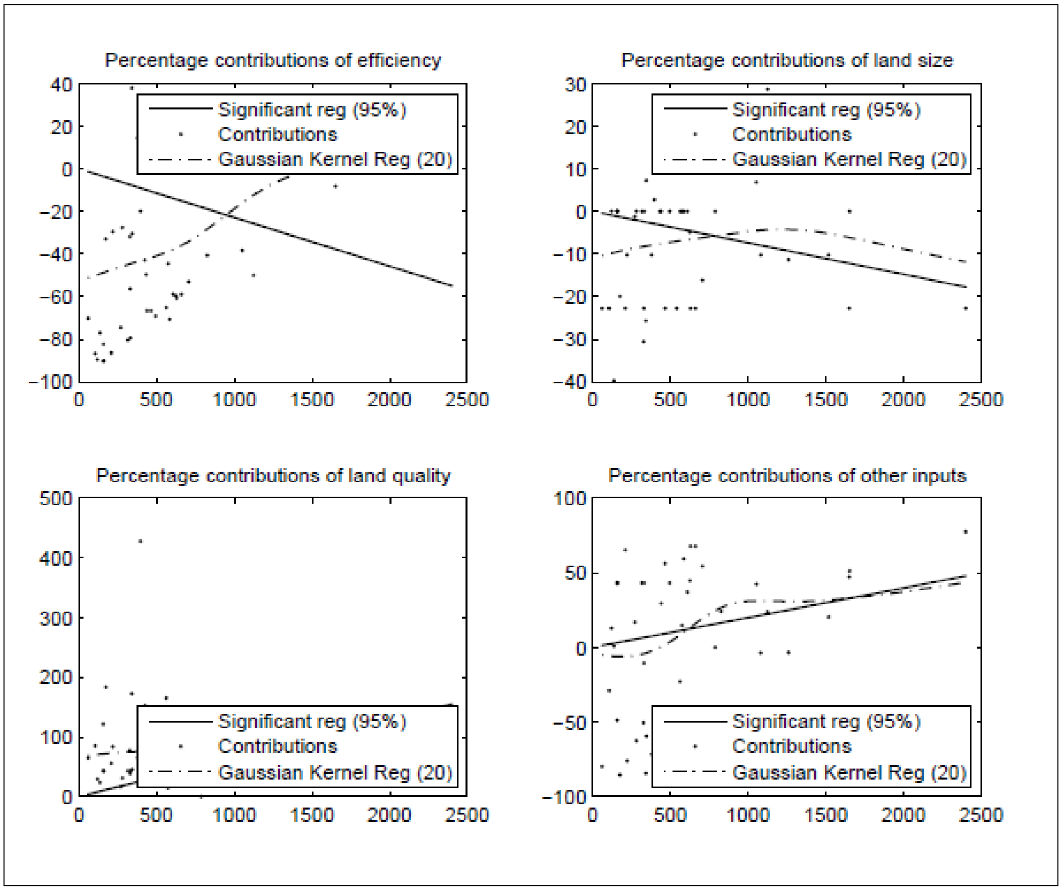

Figure 11. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with big land size, high yield, and low land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

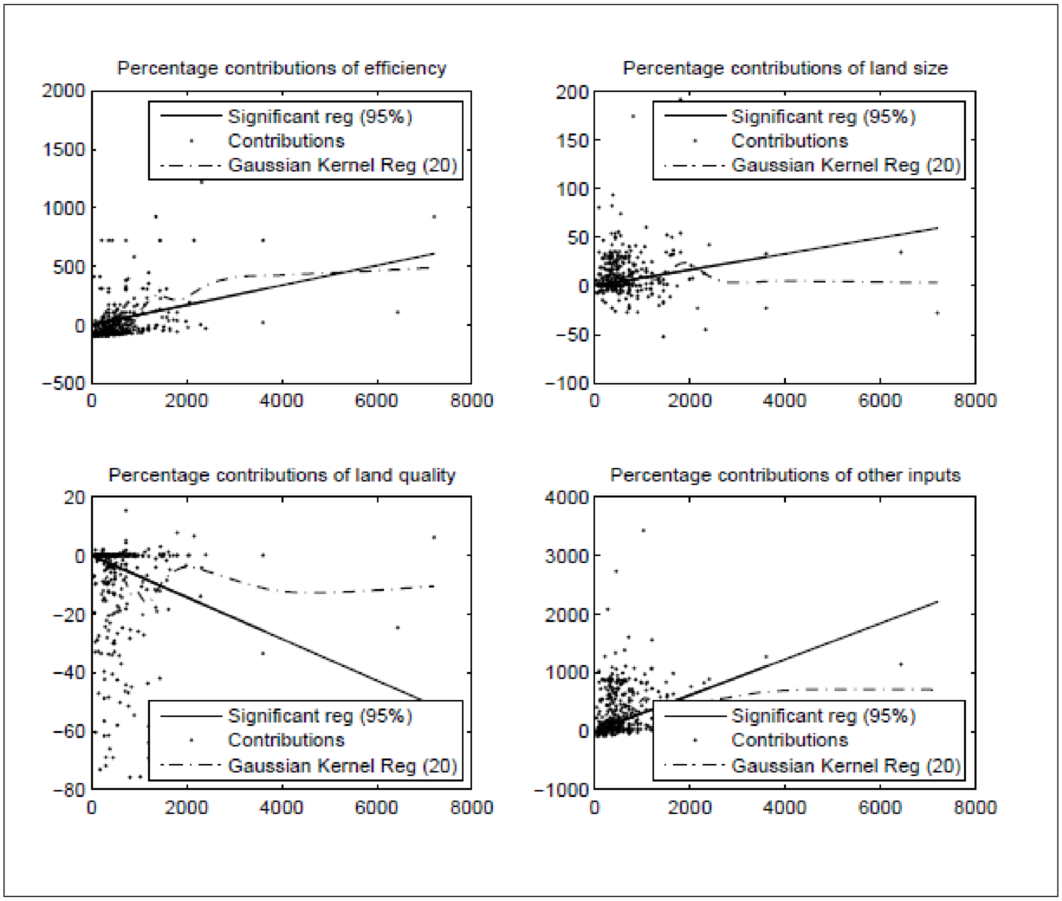

Figure 12. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with little land size, low yield, and high land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

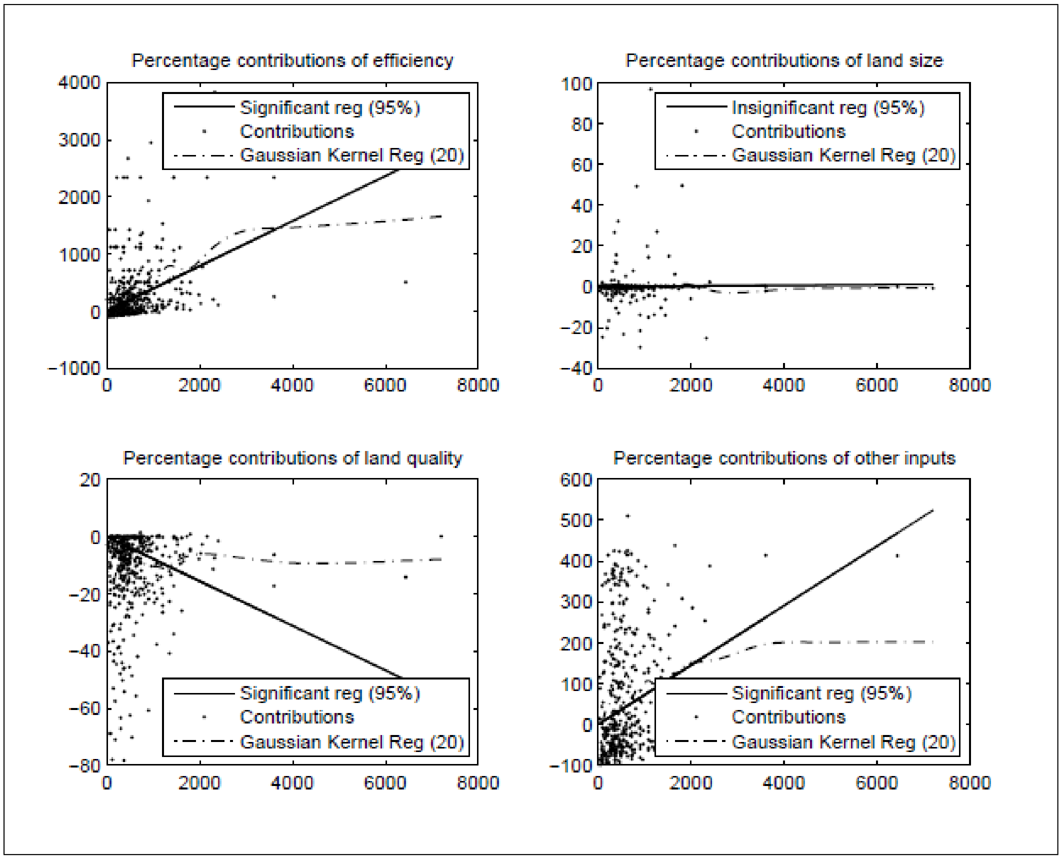

Figure 13. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with big land size, low yield, and high land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

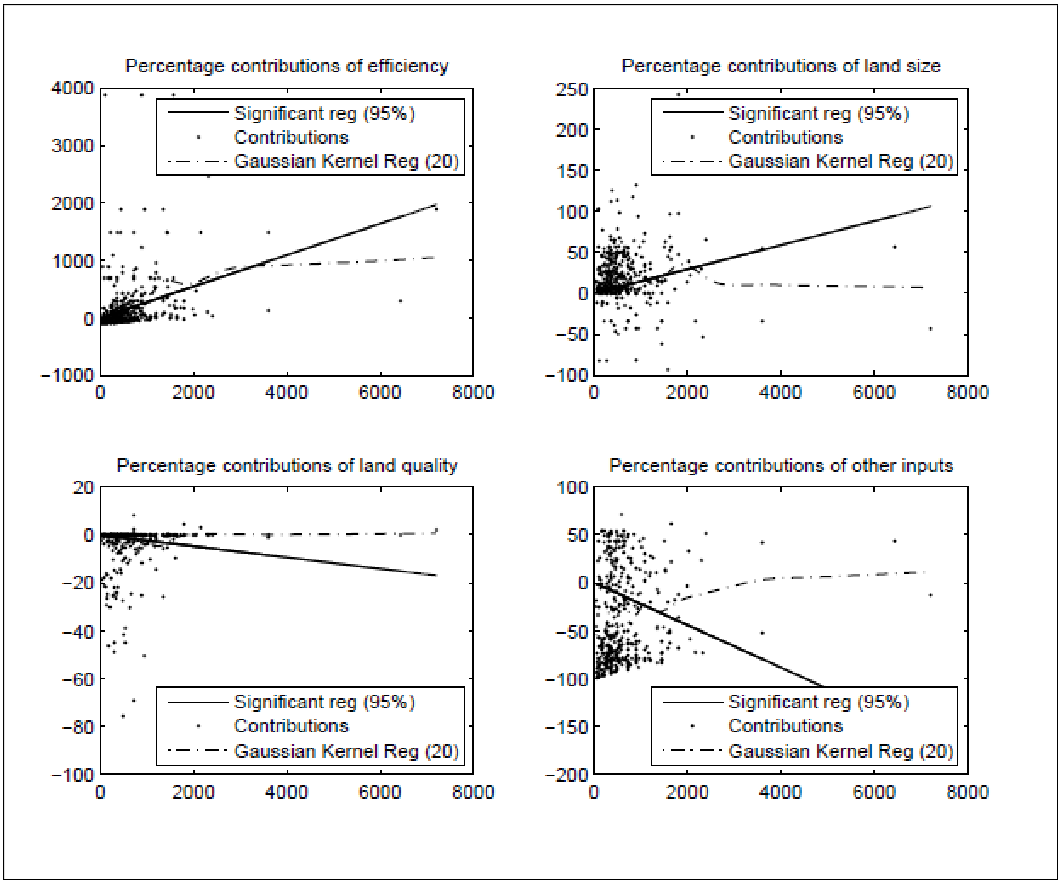

Figure 14. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with little land size, high yield, and high land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

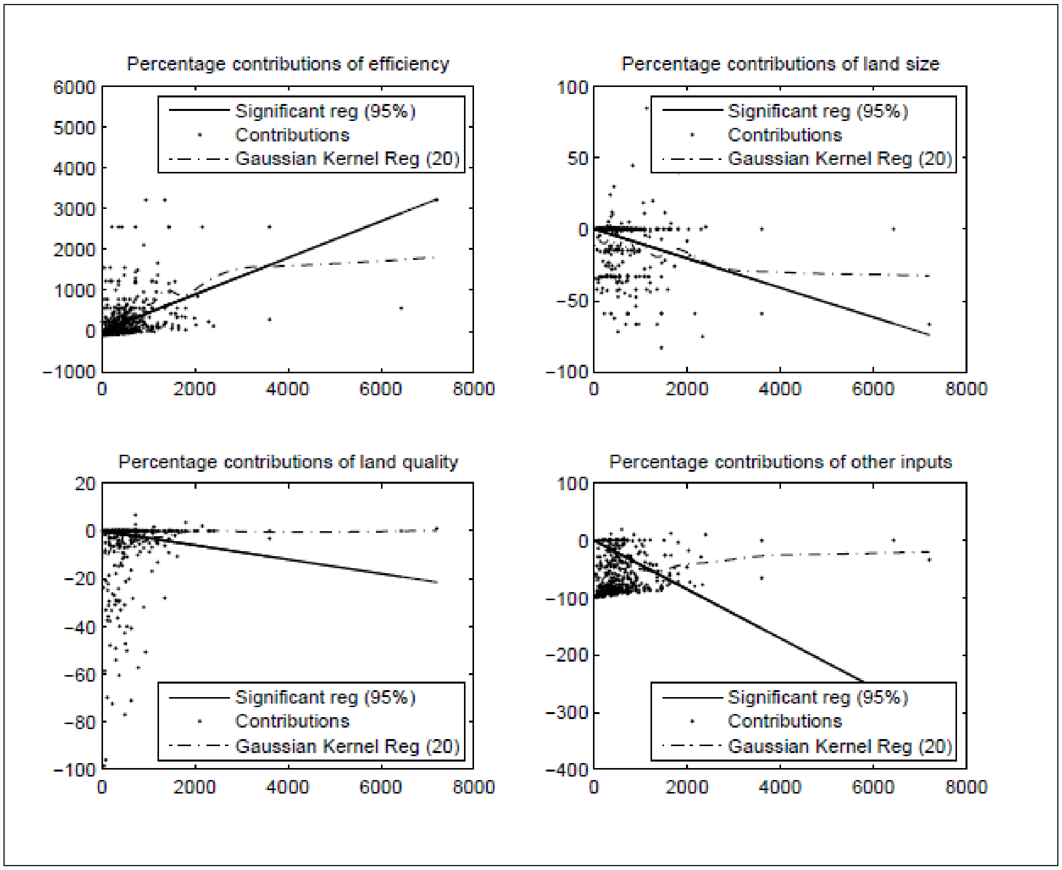

Figure 15. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with big land size, high yield, and high land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

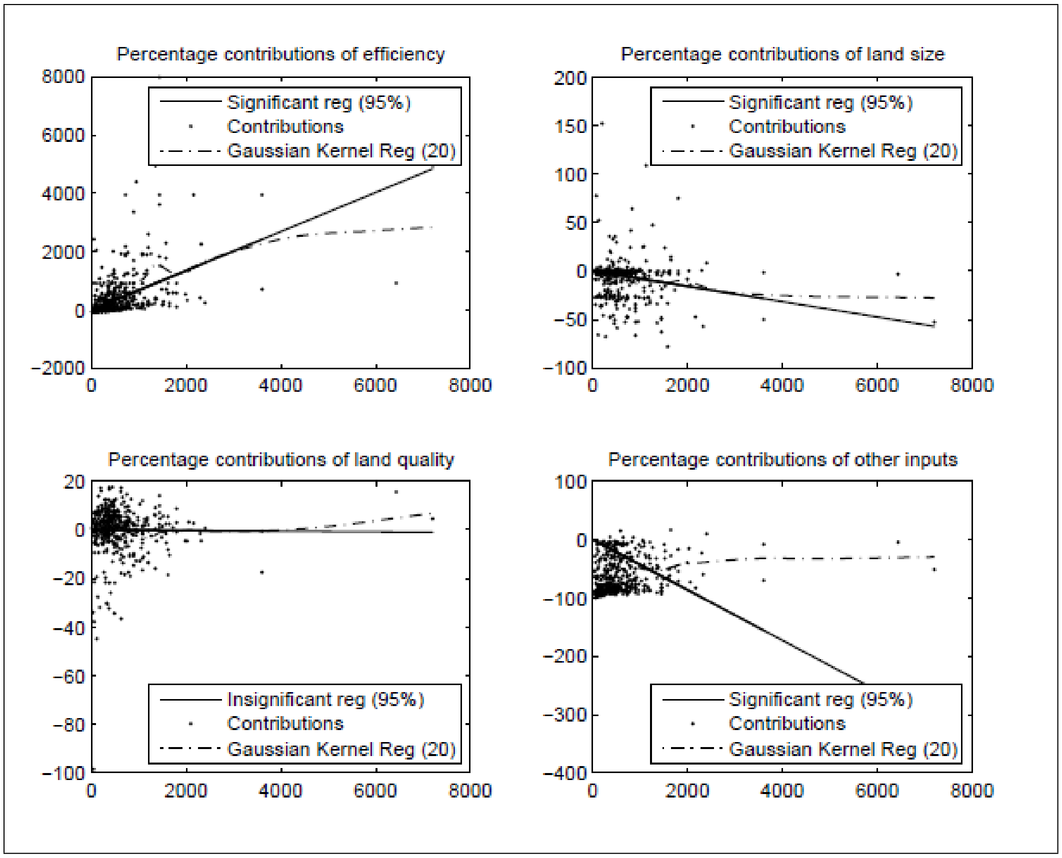

Figure 16. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with average land size, yield, and land quality under constant returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

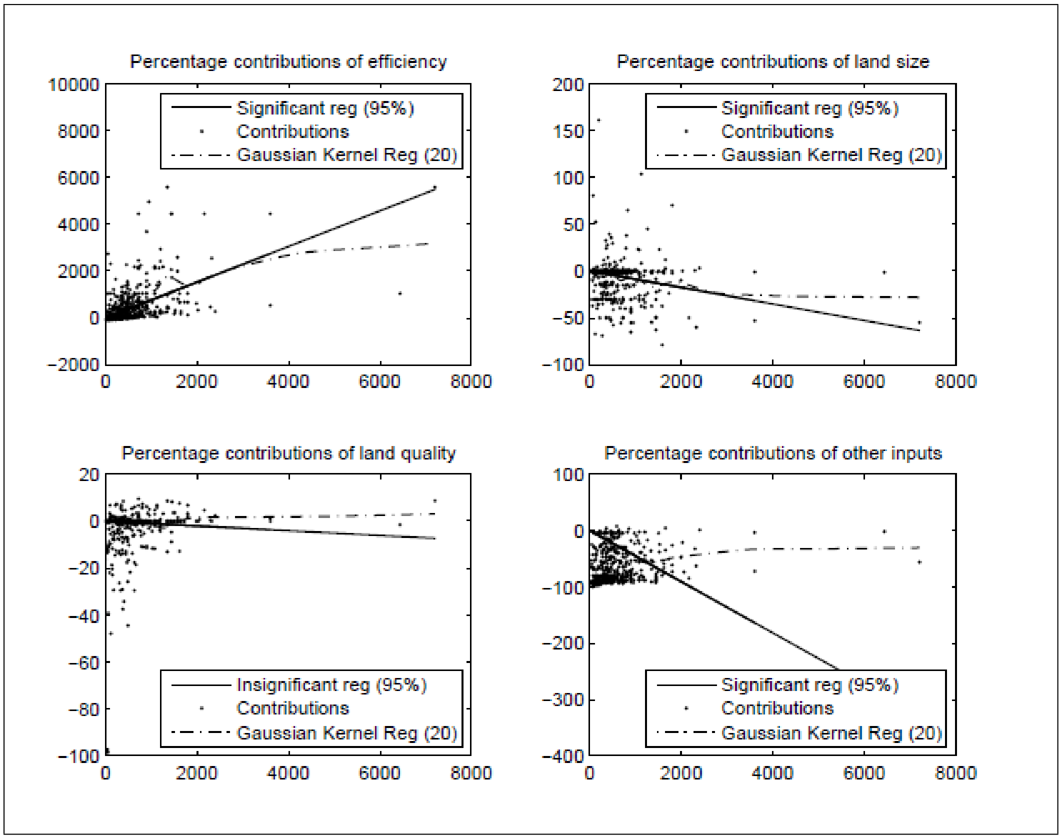

Figure 17. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with average land size, yield, and land quality under non-increasing returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

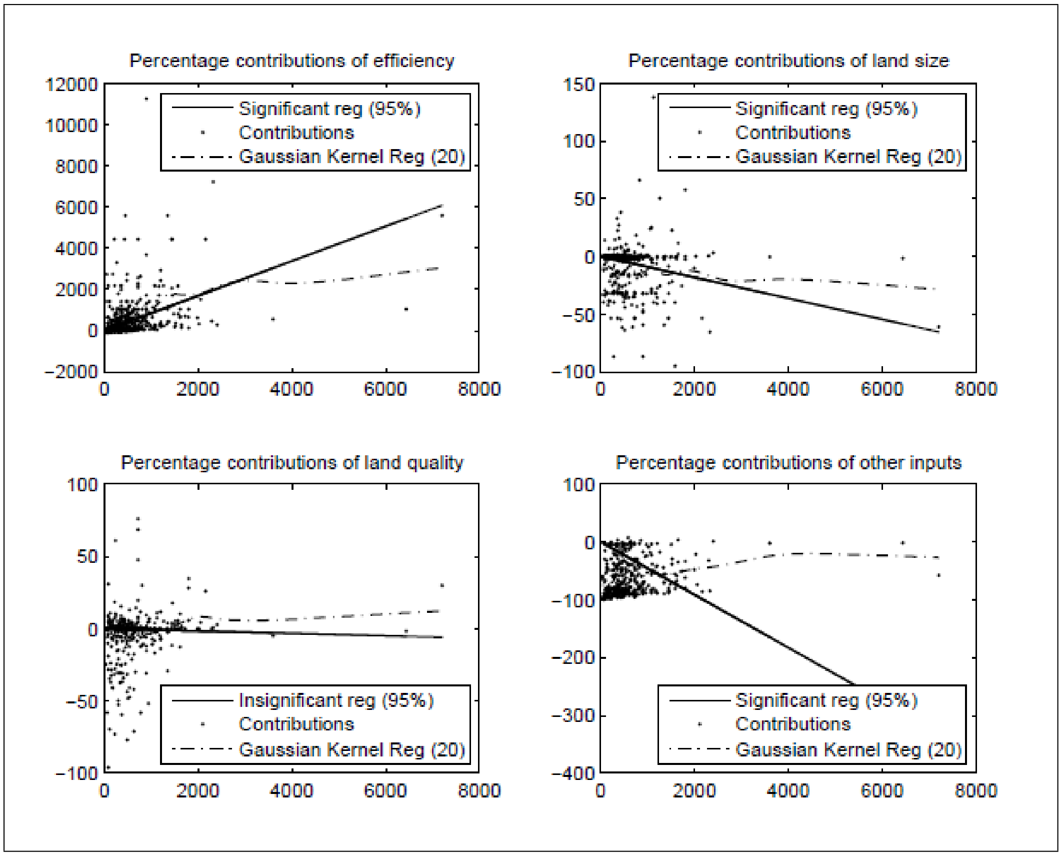

Figure 18. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with average land size, yield, and land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

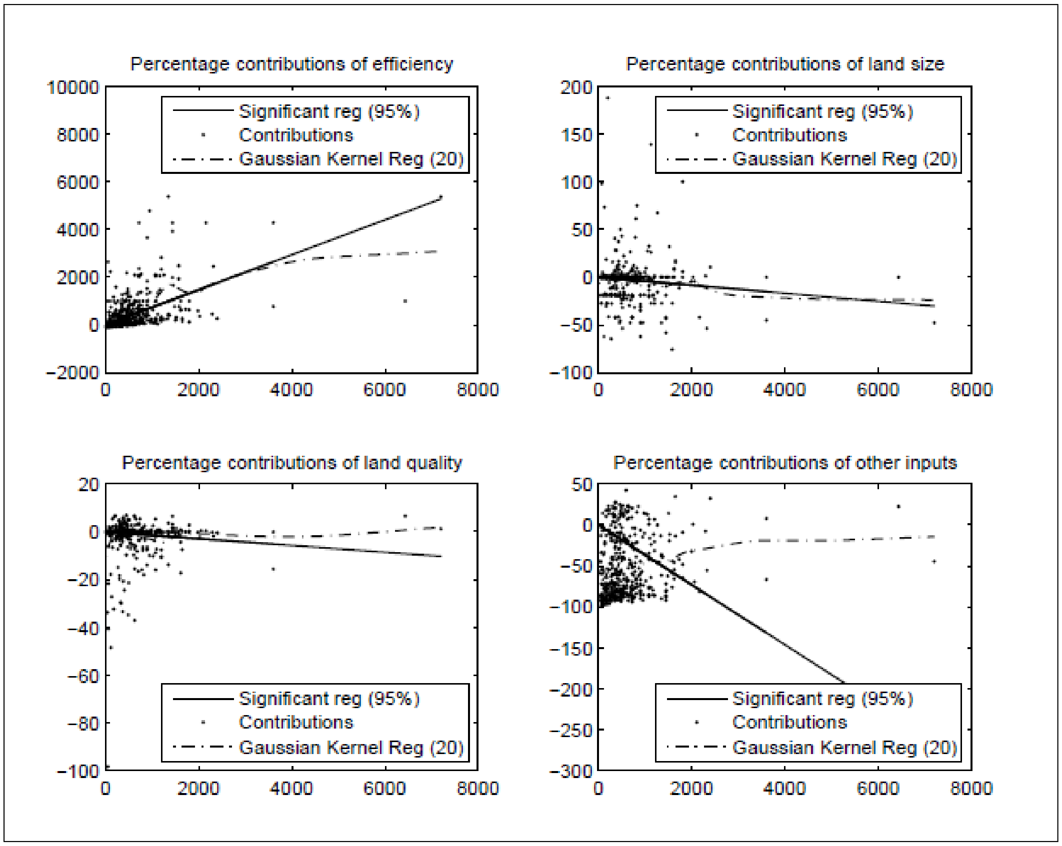

Figure 19. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with median land size, yield, and land quality under constant returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

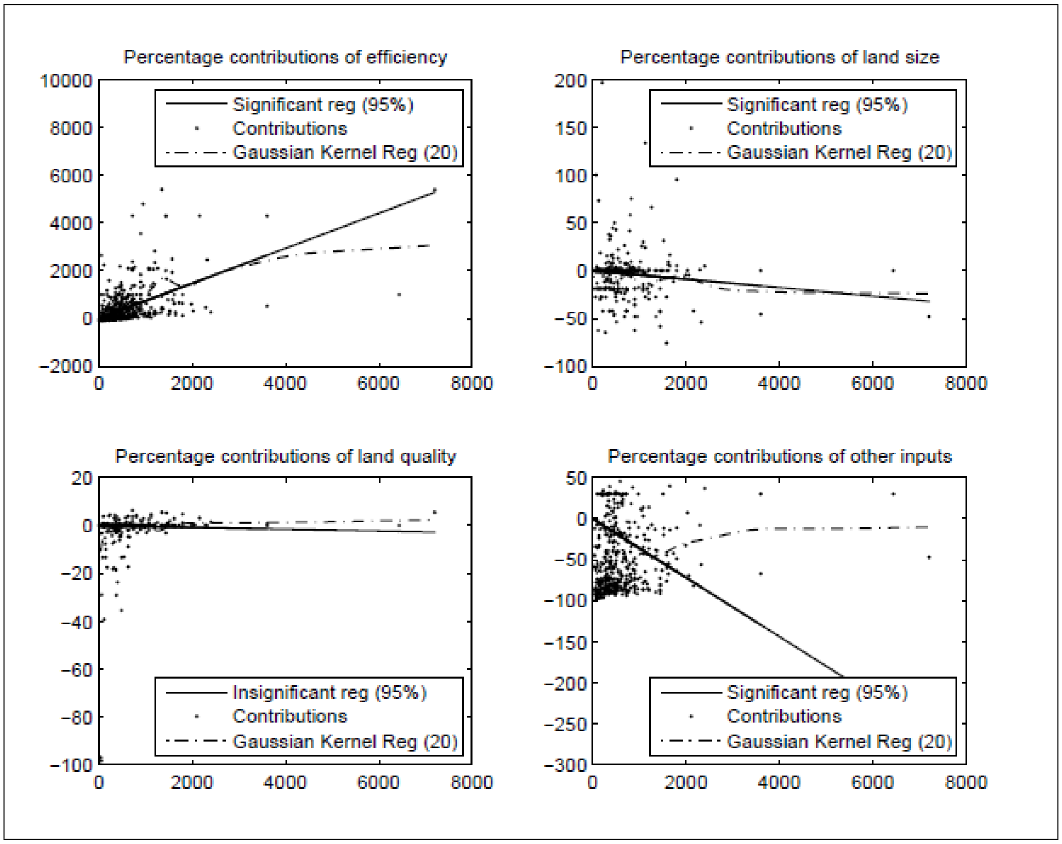

Figure 20. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with median land size, yield, and land quality under non-increasing returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

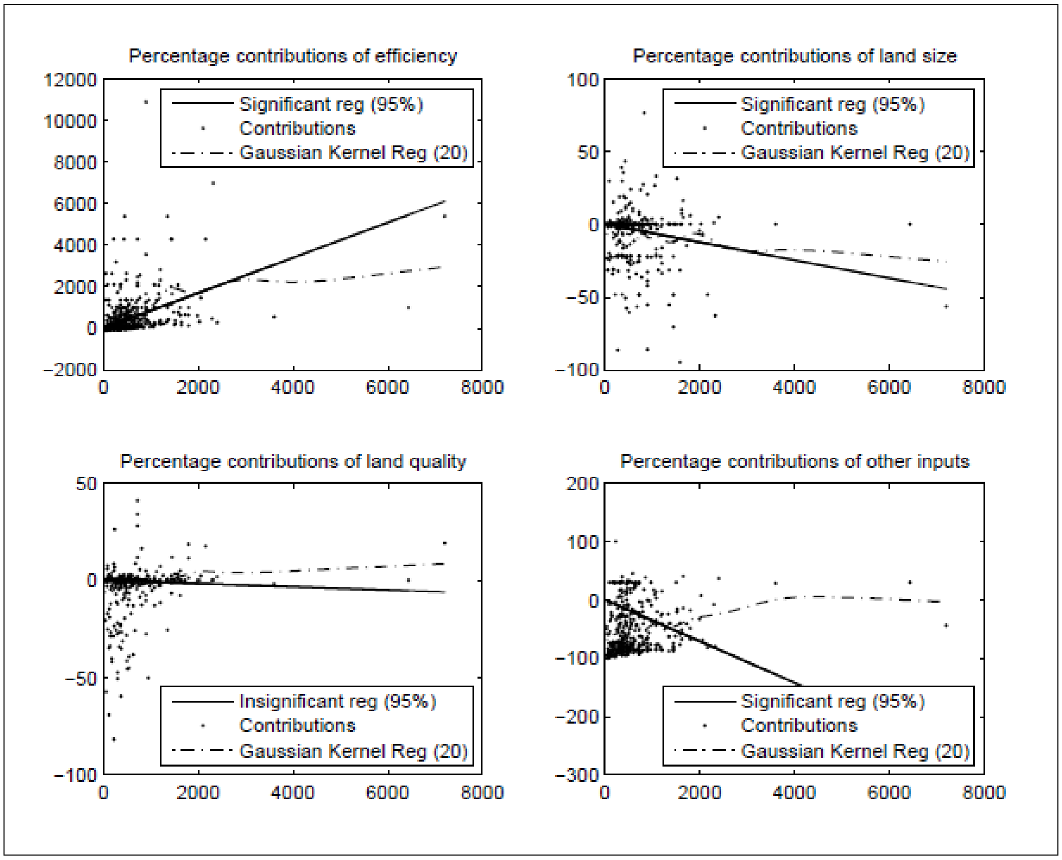

Figure 21. Percentage contributions of efficiency index, land quality, land size, and other inputs related to changes in observed yield when unit of reference is a household with median land size, yield, and land quality under variable returns to scale

Note: Percentage contributions are plotted as dots. Linear regression line is plotted with 95% significance level in the legend stating whether the coefficient is significant around the mean. Gaussian kernel line is also plotted to show the degree to which local regression (when done with 20 units at a time) differs from general regression.

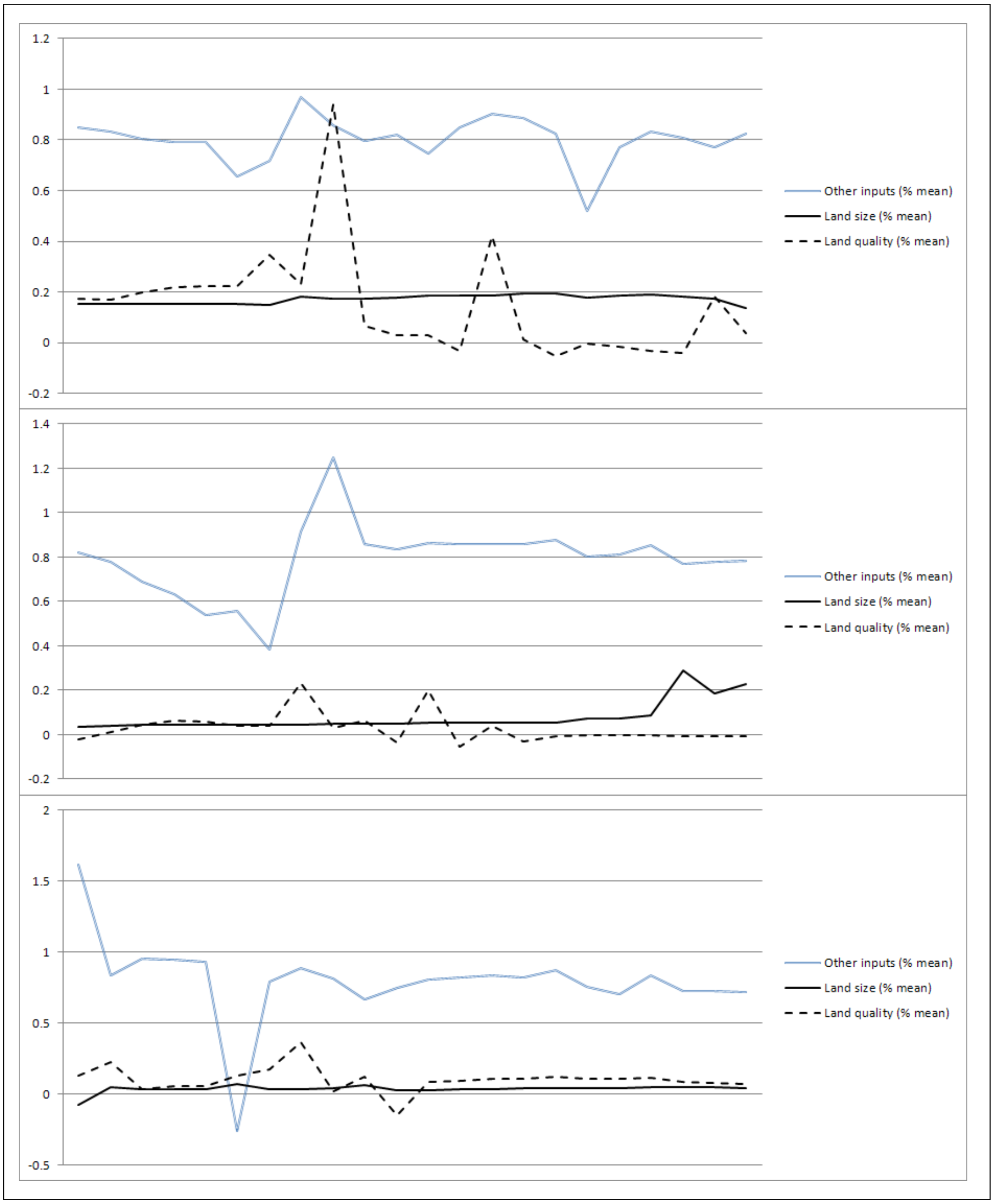

Figure 22. Average percentage contribution rates to yield difference for land quality, land size, and other inputs

Note: Measurements are presented for the last twenty percentiles (from the 80^{th} to the 100^{th}) of reference levels of inputs and outputs when calculating the land quality measure.

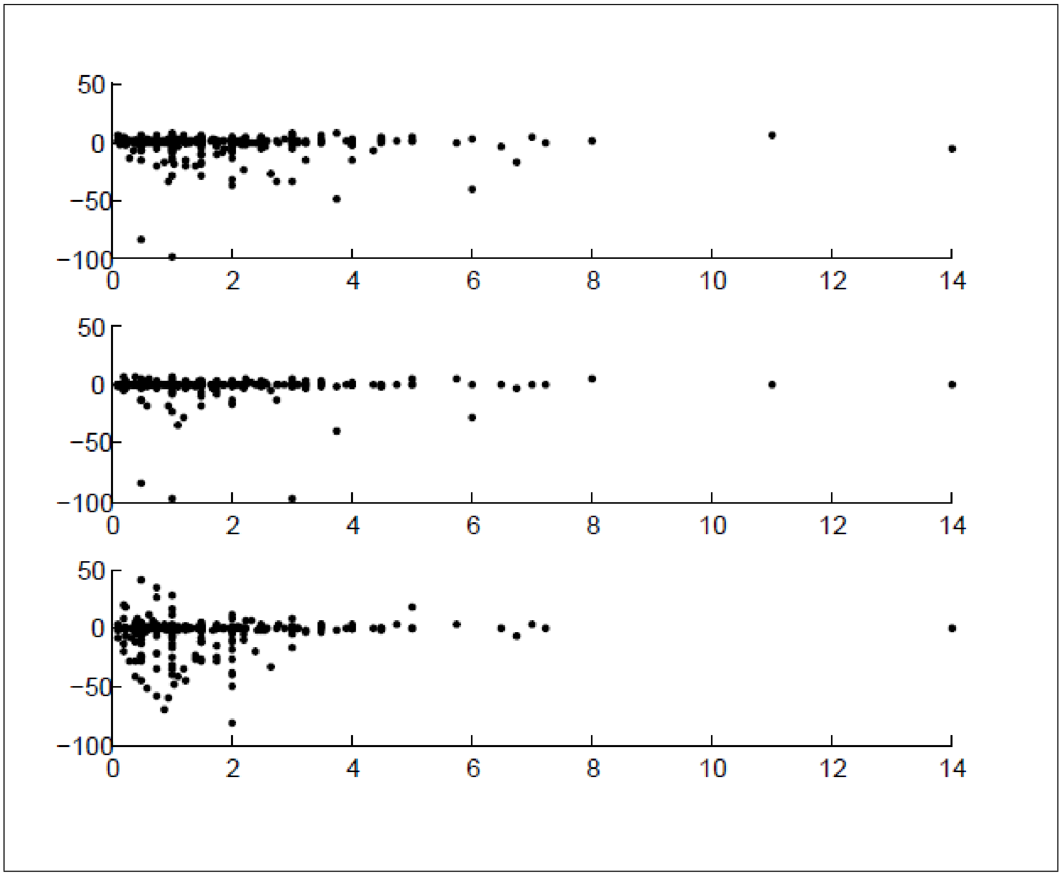

Figure 23. Percentage contributions of land quality under constant (upper), non-increasing (middle), and variable (lower) returns to scale against size of land

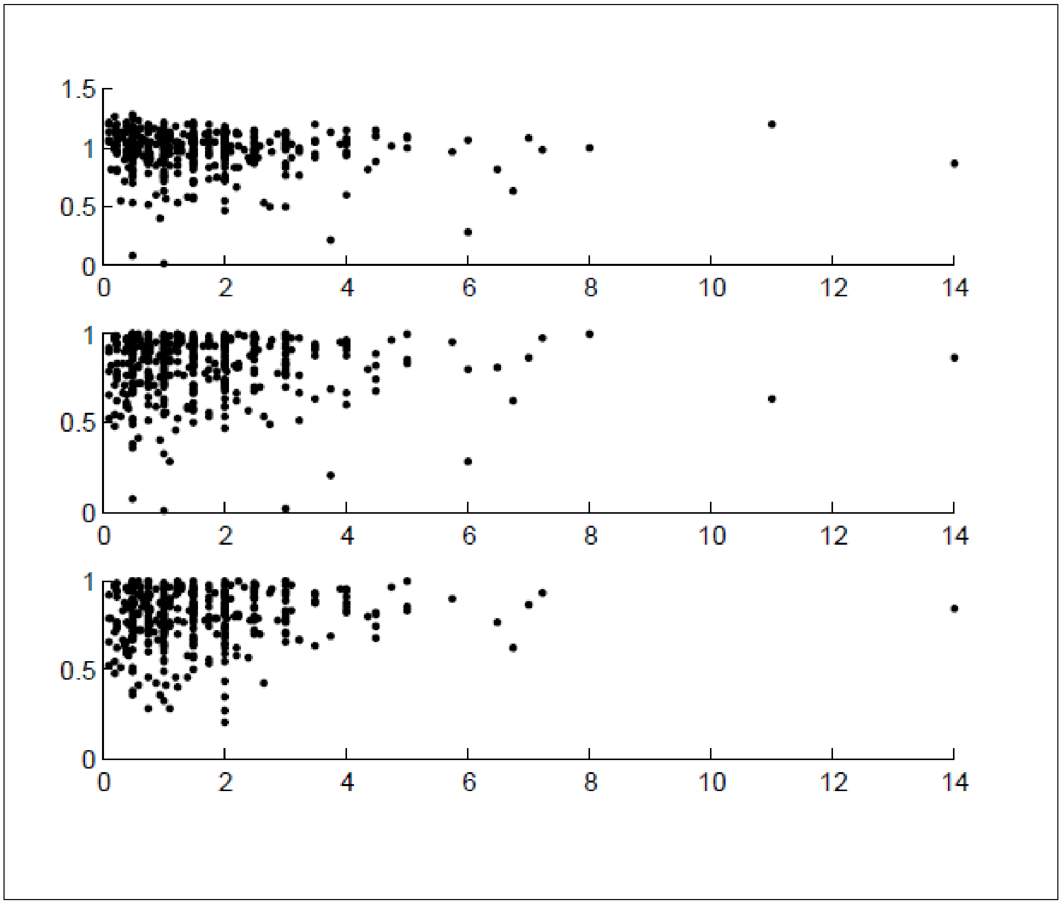

Figure 24. Land quality measurements under constant (upper), non-increasing (middle), and variable (lower) returns to scale against size of land

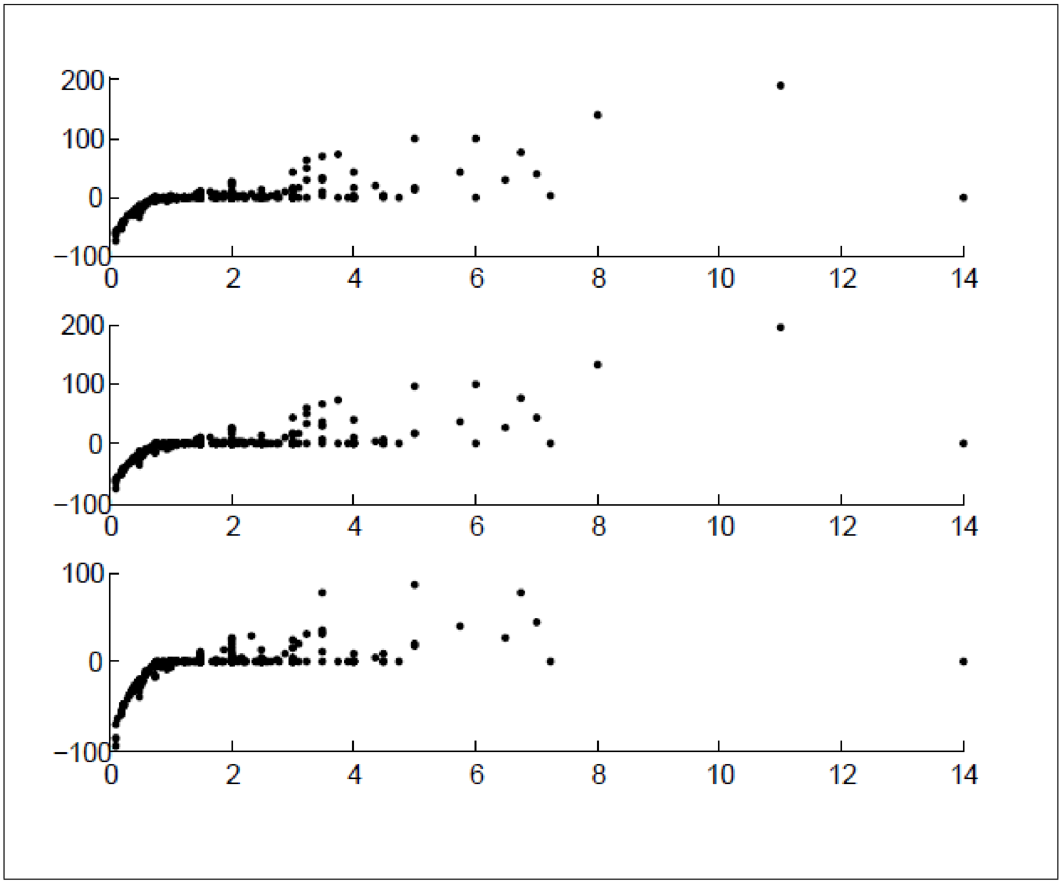

Figure 25. Percentage contributions of land size under constant (upper), non-increasing (middle), and variable (lower) returns to scale against size of land

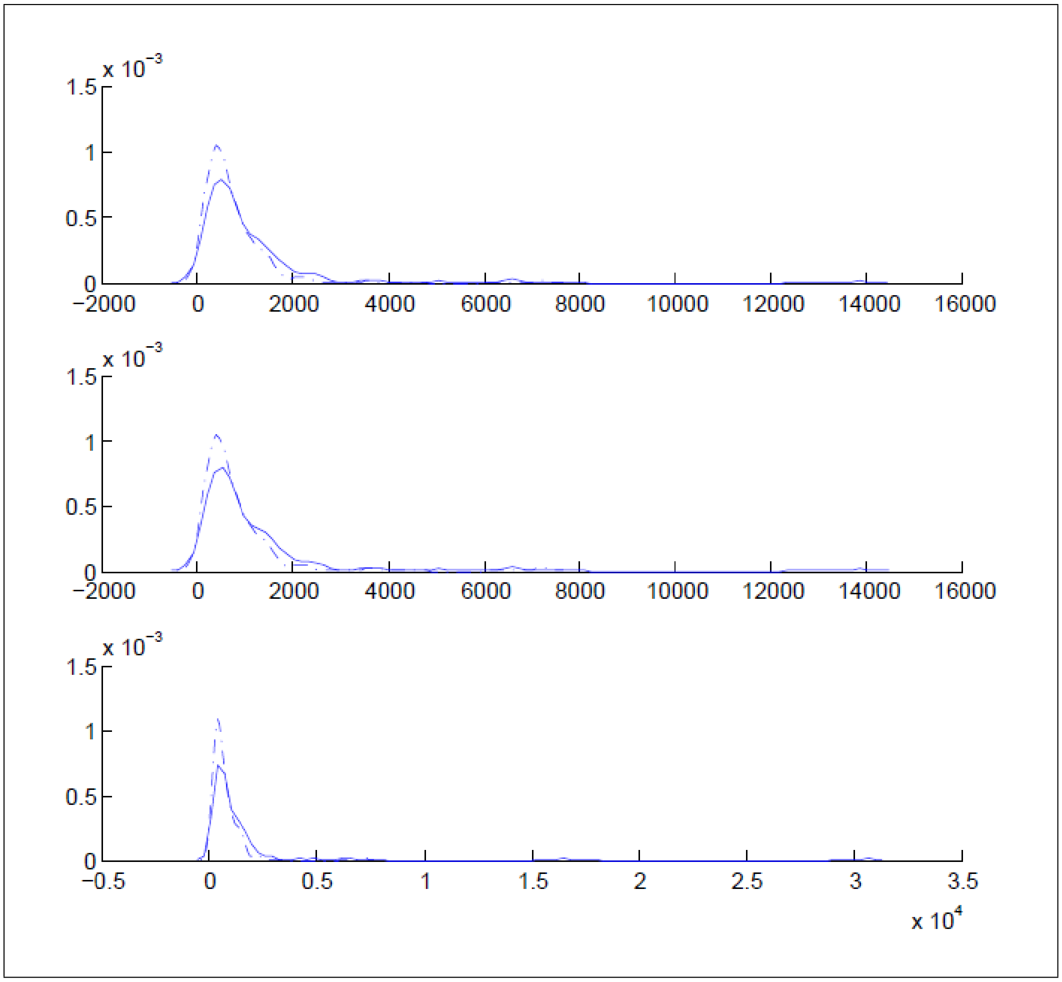

Figure 26. Land size contribution to yield distributions for smaller farmers

Note: Kernel smoothing probability densities from top to bottom under constant, non-increasing, and variable returns to scale up to 0.8 acres. Counter factual distribution y_1^Q/l_1 is plotted as a solid line while observed yield distribution is the dashed line.

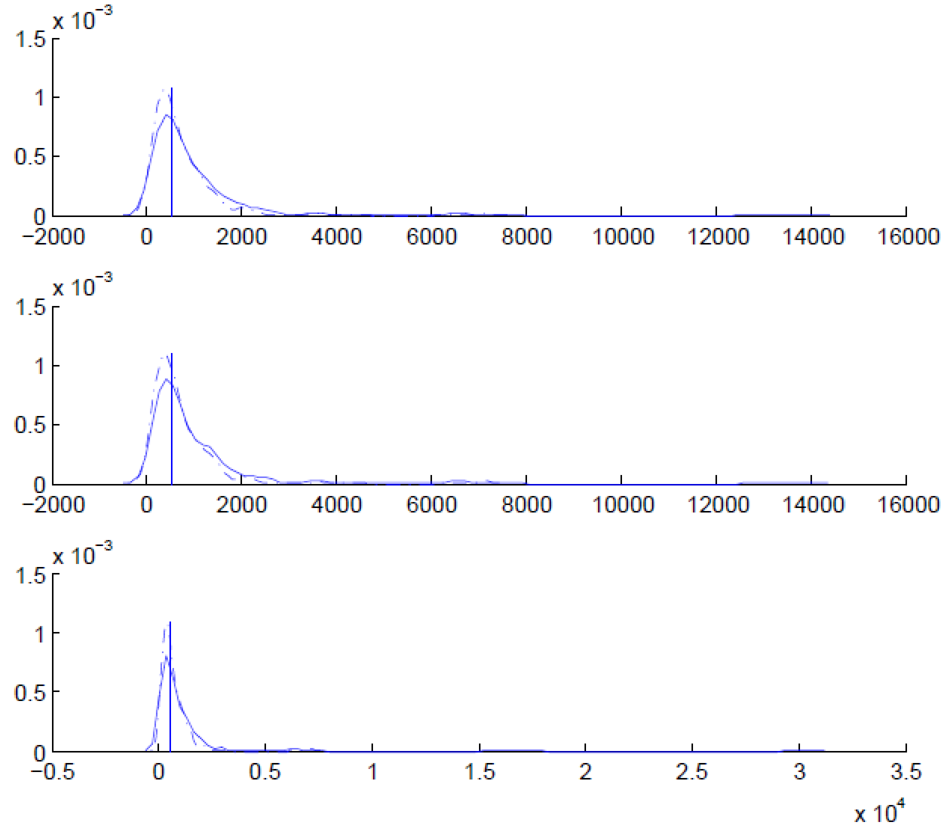

Figure 27. Negative land size contributions to observed yield distribution

Note: Kernel smoothing probability densities of land size contributions from top to bottom under constant, non-increasing, and variable returns for households with negative land size contributions. Counter factual distribution y_1^Q/l_1 is plotted as a solid line while observed yield distribution is the dashed line.

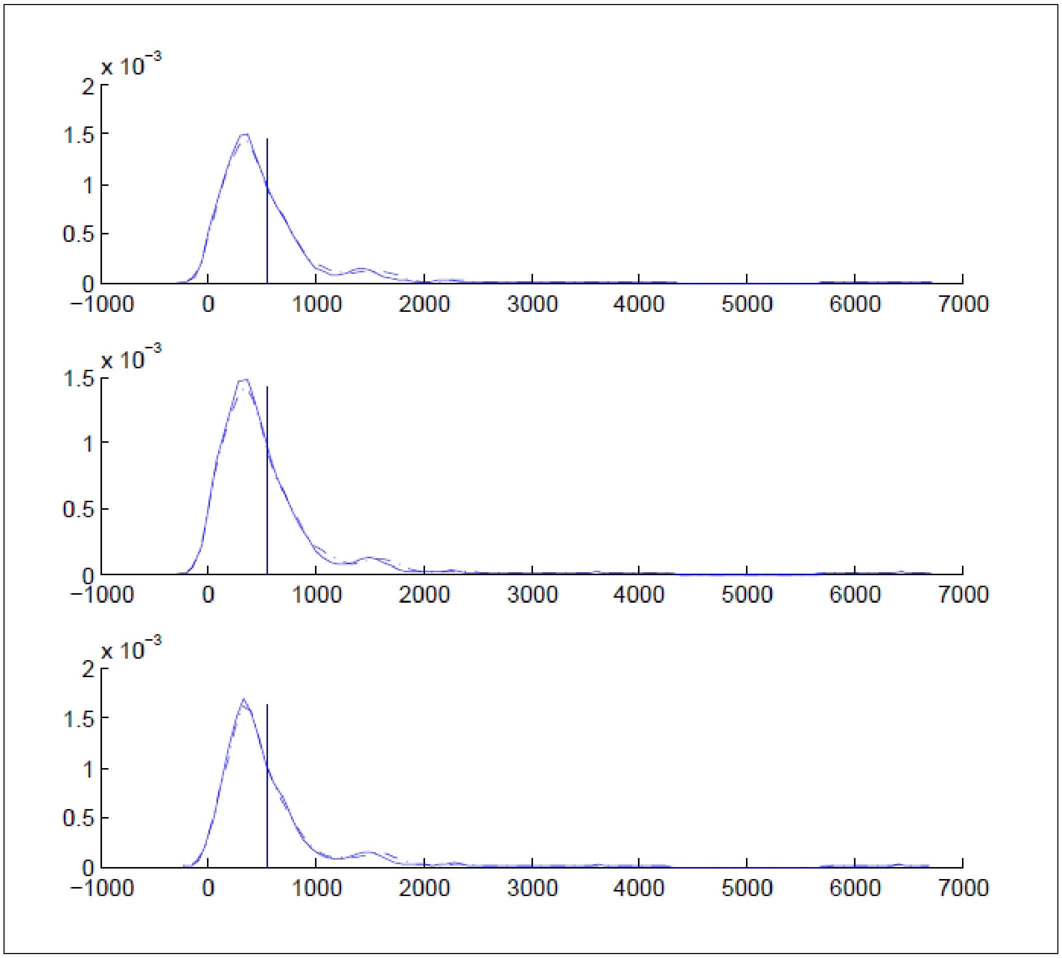

Figure 28. Non negative land size contributions to observed yield distribution

Note: Kernel smoothing probability densities of land size contributions from top to bottom under constant, non-increasing, and variable returns for households with non negative land size contributions. Counter factual distribution y_1^Q/l_1 is plotted as a solid line while observed yield distribution is the dashed line.

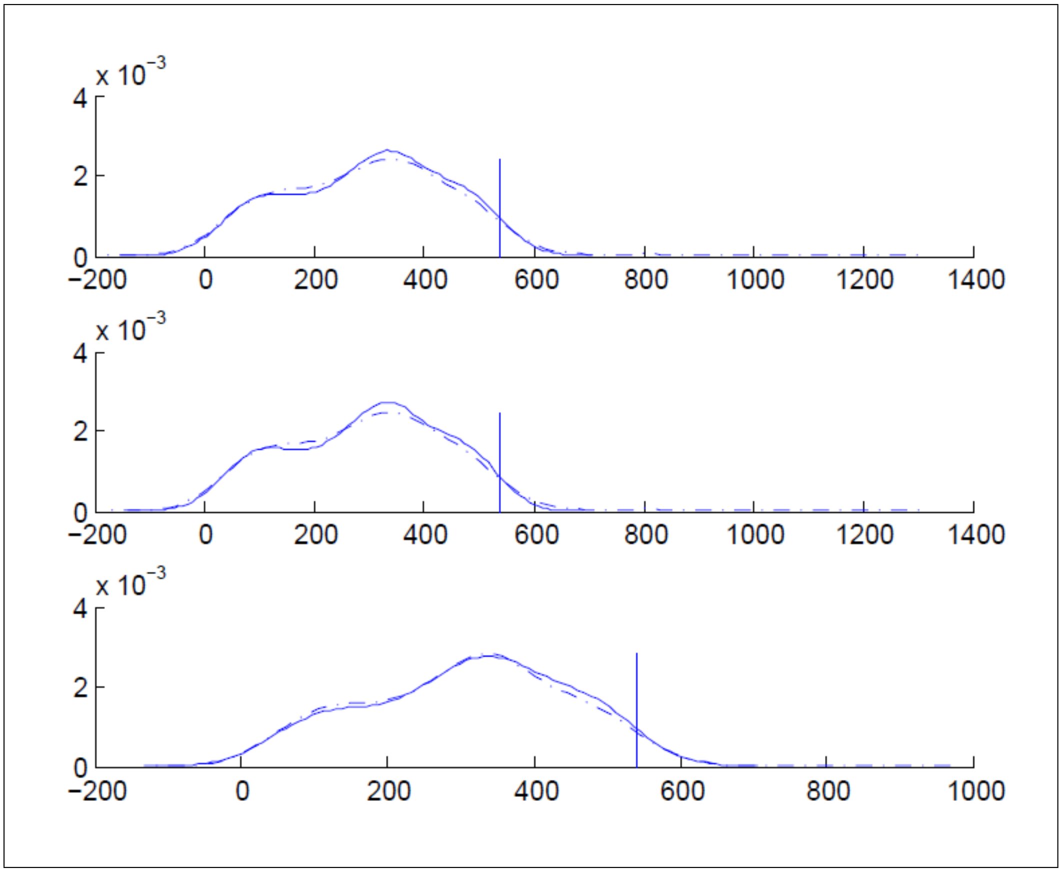

Figure 29. Land size contributions to yield distributions for farmers with yields lower than the median

Note: Kernel smoothing probability densities of land size contributions from top to bottom under constant, non-increasing, and variable returns to scale for farmers with yields lower than the median (540 Kg acre^{-1}). Counter factual distribution y_1^Q/l_1 is plotted as a solid line while observed yield distribution is the dashed line.

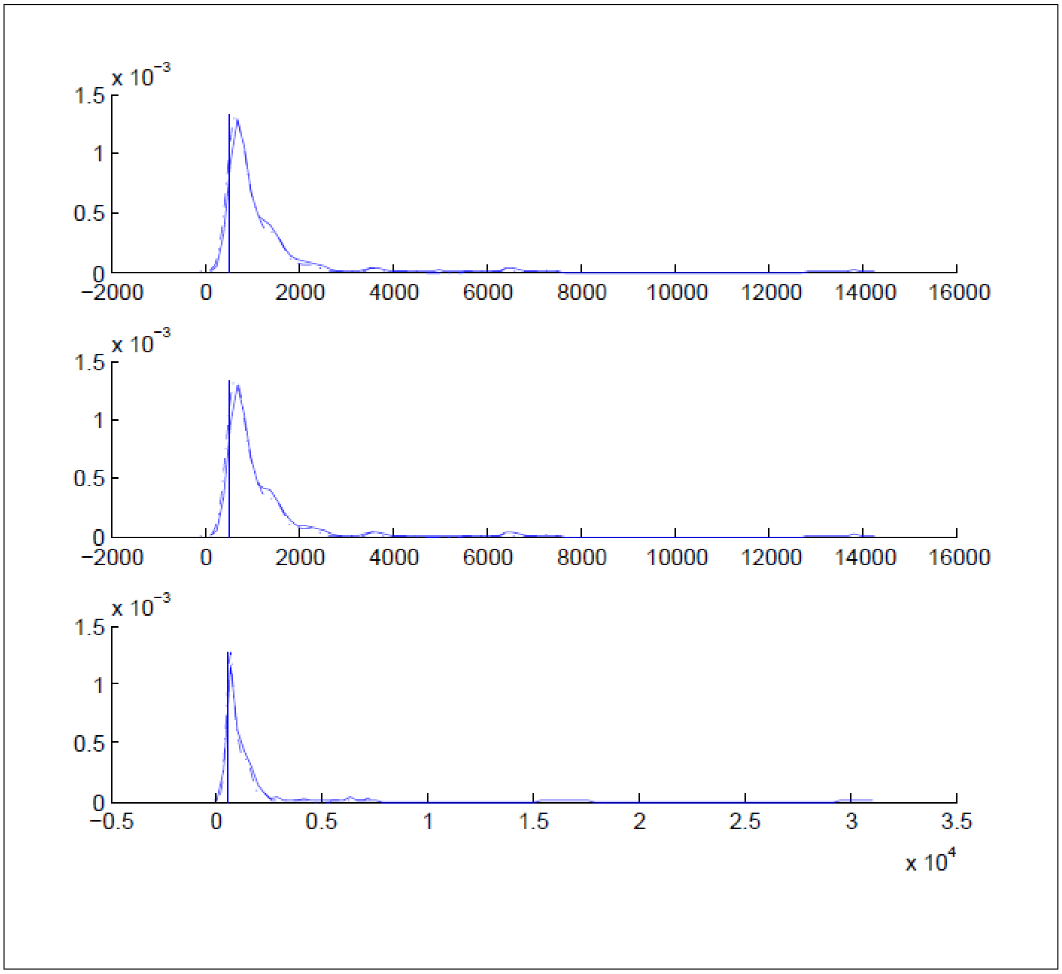

Figure 30. Land size contributions to yield distributions for farmers with yields higher than the median

Note: Kernel smoothing probability densities of land size contributions from top to bottom under constant, non-increasing, and variable returns to scale for farmers with yields higher than the median (540 Kg acre^{-1}). Counter factual distribution y_1^Q/l_1 is plotted as a solid line while observed yield distribution is the dashed line.

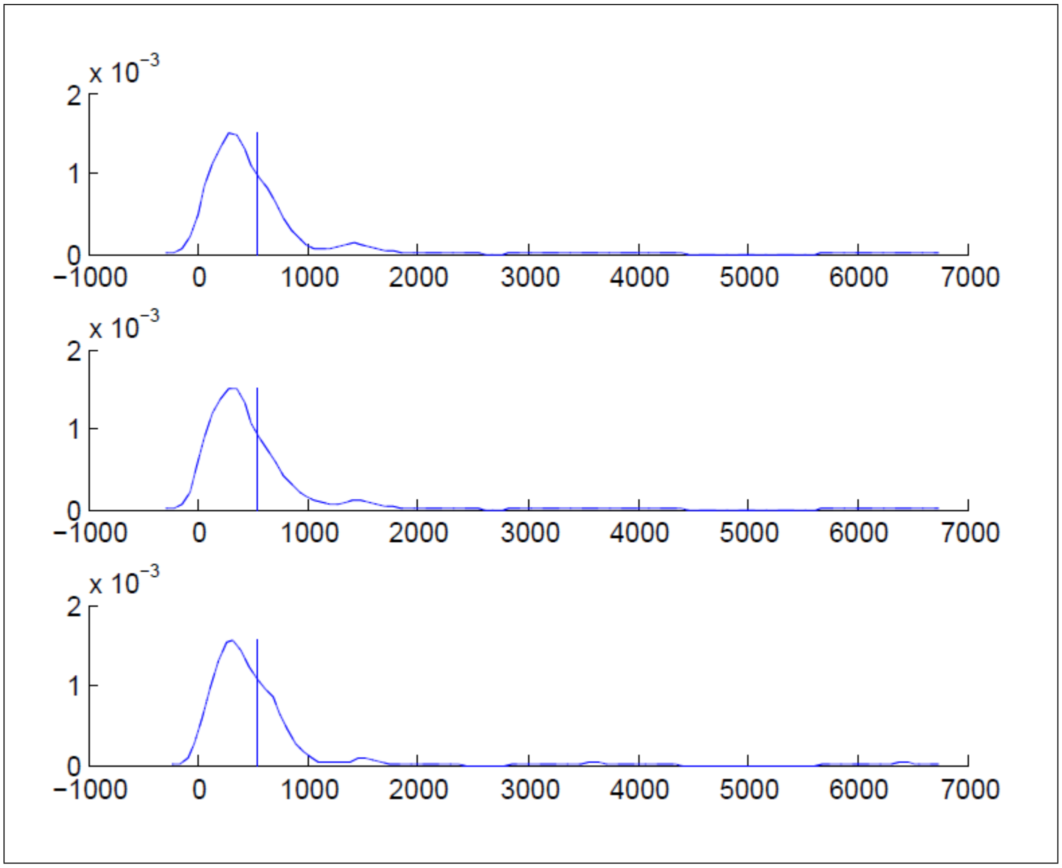

Figure 31. Observed yield distributions for farmers with zero land size contributions

Note: Kernel smoothing probability densities of yield distributions from top to bottom under constant, non-increasing, and variable returns to scale for farmers with zero land size contributions.

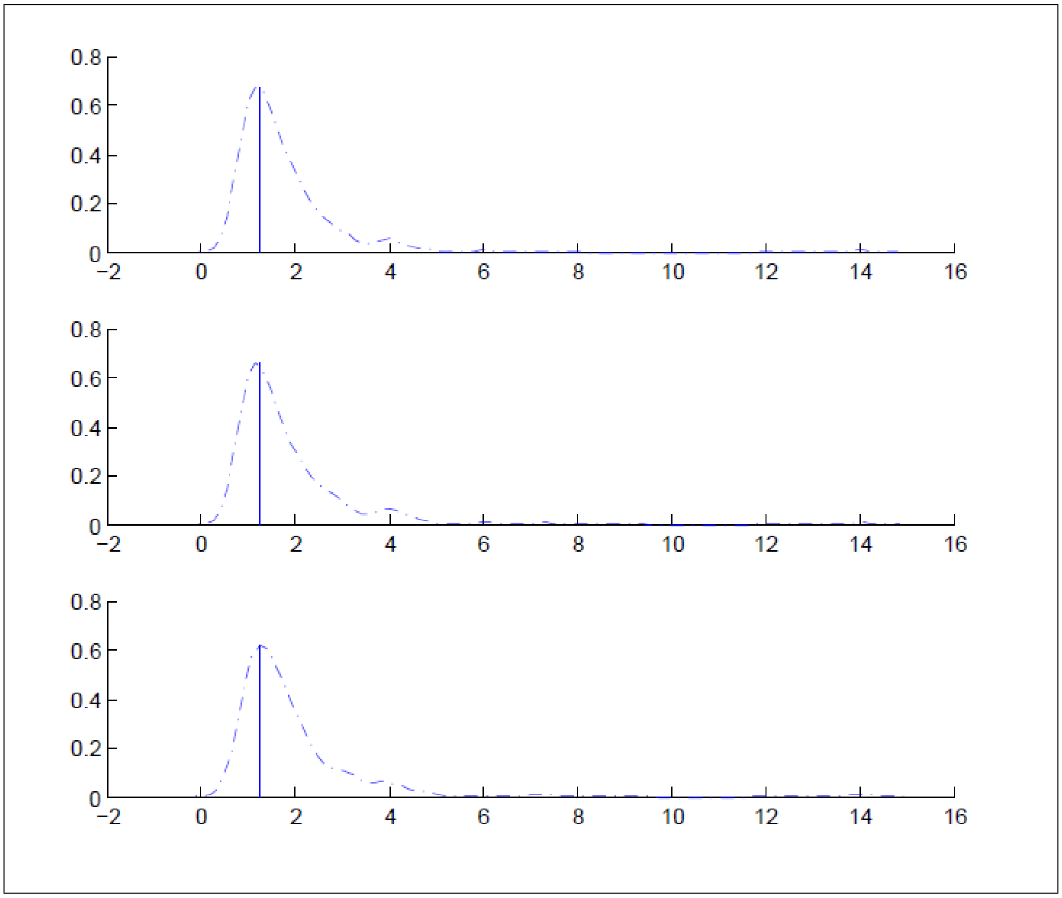

Figure 32. Observed land size distributions for farmers with zero land size contributions

Note: Kernel smoothing probability densities of land size distributions from top to bottom under constant, non-increasing, and variable returns to scale for farmers with zero land size contributions.

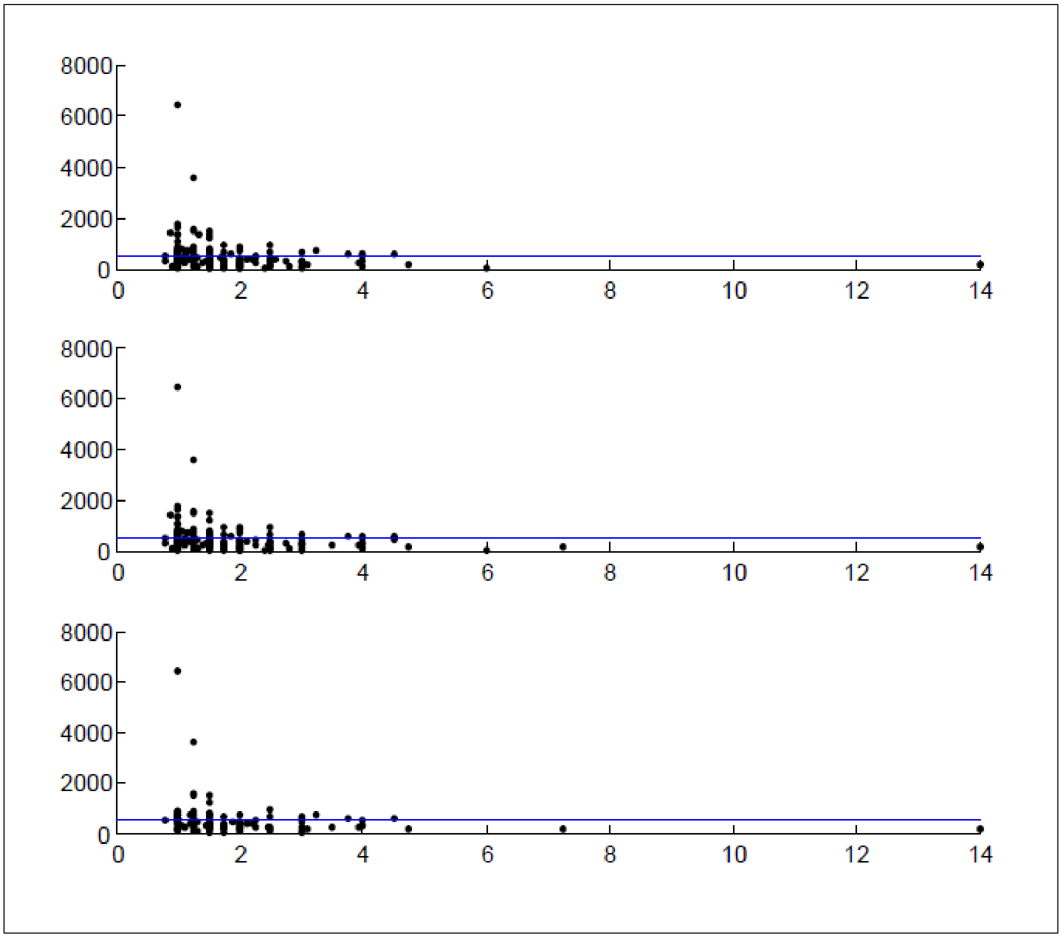

Figure 33. Yield and land size scatter diagrams for farmers with zero land size contributions

Note: Scatter diagrams of observed yields and land sizes from top to bottom under constant, non-increasing, and variable returns to scale for farmers with zero land size contributions.

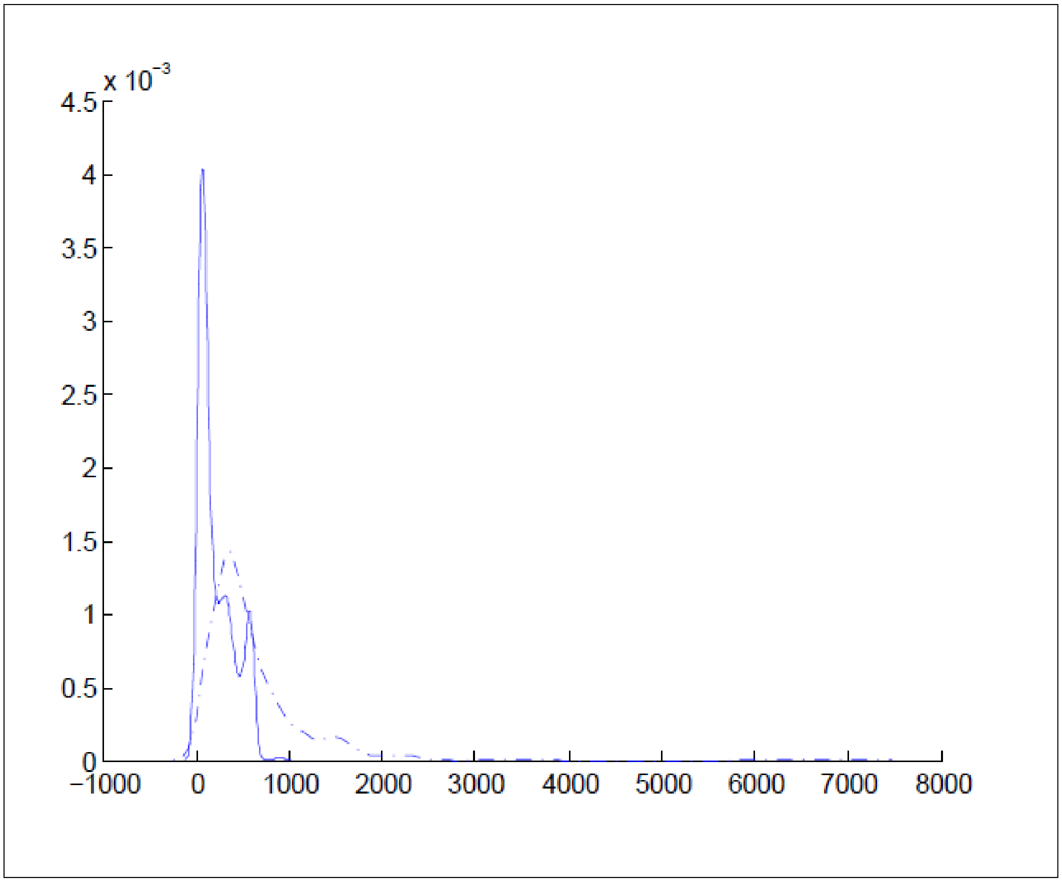

Figure 34. Counter factual distribution y_1^I/l_1 and observed yield distribution

Note: Counter factual distribution y_1^I/l_1 is plotted as a solid line while observed yield distribution is the dashed line.

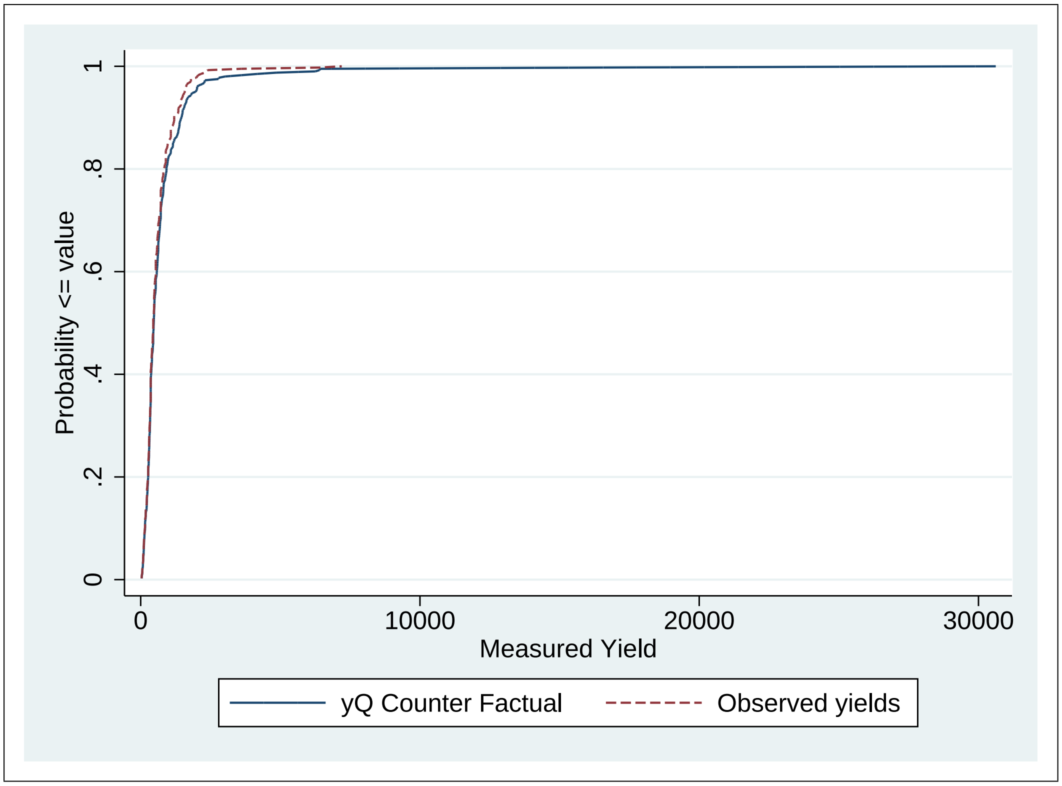

Figure 35. Cumulative empirical distribution of counter factual distribution y_1^Q/l_1 and observed yield distribution: the effect of not adjusting for land size under variable returns to scale

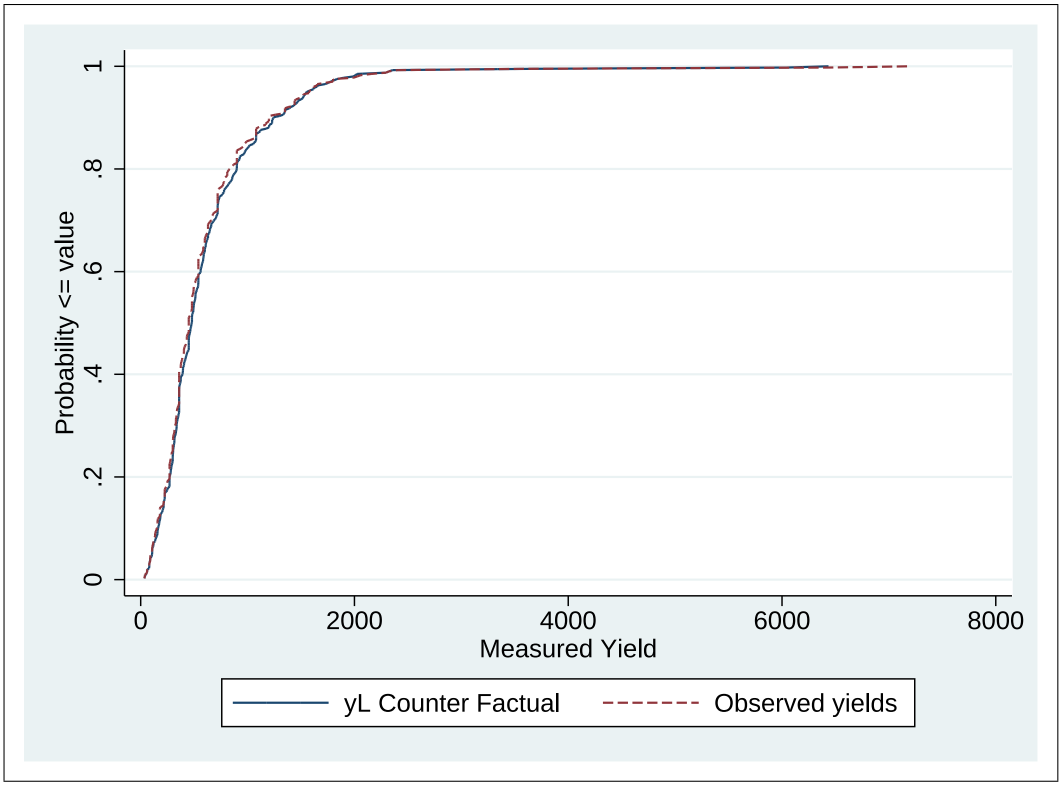

Figure 36. Cumulative empirical distribution of counter factual distribution y_1^L/l_1 and observed yield distribution: the effect of not adjusting for land quality under variable returns to scale

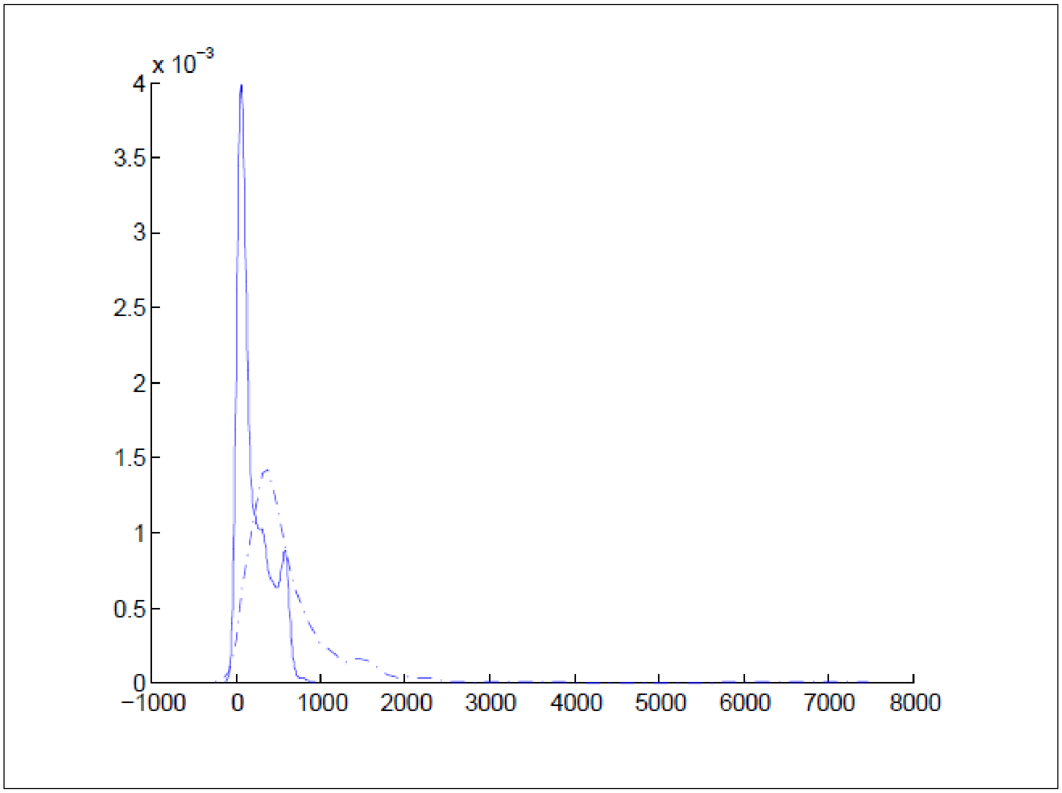

Figure 37. Counter factual distribution y_1^{QL}/l_1 and observed yield distribution: the effect of not adjusting for efficiency under variable returns to scale

Note: Counter factual distribution y_1^{QL}/l_1 is plotted as a solid line while observed yield distribution is the dashed line.

Tables

Table 1. Summary statistics of inputs, output, and land quality physical characteristics

Variable	Mean	Std.Dev.	Median	Min	Max
Inputs					
land area (acres)	1.6	1.4	1.25	0.1	14
quantity of seeds (kgs)	13.4	11	10	1	78
inorganic fertilizers (kgs)	46.8	74.4	22	0	650
organic fertilizers (kgs)	742.1	1214.6	300	0	9000
hired labor (cost in KSh)	2935.4	4911.9	1025	0	48160
family labor (hours)	431.5	510.9	287.5	0	4434.8
permanent and share labor (hours)	41.7	95.1	0	0	963
number of hand hoes	3.9	2.2	4	0	15
number of ploughs	0.1	0.3	0	0	2
number of spray-pumps	0.4	0.6	0	0	2
number of sickles	0.4	0.6	0	0	3
milking cows	1	0.9	1	0	5
Output					
total harvest dry maize (kg)	843.7	1122.8	540	0	9000
Land quality physical characteristics					
soil carbon content (% of soil weight)	2.6	1.5	2.18	0.7	15.2
soil clay content (% of soil weight)	28.3	3.9	28.6	15.5	44.9
Land quality ordinal index 100^{th} % level					
constant returns to scale	0.9619	0.1697	0.9925	0.006	1.2696
non-increasing returns to scale	0.8204	0.1630	0.8694	0.006	1
variable returns to scale	0.7816	0.1906	0.8318	0	1
Observations	452				

Table 2. Summary statistics of inefficiency index measure under constant returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	0	0.053029	0.097746	0.137025	0.19132	0.251038	0.353101	0.52239	0.736142	1.275741	7.296574	0.52986	0.777337
32	0	0.05679	0.095108	0.137001	0.186423	0.246954	0.342754	0.530227	0.730883	1.260585	7.214592	0.523548	0.769799
33	0	0.05682	0.095106	0.137073	0.191686	0.250779	0.356411	0.532066	0.745038	1.258939	6.761086	0.526376	0.763193
34	0	0.056816	0.095072	0.137062	0.192279	0.253977	0.357422	0.539397	0.754074	1.263499	6.756167	0.52914	0.765157
35	0	0.056812	0.095036	0.137055	0.192468	0.253894	0.356235	0.539369	0.753813	1.263684	6.764117	0.529303	0.765332
36	0	0.056722	0.099817	0.146119	0.20509	0.274825	0.37984	0.562126	0.817158	1.269201	6.474979	0.55599	0.79006
37	0	0.05671	0.099795	0.146086	0.205529	0.289249	0.390009	0.556693	0.823433	1.298894	6.492479	0.558269	0.78952
38	0	0.059503	0.100303	0.14712	0.206207	0.287302	0.394083	0.559449	0.833573	1.302183	6.46889	0.560737	0.782251
39	0	0.061672	0.099783	0.147094	0.206204	0.286873	0.394078	0.559723	0.835651	1.302218	6.491611	0.558877	0.778536
40	0	0.061674	0.100244	0.148329	0.205511	0.286631	0.390016	0.560076	0.836535	1.292078	6.512575	0.556268	0.773366
41	0	0.061688	0.100071	0.147817	0.205556	0.285828	0.389221	0.559244	0.837989	1.282048	6.52534	0.554186	0.769779
42	0	0.061657	0.09999	0.147742	0.205452	0.287543	0.393012	0.557716	0.837253	1.317533	6.956696	0.558123	0.783622
43	0	0.061644	0.09997	0.147711	0.206109	0.285731	0.393895	0.557156	0.835439	1.311599	6.823952	0.556943	0.779414
44	0	0.06165	0.099979	0.147725	0.206128	0.284068	0.393933	0.559775	0.844433	1.318757	6.82311	0.559166	0.780409
45	0	0.061668	0.100009	0.14777	0.206282	0.285829	0.392794	0.560637	0.827207	1.304174	6.645185	0.55562	0.771408
46	0	0.061682	0.100553	0.150215	0.207761	0.292946	0.395076	0.561108	0.842482	1.301009	6.586275	0.556823	0.768742
47	0	0.061693	0.100573	0.150243	0.20833	0.295015	0.394288	0.560054	0.840653	1.306637	6.548349	0.556849	0.767166
48	0	0.061699	0.100581	0.150256	0.208599	0.296505	0.396772	0.566271	0.840412	1.304428	6.542902	0.559898	0.771307
49	0	0.061705	0.100592	0.150272	0.208896	0.296537	0.396815	0.564772	0.839056	1.295358	6.543674	0.559624	0.771077
50	0	0.061709	0.100598	0.150281	0.20903	0.296555	0.396838	0.56456	0.837432	1.294229	6.544059	0.559439	0.770883
51	0	0.061726	0.100625	0.149233	0.209572	0.296635	0.396946	0.566483	0.829335	1.291526	6.547527	0.55787	0.769354
52	0	0.061733	0.100637	0.148925	0.209789	0.29667	0.396993	0.567099	0.827083	1.290247	6.541945	0.557684	0.769192
53	0	0.06174	0.100648	0.148386	0.210026	0.296702	0.397036	0.567793	0.819649	1.288151	6.504707	0.556835	0.767624
54	0	0.061709	0.100729	0.148472	0.210207	0.296803	0.39717	0.567985	0.803732	1.283361	6.39483	0.554389	0.762793
55	0	0.061701	0.10131	0.148529	0.210569	0.296849	0.397232	0.568073	0.800438	1.281173	6.336812	0.552797	0.759377
56	0	0.061716	0.101823	0.148459	0.210716	0.296945	0.397361	0.568258	0.804665	1.277684	6.245047	0.550802	0.754914
57	0	0.061709	0.102084	0.147432	0.208819	0.295995	0.395011	0.561255	0.790193	1.271349	6.247895	0.545669	0.748106
58	0	0.061725	0.102089	0.148585	0.210962	0.297147	0.397631	0.560662	0.805939	1.267719	6.249294	0.546085	0.7439
59	0	0.061788	0.102092	0.148695	0.211005	0.297186	0.397684	0.564007	0.804938	1.265003	6.250118	0.545243	0.741517
60	0	0.061845	0.102105	0.148954	0.211029	0.297287	0.397819	0.558333	0.794426	1.252526	6.252242	0.541065	0.732768
61	0	0.061879	0.10213	0.14926	0.210375	0.297372	0.397661	0.558492	0.792217	1.248823	6.254025	0.538515	0.726812
62	0	0.063041	0.102137	0.149299	0.210312	0.297379	0.397545	0.558505	0.792042	1.24799	6.254174	0.539135	0.7273
63	0	0.063128	0.102137	0.149386	0.210476	0.298956	0.39791	0.558482	0.792124	1.24935	6.253917	0.539703	0.728067
64	0	0.062204	0.102128	0.148706	0.210878	0.299786	0.397688	0.554163	0.774551	1.262859	6.250182	0.543272	0.737246
65	0	0.062001	0.102129	0.149734	0.210933	0.29915	0.397665	0.558116	0.772009	1.267498	6.249821	0.544694	0.739508
66	0	0.06192	0.10213	0.149592	0.21096	0.298826	0.397659	0.558109	0.771736	1.268243	6.249735	0.545308	0.740528
67	0	0.064269	0.104482	0.150547	0.213248	0.29708	0.405878	0.565043	0.839717	1.274084	6.247881	0.563877	0.791899
68	0	0.064265	0.104544	0.150539	0.213066	0.297064	0.405856	0.565212	0.840337	1.275166	6.24755	0.564369	0.792815
69	0	0.064228	0.104547	0.150535	0.213163	0.297055	0.405844	0.565867	0.840761	1.275901	6.247359	0.564725	0.793858
70	0	0.064221	0.104566	0.150528	0.213133	0.297042	0.405826	0.565674	0.840815	1.277073	6.247079	0.565229	0.795034
71	0	0.064188	0.104624	0.150514	0.213014	0.297015	0.405789	0.565933	0.840596	1.278894	6.246517	0.565871	0.796506
72	0	0.06415	0.104685	0.150505	0.21291	0.296998	0.405765	0.566789	0.840351	1.281211	6.246148	0.566754	0.798573
73	0	0.064116	0.104776	0.150486	0.212782	0.296959	0.405713	0.566333	0.840046	1.282811	6.245337	0.567332	0.799659
74	0	0.064114	0.104797	0.150486	0.212771	0.296959	0.405713	0.565688	0.8402	1.282733	6.245337	0.567498	0.799864
75	0	0.064133	0.104794	0.150487	0.212772	0.296962	0.405716	0.565701	0.840203	1.28282	6.245395	0.567667	0.800207
76	0	0.064045	0.104867	0.150461	0.212754	0.296909	0.405645	0.5654	0.839637	1.286208	6.244287	0.568934	0.803315
77	0	0.064023	0.10492	0.150449	0.212354	0.296886	0.405867	0.565206	0.841143	1.289141	6.291678	0.570169	0.806246
78	0	0.06399	0.104955	0.150435	0.21182	0.296859	0.405831	0.564485	0.842543	1.292307	6.318797	0.570908	0.807619
79	0	0.063866	0.105097	0.150403	0.211653	0.296797	0.405442	0.564464	0.846529	1.29888	6.471811	0.57268	0.812687
80	0	0.063865	0.105103	0.150401	0.211591	0.296792	0.405551	0.564692	0.846547	1.299105	6.477049	0.573249	0.813917
81	0	0.06393	0.105095	0.150405	0.211585	0.296799	0.406582	0.566231	0.846653	1.305239	6.46484	0.573664	0.814717
82	0	0.063935	0.105095	0.150405	0.211579	0.296799	0.406621	0.566486	0.846658	1.305498	6.464667	0.573732	0.814848
83	0	0.063932	0.105099	0.150404	0.21157	0.296798	0.406621	0.566485	0.846653	1.305492	6.467731	0.57379	0.814975
84	0	0.063856	0.105182	0.150381	0.211443	0.296752	0.40543	0.566397	0.846238	1.307644	6.513664	0.574547	0.816738
85	0	0.063852	0.105218	0.150383	0.211385	0.296731	0.405401	0.566916	0.846828	1.307613	6.51859	0.574943	0.817514
86	0	0.063843	0.105285	0.150424	0.21126	0.296688	0.405342	0.570152	0.847552	1.310414	6.513905	0.576103	0.819925
87	0	0.063842	0.105292	0.150444	0.211224	0.296684	0.406663	0.568742	0.84849	1.315463	6.490622	0.577009	0.821776
88	0	0.063835	0.105392	0.150496	0.211106	0.296655	0.406521	0.569872	0.849465	1.324934	6.508127	0.578034	0.823541
89	0	0.06382	0.105547	0.150307	0.212555	0.296585	0.406007	0.571618	0.863698	1.357699	6.540034	0.57938	0.826006
90	0	0.063805	0.105739	0.150261	0.212456	0.296515	0.405176	0.57356	0.861046	1.385991	6.576571	0.580885	0.82914
91	0	0.063941	0.105805	0.150598	0.212389	0.296491	0.406406	0.57393	0.862515	1.394874	6.542253	0.582697	0.832826
92	0	0.06414	0.105828	0.150674	0.212542	0.296493	0.406791	0.572663	0.871138	1.38996	6.49799	0.584224	0.836093
93	0	0.064097	0.106013	0.1519	0.213012	0.296455	0.40759	0.574214	0.870547	1.400833	6.532741	0.585326	0.838596
94	0	0.064259	0.106039	0.152039	0.213096	0.29645	0.407771	0.572397	0.871042	1.404997	6.490852	0.586768	0.841873
95	0	0.064274	0.106511	0.153116	0.213147	0.305683	0.409188	0.563883	0.873146	1.332895	6.550076	0.591741	0.863862
96	0	0.064262	0.106491	0.153525	0.213106	0.307166	0.408912	0.570553	0.873601	1.37436	6.559393	0.593168	0.867045
97	0	0.064253	0.106476	0.153729	0.213077	0.307725	0.409	0.5712	0.873484	1.363767	6.652414	0.595188	0.876177
98	0	0.064262	0.10649	0.153624	0.213104	0.308749	0.409	0.571726	0.873596	1.396678	6.678544	0.595824	0.87764
99	0	0.064272	0.106507	0.153123	0.213139	0.310158	0.408956	0.574949	0.870286	1.403774	6.679613	0.595665	0.879104
100	0	0.06435	0.107347	0.15426	0.213308	0.304359	0.408986	0.575382	0.858066	1.349001	6.68774	0.584459	0.850666

Table 3. Summary statistics of inefficiency index measure under non-increasing returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	0	0.049688	0.091346	0.137019	0.182692	0.24323	0.335833	0.513367	0.730237	1.217132	6.531256	0.5081	0.740364
32	0	0.049678	0.091299	0.136948	0.182598	0.239278	0.333793	0.519292	0.727441	1.18266	6.52787	0.504158	0.740949
33	0	0.047973	0.091248	0.136872	0.182496	0.240424	0.341319	0.525833	0.730193	1.220323	6.524237	0.512535	0.752601
34	0	0.047964	0.09123	0.136844	0.182459	0.241812	0.347751	0.526373	0.730328	1.220075	6.522911	0.515498	0.754977
35	0	0.047961	0.091225	0.136837	0.182449	0.241799	0.347901	0.526345	0.730289	1.22001	6.522562	0.515718	0.755148
36	0	0.052201	0.094241	0.145341	0.202055	0.273568	0.374941	0.550445	0.817548	1.230395	6.52004	0.548659	0.781804
37	0	0.052196	0.094233	0.145365	0.203732	0.276663	0.383039	0.546576	0.812528	1.246921	6.519497	0.551533	0.781019
38	0	0.057217	0.099948	0.146052	0.20548	0.283345	0.394032	0.550494	0.80791	1.249332	6.47551	0.554458	0.772838
39	0	0.059496	0.099707	0.144964	0.20548	0.283204	0.394033	0.55311	0.807203	1.249519	6.481243	0.553278	0.77025
40	0	0.059504	0.099784	0.145387	0.204879	0.283176	0.389829	0.553665	0.801503	1.249498	6.468001	0.550566	0.764458
41	0	0.059524	0.099819	0.145437	0.204951	0.282833	0.38745	0.554198	0.80088	1.249935	6.465385	0.548398	0.760616
42	0	0.05949	0.099761	0.145113	0.204831	0.276157	0.387246	0.553182	0.82483	1.300001	6.518904	0.550203	0.764295
43	0	0.059477	0.09974	0.14511	0.205832	0.278462	0.388638	0.55397	0.825044	1.294694	6.517554	0.549303	0.763113
44	0	0.059485	0.099753	0.145145	0.205685	0.279402	0.388439	0.55475	0.83238	1.303453	6.518366	0.551485	0.764328
45	0	0.059507	0.098398	0.145395	0.205892	0.280802	0.38473	0.5545	0.827549	1.292104	6.520832	0.548919	0.760381
46	0	0.059515	0.099804	0.1461	0.206249	0.285223	0.388011	0.553441	0.815943	1.271221	6.521737	0.549098	0.759471
47	0	0.059525	0.099821	0.146124	0.206283	0.285384	0.387188	0.553273	0.805937	1.251856	6.50102	0.547933	0.757276
48	0	0.059531	0.100064	0.146139	0.206304	0.285511	0.392073	0.553227	0.802381	1.250082	6.489038	0.54809	0.756481
49	0	0.059538	0.100076	0.146156	0.206329	0.285619	0.392119	0.552029	0.798522	1.250228	6.48669	0.547289	0.755311
50	0	0.059542	0.100082	0.146165	0.206341	0.285652	0.392142	0.551308	0.796839	1.250301	6.485715	0.546912	0.754803
51	0	0.059558	0.100109	0.146205	0.206398	0.285765	0.392044	0.549975	0.793277	1.249097	6.482075	0.544889	0.752351
52	0	0.059563	0.100117	0.146217	0.206414	0.285289	0.389861	0.549924	0.791794	1.239033	6.477158	0.544176	0.75128
53	0	0.059572	0.100133	0.146239	0.206446	0.283922	0.386115	0.548898	0.790281	1.227591	6.43985	0.543007	0.749248
54	0	0.059594	0.100169	0.145723	0.20652	0.281756	0.380746	0.547608	0.789534	1.224594	6.329704	0.540164	0.744106
55	0	0.059605	0.100188	0.145635	0.20656	0.280913	0.379209	0.547419	0.785587	1.223375	6.273934	0.538839	0.741648
56	0	0.059627	0.100224	0.145687	0.206635	0.280139	0.379232	0.545717	0.771443	1.222137	6.246136	0.536581	0.737158
57	0	0.059653	0.100268	0.145751	0.206725	0.279985	0.378899	0.544932	0.76655	1.222672	6.248872	0.533551	0.73073
58	0	0.059668	0.100293	0.145788	0.206777	0.280055	0.37854	0.545068	0.758582	1.222979	6.250436	0.531692	0.726659
59	0	0.059677	0.100309	0.146263	0.206808	0.280098	0.378543	0.545151	0.7539	1.223164	6.251385	0.530636	0.724074
60	0	0.059817	0.100343	0.145829	0.206879	0.280194	0.378065	0.544528	0.750763	1.223584	6.25353	0.527315	0.718192
61	0	0.059716	0.100374	0.145808	0.206943	0.28028	0.377578	0.544695	0.750662	1.22396	6.255454	0.524729	0.712472
62	0	0.061892	0.100373	0.14659	0.20694	0.288901	0.378592	0.545385	0.764069	1.220382	6.255376	0.526117	0.71256
63	0	0.06314	0.100368	0.146583	0.207449	0.291285	0.378968	0.545294	0.768371	1.220163	6.255076	0.526826	0.712986
64	0	0.062219	0.100314	0.145509	0.207578	0.291068	0.387655	0.547134	0.76605	1.223224	6.251689	0.531872	0.721414
65	0	0.062011	0.100824	0.145642	0.207547	0.295753	0.39093	0.548279	0.76565	1.223059	6.250846	0.534055	0.723424
66	0	0.061926	0.100816	0.145898	0.207382	0.295731	0.392968	0.548214	0.765899	1.222969	6.250386	0.535001	0.724379
67	0	0.064266	0.102122	0.149604	0.209935	0.297065	0.40456	0.557915	0.818577	1.25237	6.247571	0.558311	0.790048
68	0	0.064257	0.102121	0.149742	0.20991	0.29703	0.40458	0.557849	0.816754	1.25222	6.246822	0.558468	0.79018
69	0	0.064219	0.102121	0.14968	0.209899	0.297014	0.404628	0.557818	0.816219	1.252153	6.246484	0.558702	0.790961
70	0	0.064209	0.102121	0.148853	0.20988	0.296987	0.404764	0.557769	0.818192	1.252041	6.24593	0.559388	0.792456
71	0	0.064177	0.102126	0.148763	0.209865	0.296966	0.404773	0.557728	0.818618	1.250631	6.245474	0.560026	0.793904
72	0	0.065829	0.106988	0.152846	0.215481	0.299408	0.407249	0.579413	0.884951	1.433946	7.616657	0.612806	0.922823
73	0	0.064104	0.102137	0.148488	0.209823	0.296907	0.404889	0.557618	0.818927	1.24885	6.244236	0.561373	0.796632
74	0	0.064103	0.102142	0.148494	0.209822	0.296904	0.404886	0.557613	0.81892	1.248829	6.244187	0.561498	0.796605
75	0	0.064121	0.102142	0.148543	0.209822	0.296904	0.404973	0.557613	0.820536	1.248902	6.244187	0.561711	0.796961
76	0	0.064031	0.102145	0.148229	0.209779	0.296844	0.404978	0.557501	0.822001	1.248112	6.313087	0.562919	0.800105
77	0	0.064002	0.102145	0.148111	0.209739	0.296787	0.405282	0.557393	0.826997	1.248692	6.384753	0.564143	0.803229
78	0	0.063967	0.102144	0.147963	0.209714	0.296752	0.405234	0.557328	0.82745	1.249161	6.412103	0.564741	0.804464
79	0	0.063836	0.102155	0.147917	0.209828	0.296656	0.403666	0.557146	0.830508	1.254484	6.526423	0.566099	0.808801
80	0	0.063832	0.102154	0.147908	0.209872	0.296637	0.404794	0.55711	0.832353	1.26458	6.526006	0.566724	0.809999
81	0	0.063895	0.102153	0.147898	0.209677	0.296633	0.405267	0.557104	0.832413	1.266527	6.525927	0.567297	0.811147
82	0	0.063899	0.102153	0.14788	0.209629	0.296632	0.405266	0.557102	0.832449	1.267609	6.525913	0.567379	0.811286
83	0	0.063896	0.102153	0.147879	0.20963	0.296631	0.405265	0.5571	0.832928	1.270097	6.525882	0.567416	0.81131
84	0	0.063819	0.10216	0.147878	0.209675	0.296527	0.404086	0.556997	0.839776	1.290373	6.524679	0.567861	0.812128
85	0	0.063813	0.102163	0.147866	0.209695	0.295675	0.403391	0.556951	0.844595	1.300826	6.524141	0.568189	0.812756
86	0	0.063795	0.102162	0.147823	0.209879	0.295002	0.403536	0.557001	0.849447	1.305907	6.52227	0.569309	0.815137
87	0	0.06379	0.102164	0.149748	0.209965	0.294978	0.405007	0.557137	0.853133	1.307305	6.521741	0.570375	0.817285
88	0	0.063775	0.102171	0.150094	0.211079	0.294911	0.404916	0.557414	0.85631	1.31049	6.520263	0.570953	0.818282
89	0	0.063753	0.102185	0.150041	0.212393	0.294809	0.404774	0.557808	0.856699	1.312694	6.51799	0.571511	0.81943
90	0	0.063739	0.102221	0.150303	0.21292	0.294741	0.404211	0.557873	0.856648	1.314287	6.516502	0.571967	0.820693
91	0	0.063879	0.102244	0.150277	0.21292	0.294741	0.404682	0.558872	0.858906	1.314287	6.516502	0.573933	0.824856
92	0	0.064078	0.102244	0.150251	0.21292	0.294741	0.405129	0.560004	0.861091	1.314287	6.516502	0.575715	0.828685
93	0	0.064043	0.103088	0.150185	0.21292	0.294741	0.406395	0.561462	0.861091	1.314287	6.516502	0.575724	0.8287
94	0	0.064206	0.103599	0.15092	0.21292	0.296205	0.408641	0.561378	0.861091	1.314287	6.516502	0.57733	0.832295
95	0	0.064206	0.105808	0.154431	0.21292	0.296449	0.408647	0.559846	0.861091	1.416815	6.575354	0.583508	0.843059
96	0	0.064206	0.105808	0.154429	0.212904	0.296449	0.40819	0.559437	0.861091	1.416815	6.613907	0.583548	0.843862
97	0	0.064206	0.105808	0.15466	0.212096	0.296449	0.406395	0.55888	0.861091	1.416815	6.657778	0.584718	0.846156
98	0	0.064206	0.105808	0.155585	0.211855	0.296449	0.406395	0.558396	0.861091	1.416815	6.672761	0.585215	0.847368
99	0	0.064206	0.106004	0.155585	0.212297	0.296205	0.406395	0.557058	0.861091	1.416815	6.672761	0.585552	0.848084
100	0	0.064206	0.107159	0.155585	0.212255	0.296205	0.406395	0.556504	0.861091	1.416815	6.672761	0.585641	0.848296

Table 4. Summary statistics of inefficiency index measure under variable returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	0	0.117458	0.233445	0.320114	0.4239	0.535889	0.70475	1.03557	1.527546	2.589658	9.013365	1.022433	1.300851
32	0	0.124765	0.208615	0.311911	0.42927	0.534218	0.747338	1.003691	1.541034	2.689741	9.574029	1.050912	1.363403
33	0	0.068088	0.116277	0.176138	0.241459	0.296083	0.415948	0.595153	0.874714	1.494977	5.224818	0.589444	0.768763
34	0	0.060764	0.103414	0.157191	0.21274	0.263256	0.364581	0.533011	0.780623	1.334166	8.225592	0.538124	0.776539
35	0	0.058472	0.099721	0.151263	0.204716	0.253327	0.350831	0.51938	0.761187	1.288946	7.915355	0.5226	0.750709
36	0	0.052804	0.088768	0.127634	0.169658	0.223343	0.313511	0.433083	0.668567	1.109376	5.249537	0.458034	0.644173
37	0	0.053645	0.090302	0.130836	0.183139	0.230728	0.321869	0.472357	0.697378	1.139909	5.211421	0.47565	0.666877
38	0	0.057656	0.097054	0.139542	0.191388	0.252388	0.345934	0.517111	0.749229	1.241458	5.202588	0.511919	0.703924
39	0	0.059685	0.10047	0.142645	0.197837	0.259592	0.358111	0.529942	0.769478	1.277317	5.408618	0.530408	0.729637
40	0	0.061811	0.106659	0.14829	0.204943	0.267793	0.370865	0.539799	0.788937	1.327519	5.531054	0.549221	0.753109
41	0	0.061849	0.107435	0.154622	0.216471	0.270929	0.371094	0.54209	0.800149	1.327578	5.484027	0.54994	0.749228
42	0	0.062284	0.107163	0.15571	0.218063	0.272835	0.373704	0.54835	0.791572	1.336137	5.410146	0.553024	0.751455
43	0	0.061925	0.105924	0.154921	0.216738	0.271705	0.37155	0.539757	0.81412	1.328953	5.339181	0.552275	0.745649
44	0	0.060594	0.103941	0.152326	0.212642	0.266945	0.370557	0.52772	0.79703	1.306689	5.39327	0.543053	0.732615
45	0	0.060774	0.108054	0.159435	0.212776	0.267015	0.371144	0.528532	0.799656	1.33393	5.273557	0.545031	0.729964
46	0	0.06129	0.108975	0.160668	0.214584	0.269395	0.367742	0.532958	0.795583	1.310704	4.984771	0.542181	0.719889
47	0	0.060824	0.108166	0.154194	0.214955	0.26756	0.364944	0.530068	0.788981	1.300731	4.840315	0.538645	0.713843
48	0	0.060364	0.107427	0.153027	0.214789	0.267815	0.369149	0.533261	0.782283	1.290999	4.776534	0.53598	0.709324
49	0	0.059591	0.106151	0.151067	0.213307	0.267367	0.36442	0.537922	0.772781	1.274669	4.86668	0.53152	0.705785
50	0	0.059166	0.105395	0.149989	0.215146	0.266348	0.361821	0.53746	0.767513	1.265668	4.968146	0.528853	0.702747
51	0	0.059265	0.112721	0.15024	0.217604	0.265406	0.367332	0.53673	0.767276	1.2682	5.180204	0.529104	0.702606
52	0	0.058664	0.111628	0.148717	0.212964	0.265751	0.358377	0.531449	0.7539	1.248564	5.399376	0.524391	0.700078
53	0	0.058857	0.11195	0.149206	0.214421	0.268486	0.357695	0.535584	0.756139	1.252749	5.444785	0.525974	0.701953
54	0	0.059458	0.112914	0.154169	0.220842	0.271741	0.357348	0.542629	0.757336	1.265557	5.586159	0.530479	0.707573
55	0	0.059657	0.108545	0.151236	0.221581	0.272681	0.357945	0.546555	0.756676	1.269978	5.657423	0.531808	0.709926
56	0	0.059995	0.109175	0.158034	0.222835	0.274248	0.35997	0.551137	0.750811	1.291166	5.747874	0.536044	0.71521
57	0	0.060765	0.110549	0.157578	0.218926	0.275195	0.364587	0.555021	0.760105	1.307725	5.829624	0.540712	0.721941
58	0	0.061132	0.111198	0.16095	0.220259	0.278979	0.366795	0.55669	0.767518	1.315644	5.991586	0.54463	0.727309
59	0	0.060768	0.110666	0.159774	0.218938	0.276521	0.364608	0.556611	0.762816	1.307799	6.052632	0.541724	0.724521
60	0	0.060936	0.111766	0.156162	0.219623	0.27743	0.365887	0.555168	0.763213	1.311426	6.138806	0.542305	0.72526
61	0	0.061178	0.112932	0.155091	0.221206	0.279128	0.367068	0.555869	0.764325	1.316626	6.14111	0.543529	0.725681
62	0	0.060703	0.115002	0.153887	0.219856	0.279589	0.364451	0.554443	0.783838	1.309161	6.175432	0.5444	0.729106
63	0	0.060489	0.11456	0.159894	0.219906	0.277609	0.365907	0.55448	0.781074	1.315968	6.183036	0.544895	0.730188
64	0	0.059811	0.112539	0.165698	0.216402	0.26872	0.360409	0.549897	0.75841	1.286841	5.654233	0.531575	0.701429
65	0	0.059265	0.114142	0.164309	0.216382	0.26922	0.360681	0.549855	0.763912	1.276438	5.777168	0.531104	0.703138
66	0	0.057895	0.111502	0.16141	0.217925	0.270035	0.362276	0.563585	0.773957	1.273637	6.073156	0.534878	0.719491
67	0	0.056376	0.112751	0.157938	0.210938	0.264651	0.341213	0.563307	0.776706	1.248292	6.380701	0.537877	0.752184
68	0	0.056114	0.112228	0.157206	0.20996	0.264088	0.345001	0.560695	0.766941	1.234455	6.328367	0.536262	0.750079
69	0	0.056153	0.112306	0.156468	0.209925	0.2658	0.346448	0.561529	0.767648	1.235297	6.378983	0.538165	0.755408
70	0	0.056032	0.112064	0.157988	0.213412	0.267943	0.349126	0.560321	0.769264	1.232646	6.401079	0.538913	0.758379
71	0	0.055763	0.111404	0.156222	0.21657	0.265417	0.347449	0.557629	0.767109	1.226723	6.380834	0.537175	0.75634
72	0	0.056109	0.112219	0.156347	0.213521	0.266231	0.350333	0.565158	0.774023	1.233768	6.459035	0.539944	0.762207
73	0	0.056216	0.112432	0.155531	0.213733	0.266483	0.351599	0.56586	0.766447	1.236115	6.475741	0.540764	0.763776
74	0	0.056509	0.113018	0.156324	0.216886	0.267602	0.353431	0.567971	0.767811	1.242554	6.487752	0.542871	0.766588
75	0	0.057108	0.114217	0.157579	0.221795	0.270078	0.357914	0.572946	0.77527	1.25574	6.562933	0.548343	0.775244
76	0	0.056994	0.109768	0.157398	0.220576	0.2695	0.35792	0.572226	0.775156	1.256721	6.703302	0.549173	0.781444
77	0	0.056044	0.107466	0.154946	0.216676	0.265359	0.351822	0.564571	0.762654	1.243357	6.758281	0.540697	0.775366
78	0	0.0515	0.097831	0.142383	0.200814	0.250005	0.339892	0.516078	0.719444	1.167551	6.971587	0.506048	0.734751
79	0	0.050514	0.097287	0.136712	0.198271	0.245443	0.336724	0.509259	0.70813	1.154956	6.838102	0.499118	0.728606
80	0	0.050218	0.096718	0.135596	0.198063	0.244485	0.335618	0.507133	0.70577	1.146065	6.798074	0.497959	0.727299
81	0	0.049602	0.09553	0.135183	0.19624	0.241567	0.333322	0.499606	0.704813	1.131775	6.7146	0.493617	0.721241
82	0	0.04957	0.09547	0.135282	0.196116	0.241417	0.331729	0.499289	0.704518	1.13168	6.710358	0.493545	0.7209
83	0	0.04957	0.099139	0.135489	0.196114	0.241407	0.331966	0.499153	0.70451	1.131736	6.71028	0.493756	0.720936
84	0	0.048991	0.097983	0.136956	0.193825	0.238981	0.326793	0.492955	0.696289	1.124817	6.631977	0.489258	0.715358
85	0	0.048598	0.097197	0.135857	0.192271	0.237379	0.32603	0.488856	0.691774	1.118195	6.578776	0.486105	0.711159
86	0	0.048052	0.096104	0.134645	0.19011	0.236329	0.324454	0.483362	0.693273	1.117374	6.50484	0.483223	0.708355
87	0	0.047513	0.095027	0.133188	0.186097	0.234746	0.321118	0.475133	0.690444	1.114749	6.431903	0.479704	0.705414
88	0	0.046681	0.093363	0.132849	0.184889	0.233407	0.317574	0.469601	0.679036	1.102515	6.319289	0.473433	0.695152
89	0	0.046248	0.092496	0.132039	0.183484	0.232471	0.314483	0.464838	0.67135	1.105837	6.26063	0.47044	0.691772
90	0	0.045833	0.088273	0.129734	0.182658	0.230387	0.31179	0.458335	0.664532	1.095924	6.204503	0.467349	0.687914
91	0	0.045768	0.091535	0.130956	0.183071	0.230056	0.313862	0.464578	0.669935	1.094349	6.195589	0.469754	0.692436
92	0	0.045748	0.091496	0.131214	0.182993	0.228741	0.31547	0.46198	0.676865	1.093884	6.192954	0.471851	0.69711
93	0	0.045721	0.091442	0.131132	0.182885	0.228606	0.315797	0.461605	0.676909	1.093239	6.189302	0.471754	0.696919
94	0	0.045669	0.091339	0.136184	0.182678	0.227114	0.315301	0.461047	0.676454	1.091999	6.182287	0.472875	0.700765
95	0	0.04557	0.09114	0.13671	0.18228	0.233381	0.31899	0.474065	0.728283	1.096862	6.516502	0.486944	0.726522
96	0	0.04557	0.09114	0.13671	0.18228	0.233381	0.31899	0.475019	0.729559	1.096465	6.516502	0.489771	0.729982
97	0	0.04557	0.09114	0.13671	0.18228	0.237343	0.31899	0.475038	0.729559	1.128596	6.516502	0.49682	0.742276
98	0	0.04557	0.09114	0.13671	0.18228	0.238712	0.328846	0.476828	0.738008	1.139868	6.516502	0.503312	0.757183
99	0	0.04557	0.09114	0.13671	0.18228	0.242555	0.330836	0.478894	0.738008	1.147225	6.516502	0.505716	0.760243
100	0	0.04557	0.09114	0.13671	0.18228	0.239313	0.333545	0.489803	0.732699	1.164537	6.516502	0.508289	0.764035

Table 5. Summary statistics of land quality contribution under constant returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-89.5373	-63.9036	-21.7769	-6.62849	-0.21091	-0.001	0.091405	0.172619	1.077832	3.781631	11.53956	-12.5535	25.67421
32	-100	-70.1841	-18.6406	-3.7918	-0.11747	-0.00262	0.090218	0.169166	1.033431	3.559978	11.1061	-12.4909	27.1491
33	-100	-70.1764	-14.5828	-2.91341	-0.13815	-0.00011	0.092001	0.171316	1.271654	3.665605	10.30662	-11.2808	26.1403
34	-100	-70.1775	-13.4287	-2.48488	-0.10455	0	0.091261	0.167463	1.235185	3.478194	10.03209	-10.9887	25.85251
35	-100	-70.1783	-13.1004	-2.49067	-0.08538	-0.00059	0.087164	0.165192	1.231483	3.430232	9.863719	-10.979	25.83562
36	-100	-17.3792	-0.9435	-0.08641	-0.02284	0	0.02565	0.049759	0.354156	1.015534	2.909107	-6.73176	20.86168
37	-100	-18.2282	-0.88381	-0.09138	-0.02036	-0.00039	0.020051	0.037828	0.284159	0.776071	2.190395	-6.63059	20.48821
38	-100	-16.3202	-1.10189	-0.11731	-0.0183	0	0.016103	0.032247	0.216565	0.562257	1.901697	-6.34318	19.31596
39	-100	-18.969	-1.42069	-0.14968	-0.01982	0	0.017203	0.033482	0.238675	0.609055	1.841528	-6.34902	19.10388
40	-100	-18.0981	-3.15835	-0.16843	-0.03601	-0.00017	0.01911	0.035877	0.278824	0.741053	2.03364	-6.50729	19.06972
41	-100	-19.8453	-3.11028	-0.23429	-0.04245	-0.00042	0.0284	0.05018	0.402403	1.160566	2.842454	-6.56712	19.1408
42	-100	-23.1908	-1.98751	-0.15094	-0.03208	-0.00036	0.026905	0.054973	0.395869	0.968738	3.585956	-6.50283	19.10964
43	-100	-21.5849	-2.2224	-0.1625	-0.02812	0	0.016064	0.033726	0.211579	0.56565	2.053973	-6.67986	18.94028
44	-100	-21.0542	-2.09696	-0.16993	-0.03119	-0.00033	0.021258	0.040478	0.273398	0.691454	2.313606	-6.54555	18.63299
45	-100	-22.1643	-3.02847	-0.20719	-0.04157	-0.00016	0.021119	0.040777	0.336188	0.878982	2.146328	-6.70171	18.61583
46	-100	-22.8523	-3.76131	-0.30114	-0.0432	0	0.02492	0.045462	0.427576	1.0606	2.369398	-6.54118	18.10729
47	-100	-23.1796	-3.92461	-0.38675	-0.0484	0	0.031161	0.050987	0.513006	1.337464	2.892145	-6.51918	18.03386
48	-100	-22.6355	-3.83658	-0.37024	-0.04786	-0.0007	0.035069	0.055201	0.543621	1.499281	3.06644	-6.28347	17.68543
49	-100	-22.7346	-3.86431	-0.40778	-0.04784	-0.00163	0.037683	0.060204	0.568535	1.673475	3.400106	-6.2659	17.66436
50	-100	-22.7792	-3.82971	-0.49967	-0.04802	-0.00168	0.039341	0.062852	0.600202	1.785526	3.580278	-6.26327	17.66882
51	-100	-23.6073	-4.47702	-0.63189	-0.05399	-0.00093	0.047153	0.075911	0.644969	2.13618	4.42584	-6.23614	17.52572
52	-100	-23.9143	-4.64267	-0.69164	-0.05931	0	0.051597	0.082773	0.71729	2.238978	4.797111	-6.21113	17.50725
53	-100	-24.4557	-4.79771	-0.71603	-0.065	-0.00046	0.054343	0.088298	0.74825	2.262394	5.147214	-6.26323	17.54287
54	-100	-24.8817	-5.28698	-1.01095	-0.07361	-0.00135	0.062013	0.104069	0.824502	2.501791	6.241541	-6.39066	17.6785
55	-100	-25.381	-5.67481	-1.16956	-0.08396	-0.00224	0.063095	0.111513	0.847516	2.677614	6.76003	-6.45598	17.69762
56	-100	-25.3841	-6.20645	-1.6549	-0.0984	-0.00048	0.068929	0.122553	0.911047	2.846076	7.86014	-6.54176	17.76233
57	-100	-26.6941	-7.90558	-2.17999	-0.16496	-0.00036	0.072089	0.14662	0.956928	3.173562	9.454873	-6.88305	18.3098
58	-100	-26.5258	-7.77984	-2.53321	-0.24063	-0.00046	0.074463	0.148004	0.94908	3.32401	10.26092	-6.78853	17.96107
59	-100	-26.3295	-8.09872	-2.81953	-0.41435	-0.00011	0.071606	0.147408	0.930493	3.419038	10.75283	-6.84752	17.94523
60	-100	-29.1374	-9.89982	-3.84468	-0.79732	0	0.070735	0.183417	0.940666	3.556725	12.04855	-7.94818	20.54849
61	-100	-29.4588	-10.218	-4.45167	-1.23544	-0.00018	0.069724	0.199637	0.940842	3.534256	13.15302	-8.17614	20.59642
62	-100	-28.8426	-10.3563	-4.67066	-1.39981	-0.00018	0.068442	0.185675	0.880203	3.476854	13.29772	-7.91836	19.86244
63	-100	-28.8691	-10.4405	-4.66338	-1.29027	-0.00018	0.066694	0.164658	0.849699	3.414352	13.14245	-7.83949	19.72893
64	-100	-27.8802	-9.76407	-3.23041	-0.4465	-0.00017	0.061773	0.133597	0.787817	3.450786	10.83437	-7.49778	19.36585
65	-100	-26.8898	-9.94707	-3.02746	-0.39409	-0.00055	0.064448	0.140583	0.770047	3.514236	10.60504	-7.29655	19.09851
66	-100	-26.5903	-9.80505	-2.93936	-0.37274	-0.00016	0.067202	0.139185	0.786735	3.560661	10.52624	-7.20172	18.99442
67	-98.3473	-17.2344	-6.61595	-2.01706	-0.0905	0.000171	0.064291	0.141749	0.856012	3.699953	9.973887	-4.08685	11.95127
68	-98.3473	-16.7595	-6.30531	-1.90806	-0.07404	0	0.068789	0.138463	0.917537	3.668487	9.778076	-4.03282	11.89621
69	-98.3473	-16.5588	-6.13472	-1.90088	-0.08138	0	0.070483	0.138591	0.915258	3.730502	9.795168	-3.99674	11.86949
70	-98.3474	-16.293	-5.8944	-1.85209	-0.08089	0	0.068649	0.13203	0.911156	3.750157	9.81363	-3.9443	11.79183
71	-98.3474	-16.2005	-5.73717	-1.69118	-0.07431	0.000737	0.064427	0.133733	0.910971	3.618315	9.664913	-3.90199	11.74622
72	-98.3475	-15.9109	-5.2199	-1.55215	-0.06437	0.002299	0.067459	0.136858	0.939586	3.71688	9.775931	-3.79942	11.67141
73	-98.3476	-15.9211	-5.28268	-1.51914	-0.06054	0.000196	0.062602	0.127645	0.861468	3.524389	9.474224	-3.80159	11.61662
74	-98.3476	-15.8882	-5.28275	-1.45485	-0.06059	0.000212	0.062575	0.127717	0.861239	3.530585	9.482476	-3.76628	11.59271
75	-98.3476	-15.7686	-5.20537	-1.4823	-0.05939	0.000212	0.06319	0.128535	0.870902	3.536188	9.489973	-3.73064	11.54398
76	-98.3477	-15.7059	-4.90319	-1.17501	-0.05558	0.00128	0.06068	0.124525	0.839591	3.271343	9.438629	-3.68004	11.47901
77	-98.3478	-15.3641	-4.56113	-0.97923	-0.05534	0.001015	0.062663	0.126115	0.87509	3.108442	9.480016	-3.55416	11.35691
78	-98.3479	-15.3393	-3.90872	-0.72385	-0.05411	0.000274	0.060425	0.1241	0.854255	3.024089	9.218921	-3.49061	11.29764
79	-98.3481	-15.2327	-3.67253	-0.58133	-0.04744	0.002408	0.058629	0.11974	0.794088	2.759892	8.80519	-3.42189	11.25642
80	-98.3481	-14.8935	-3.39986	-0.52208	-0.0458	0.002402	0.059161	0.118574	0.792195	2.751062	8.77843	-3.34356	11.14582
81	-98.348	-14.5372	-3.11409	-0.52185	-0.04586	0.002401	0.060515	0.118525	0.790518	2.833891	8.775089	-3.25742	11.0298
82	-98.348	-14.501	-3.08482	-0.52044	-0.04596	0.002419	0.060526	0.119796	0.790532	2.834893	8.774197	-3.24497	11.01367
83	-98.348	-14.5013	-3.08491	-0.49985	-0.04601	0.002367	0.060788	0.122486	0.790523	2.831498	8.770614	-3.23593	11.00558
84	-98.3482	-14.4969	-3.09408	-0.43116	-0.04426	0.000757	0.054854	0.123019	0.783536	2.696782	8.637683	-3.23975	10.992
85	-98.3482	-13.9959	-3.03402	-0.39904	-0.04536	0.000274	0.054552	0.122641	0.774652	2.621476	8.48407	-3.23305	10.95859
86	-98.3484	-13.4321	-2.91132	-0.32146	-0.04642	0.000243	0.047972	0.115126	0.661923	2.598364	8.41904	-3.16902	10.78369
87	-98.3484	-12.9773	-2.75127	-0.30517	-0.04576	0.00028	0.050454	0.114929	0.619719	2.586303	8.379475	-3.04161	10.57454
88	-98.3484	-12.7865	-2.72786	-0.23664	-0.04502	0	0.049808	0.114078	0.624039	2.431712	8.6515	-3.00533	10.55798
89	-98.3486	-13.1586	-2.88943	-0.2582	-0.04247	0.000875	0.041799	0.111661	0.549347	2.215716	8.682511	-3.05404	10.55959
90	-98.3488	-13.0248	-2.84068	-0.30859	-0.04683	0	0.039635	0.098829	0.442216	1.817958	8.446101	-3.11976	10.55766
91	-98.3489	-11.5885	-2.54929	-0.20552	-0.04672	0	0.035918	0.09641	0.375946	1.794931	8.242532	-2.93975	10.19787
92	-98.3489	-10.2141	-2.36695	-0.21143	-0.04523	0.000382	0.037475	0.092933	0.385405	1.711872	8.311142	-2.72537	9.845162
93	-98.349	-10.2284	-2.50402	-0.16611	-0.04322	0.000148	0.035924	0.089641	0.369428	1.795546	8.800743	-2.76033	9.87439
94	-98.349	-8.90278	-2.36467	-0.23008	-0.04574	0.001086	0.03425	0.089918	0.36711	1.714507	8.815647	-2.59172	9.576428
95	-98.3488	-6.65525	-1.12776	-0.12339	-0.03804	0	0.028914	0.075488	0.361821	1.524775	7.131694	-1.99568	8.413589
96	-98.349	-6.83112	-1.62208	-0.1524	-0.04602	0.000308	0.032939	0.093401	0.369994	1.442255	7.884508	-2.0175	8.437061
97	-98.3491	-6.7509	-1.30502	-0.13395	-0.04354	0.000315	0.027762	0.08193	0.314074	1.414228	6.631591	-1.89555	8.186257
98	-98.349	-5.33358	-0.85535	-0.1272	-0.05869	0.000991	0.033652	0.09604	0.422348	1.690784	7.002567	-1.63924	8.123901
99	-98.3489	-3.63679	-0.69911	-0.11418	-0.05119	0	0.032718	0.094034	0.407525	1.578662	7.201806	-1.4798	8.100025
100	-98.3479	-7.13696	-1.6819	-0.22976	-0.03928	0.001243	0.044125	0.103305	0.486762	2.170289	6.947068	-2.14562	9.118594

Table 6. Summary statistics of land size contribution to yield difference under constant returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-75.8212	-22.7953	-14.5604	-1.03219	0	0	0	0	1.490522	8.145222	183.9652	-2.37149	22.10468
32	-75.8226	-22.5544	-13.3592	-1.0342	0	0	0	0.000735	1.256817	7.398089	184.4233	-2.32423	22.12715
33	-75.8166	-22.384	-13.3311	-0.99672	0	0	0	0	0.873523	7.153378	185.1689	-2.39363	22.11403
34	-75.8172	-22.4325	-13.3482	-1.00404	0	0	0	0	0.933372	7.205832	185.417	-2.40363	22.12164
35	-75.8177	-22.482	-13.3509	-1.01173	0	0	0	0	0.965311	7.228081	185.5952	-2.40466	22.1265
36	-75.8311	-23.0486	-14.0002	-1.07765	0	0	0	0	0.762713	6.695958	193.4823	-2.63077	22.31757
37	-75.833	-23.058	-13.8826	-1.08632	0	0	0	0	0.780436	6.733732	194.1807	-2.65765	22.3373
38	-75.8339	-23.0593	-13.7775	-1.09108	0	0	0	0	0.710318	6.276778	194.8556	-2.71442	22.32782
39	-75.834	-23.0582	-13.7437	-1.08812	0	0	0	0	0.501729	6.276778	194.8723	-2.71353	22.32683
40	-75.8339	-23.0546	-13.878	-1.08567	0	0	0	0	0.522154	6.276778	194.9448	-2.71806	22.33126
41	-75.8325	-23.0476	-13.9031	-1.07698	0	0	0	0	0.369949	6.276778	194.8017	-2.71285	22.32572
42	-75.8375	-23.0693	-13.9788	-1.10529	0	0	0	0	0.319457	6.276778	195.4005	-2.73885	22.33903
43	-75.8391	-23.0663	-14.0356	-1.11553	0	0	0	0	0.309068	6.276778	195.977	-2.73513	22.34377
44	-75.8383	-23.0607	-14.0346	-1.11211	0	0	0	0	0.300195	6.265857	195.7319	-2.8924	22.07753
45	-75.8356	-23.043	-13.9253	-1.09283	0	0	0	0	0.303743	6.265857	195.0892	-2.87434	22.05507
46	-75.8334	-23.0331	-13.9264	-1.08206	0	0	0	0	0.310141	6.265857	194.7284	-2.88326	22.0425
47	-75.8316	-23.0249	-13.919	-1.07592	0	0	0	0	0.31805	6.265857	194.1211	-2.88088	22.02241
48	-75.8307	-23.0286	-13.9496	-1.07255	0	0	0	0	0.321308	6.265857	193.6185	-2.88939	22.00996
49	-75.8299	-23.0245	-13.9638	-1.06763	0	0	0	0	0.327249	6.265857	193.3326	-2.8881	22.00122
50	-75.8294	-23.0223	-13.9694	-1.06437	0	0	0	0	0.330298	6.265857	193.1757	-2.8865	21.99664
51	-75.8272	-23.012	-13.9918	-1.04926	0	0	0	0	0.337058	6.265857	192.4343	-2.88733	21.9696
52	-75.8263	-23.0087	-13.9985	-1.04246	0	0	0	0	0.340226	6.267029	192.1106	-2.88364	21.95942
53	-75.8254	-23.0047	-14.0049	-1.03521	0	0	0	0	0.347909	6.276778	191.8054	-2.87627	21.95116
54	-75.8226	-22.9644	-14.0118	-1.01679	0	0	0	0	0.364015	6.276778	190.8375	-2.85667	21.92254
55	-75.8213	-22.941	-14.0108	-1.00921	0	0	0	0	0.370858	6.276778	190.3851	-2.84753	21.90723
56	-75.8186	-22.7626	-13.9998	-0.99239	0	0	0	0	0.381486	6.29047	189.4241	-2.82869	21.87692
57	-75.8144	-22.5167	-13.9996	-0.97002	0	0	0	0	0.397413	6.379739	188.036	-2.78304	21.8433
58	-75.8113	-22.3668	-14.0012	-0.959	0	0	0	0	0.379351	6.276778	187.3477	-2.78277	21.81827
59	-75.8093	-22.331	-13.9904	-0.95244	0	0	0	0	0.38882	6.276778	186.9393	-2.77342	21.8054
60	-75.8048	-22.5125	-13.7849	-0.94399	0	0	0	0	0.367605	5.284342	185.8478	-3.08292	21.3648
61	-75.8008	-22.3096	-13.7602	-0.93487	0	0	0	0	0.368723	5.298897	184.9326	-3.05188	21.33866
62	-75.8001	-22.3253	-13.4297	-0.92557	0	0	0	0	0.300157	5.198984	184.6757	-3.04562	21.28497
63	-75.8003	-22.3909	-13.4183	-0.92761	0	0	0	0	0.300157	5.198984	184.345	-3.05428	21.2787
64	-75.8077	-22.4638	-13.3644	-0.95774	0	0	0	0	0.290158	5.648593	185.6039	-3.06888	21.3007
65	-75.808	-22.6046	-13.3312	-0.96356	0	0	0	0	0.240132	5.634555	185.2211	-3.08602	21.2882
66	-75.808	-22.6285	-13.3101	-0.96448	0	0	0	0	0.23003	5.623251	184.721	-3.09539	21.27446
67	-75.81	-22.9782	-13.5751	-0.97904	0	0	0	0	0.015921	5.516851	184.2376	-3.01414	21.54356
68	-75.8104	-22.9797	-13.7319	-0.98234	0	0	0	0	0.015921	5.446971	184.4348	-3.02037	21.54719
69	-75.8106	-22.9805	-13.8036	-0.98383	0	0	0	0	0.015921	5.417116	184.306	-3.02466	21.54572
70	-75.8109	-22.9819	-13.9091	-0.98603	0	0	0	0	0.015921	5.377845	184.2993	-3.03033	21.54679
71	-75.8116	-22.9843	-14.0762	-0.99084	0	0	0	0	0.015921	5.288721	184.452	-3.03841	21.5508
72	-75.8121	-22.9738	-14.1573	-0.99479	0	0	0	0	0.015269	5.198984	184.3691	-3.04965	21.54781
73	-75.8131	-22.9791	-14.1612	-1.00092	0	0	0	0	0.012265	5.198984	184.6532	-3.05564	21.55717
74	-75.8131	-22.9797	-14.1612	-1.00097	0	0	0	0	0.012296	5.198984	184.6462	-3.05641	21.55874
75	-75.813	-22.9794	-14.2002	-1.00055	0	0	0	0	0.012235	5.198984	184.6425	-3.05779	21.55902
76	-75.8143	-22.9867	-14.2452	-1.0097	0	0	0	0	0.012618	5.198984	184.7215	-3.07306	21.56164
77	-75.8148	-22.9906	-14.3634	-1.0144	0	0	0	0	0.015921	5.198984	184.667	-3.08703	21.55957
78	-75.8155	-22.9955	-14.3662	-1.01839	0	0	0	0	0.015921	5.198984	184.8113	-3.09348	21.56487
79	-75.817	-23.0041	-14.4177	-1.03075	0	0	0	0	0.016373	5.020374	184.6792	-3.11506	21.55939
80	-75.8171	-23.0053	-14.5296	-1.03147	0	0	0	0	0.017189	5.008489	184.7135	-3.11973	21.56166
81	-75.8169	-23.0053	-14.644	-1.03035	0	0	0	0	0.017858	5.031004	184.7177	-3.12279	21.56218
82	-75.8169	-23.0053	-14.6558	-1.03035	0	0	0	0	0.018118	5.031209	184.7189	-3.12317	21.56239
83	-75.8169	-23.0054	-14.6559	-1.03053	0	0	0	0	0.018512	5.028707	184.7235	-3.12333	21.56258
84	-75.818	-23.0094	-14.6611	-1.03882	0	0	0	0	0.027859	4.97799	184.8929	-3.13331	21.56678
85	-75.8186	-23.0114	-14.6893	-1.04254	0	0	0	0	0.027859	4.97799	185.1408	-3.13745	21.57252
86	-75.8196	-23.0162	-14.8711	-1.04979	0	0	0	0	0.027859	4.97799	185.7473	-3.14793	21.58735
87	-75.8198	-23.0214	-15.0953	-1.05047	0	0	0	0	0.031134	4.97799	185.9692	-3.15535	21.59258
88	-75.8204	-23.0267	-15.121	-1.05694	0	0	0	0	0.045602	4.97799	186.2986	-3.16756	21.59107
89	-75.8221	-23.0369	-15.128	-1.06691	0	0	0	0	0.04999	4.97799	187.0737	-3.18299	21.59891
90	-75.8237	-23.0448	-15.1612	-1.07685	0	0	0	0	0.053209	4.97799	187.8847	-3.19887	21.60543
91	-75.8243	-23.0468	-15.5608	-1.081	0	0	0	0	0.045143	4.97799	188.4766	-3.21493	21.61683
92	-75.8243	-23.0467	-15.7396	-1.081	0	0	0	0	0.042959	4.97799	188.797	-3.22764	21.62193
93	-75.8251	-23.0494	-15.7432	-1.08825	0	0	0	0	0.027859	4.97799	189.2518	-3.23831	21.62096
94	-75.8253	-23.0499	-15.7437	-1.08677	0	0	0	0	0.058535	4.97799	189.6504	-3.24858	21.62916
95	-75.8238	-23.0475	-15.737	-1.07605	0	0	0	0	0.027859	4.97799	189.9326	-3.25786	21.65085
96	-75.8252	-23.0523	-16.0551	-1.08658	0	0	0	0	0.030731	4.97799	190.7498	-3.27905	21.63982
97	-75.8266	-23.0609	-15.9102	-1.09357	0	0	0	0	0.032723	5.126552	191.1718	-3.28614	21.6493
98	-75.8257	-23.0526	-16.821	-1.08941	0	0	0	0	0.027859	5.198984	190.8879	-3.30787	21.61428
99	-75.8247	-23.049	-17.7428	-1.07825	0	0	0	0	0.027859	5.198984	190.5454	-3.31425	21.61192
100	-75.8148	-23.0182	-16.9921	-0.99717	0	0	0	0	0.023868	5.198984	187.9219	-3.18715	21.59904

Table 7. Summary statistics of other inputs contribution to yield difference under constant returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-100	-89.7526	-85.8764	-80.601	-75.8712	-66.5401	-52.144	-32.7541	-9.16267	20.29926	205.9349	-48.9915	43.28737
32	-100	-89.4219	-85.8715	-80.5039	-75.7563	-66.0569	-52.481	-26.8646	-8.10175	19.80695	298.1742	-47.9066	46.08336
33	-100	-89.4103	-85.8662	-80.5787	-75.8989	-66.1949	-52.7356	-28.4692	-9.12116	18.16277	294.0353	-48.8069	44.97799
34	-100	-89.5351	-85.866	-80.5552	-75.89	-66.1772	-52.7668	-28.8907	-9.10229	18.17717	294.5507	-48.8157	45.01732
35	-100	-89.5159	-85.8659	-80.5405	-75.8858	-66.2179	-52.7569	-28.8614	-9.10646	18.06697	294.9114	-48.8056	45.03949
36	-100	-90.1211	-86.1686	-80.999	-76.2116	-67.2781	-55.3986	-32.9114	-11.4949	19.08511	124.4191	-50.5387	41.8519
37	-100	-89.8944	-86.1867	-81.0132	-76.2272	-67.2836	-54.9601	-33.5317	-11.4817	19.09237	124.824	-50.6001	41.63215
38	-100	-89.8938	-86.1501	-81.1043	-76.242	-67.8362	-54.964	-33.5357	-11.5012	19.08306	125.2536	-50.5802	41.71176
39	-100	-89.8933	-86.1397	-81.1325	-76.3056	-68.3118	-54.9651	-33.542	-11.5009	19.08404	125.2304	-50.7048	41.66941
40	-100	-89.8756	-86.131	-81.1365	-76.2417	-68.3893	-54.7485	-33.5436	-11.4972	19.09313	125.1154	-50.7601	41.53205
41	-100	-89.8909	-86.1398	-81.1556	-76.2397	-68.33	-54.7436	-33.5444	-11.481	18.60924	124.618	-50.8856	41.30526
42	-100	-89.8981	-86.0782	-81.2613	-76.2473	-68.4006	-54.7515	-33.5157	-11.4811	19.06929	123.6543	-50.5726	42.03929
43	-100	-89.8999	-86.0739	-81.2562	-76.2498	-68.2026	-54.6425	-33.4632	-11.4965	19.03736	124.7606	-50.4855	42.14108
44	-100	-89.8988	-86.0749	-81.1989	-76.2485	-68.0792	-54.4837	-33.475	-11.4907	19.04857	128.0115	-50.4729	42.16683
45	-100	-89.8949	-86.1002	-81.158	-76.2442	-68.0131	-54.48	-33.4641	-11.4833	19.07208	128.2417	-50.6437	41.7685
46	-100	-89.8925	-86.1186	-81.1497	-76.2408	-68.0196	-54.247	-33.6189	-11.4873	18.70935	128.0395	-50.7366	41.5652
47	-100	-89.8906	-86.134	-81.1378	-76.238	-68.0183	-54.3625	-33.4813	-11.4893	18.43941	127.7879	-50.803	41.41648
48	-100	-89.8898	-86.1419	-81.1295	-76.2367	-67.9677	-54.401	-33.4929	-11.49	18.65122	127.675	-50.8446	41.37971
49	-100	-89.8885	-86.1491	-81.1207	-76.2354	-67.9544	-54.4623	-33.494	-11.4843	18.47992	127.4415	-50.8954	41.29515
50	-100	-89.8879	-86.1526	-81.1173	-76.2347	-67.9618	-54.4914	-33.4956	-11.4599	18.13065	127.3143	-50.9199	41.2512
51	-100	-90.165	-86.263	-81.2605	-76.2313	-68.0943	-54.4828	-33.4982	-11.4473	16.11635	126.7173	-51.0651	41.04218
52	-100	-90.1518	-86.2681	-81.2318	-76.2299	-68.2313	-54.4794	-33.5031	-11.4414	15.66004	126.4587	-51.1197	40.94796
53	-100	-90.1112	-86.2681	-81.1892	-76.2285	-68.39	-54.4757	-33.5068	-11.4475	14.90164	126.2152	-51.1649	40.85369
54	-100	-90.0247	-86.2346	-81.091	-76.2243	-68.6546	-54.4649	-33.5128	-11.4346	12.87266	125.7537	-51.2983	40.57467
55	-100	-89.9797	-86.2413	-81.08	-76.2223	-68.6599	-54.4598	-33.5164	-11.4272	12.43517	125.7113	-51.3792	40.43999
56	-100	-89.9074	-86.1869	-81.0856	-76.2182	-68.6542	-54.4502	-33.248	-11.4122	12.11812	125.5642	-51.5102	40.15081
57	-100	-89.8725	-86.1816	-81.0982	-76.195	-68.7447	-54.4353	-32.7285	-11.3916	10.91916	125.1663	-51.6349	39.8812
58	-100	-89.8751	-86.189	-81.0858	-76.1865	-68.6709	-54.4278	-32.4793	-11.3814	10.84487	125.2583	-51.7756	39.56503
59	-100	-89.894	-86.1686	-81.0715	-76.1918	-68.5079	-54.4234	-32.4231	-11.3753	10.50341	125.4515	-51.8229	39.44326
60	-100	-89.564	-86.0732	-81.0779	-76.1549	-68.7252	-55.3773	-33.5994	-11.4058	6.651862	43.08339	-52.9771	37.00735
61	-100	-89.5832	-86.0572	-81.06	-76.1279	-68.6977	-55.1276	-33.6054	-11.3246	6.301788	41.90984	-53.0613	36.75367
62	-100	-89.9112	-86.1208	-81.0768	-76.1739	-69.1096	-55.2552	-33.7241	-11.4002	6.203673	41.80756	-53.2214	36.64397
63	-100	-89.9362	-86.13	-81.0747	-76.1741	-69.1183	-55.2421	-33.719	-11.5309	6.288821	41.90748	-53.2399	36.66746
64	-100	-89.8674	-86.176	-81.1607	-76.209	-69.2996	-55.7122	-33.5706	-11.4718	7.356596	117.3943	-52.7172	38.00067
65	-100	-89.8659	-86.1898	-81.1613	-76.212	-69.3445	-55.7935	-33.5685	-11.5379	7.480842	80.72785	-52.8102	37.72666
66	-100	-89.8652	-86.1977	-81.1614	-76.2386	-69.3451	-55.8016	-33.5671	-11.5347	7.604955	69.1282	-52.8408	37.6658
67	-100	-90.2317	-86.2808	-81.1417	-76.3922	-69.8027	-55.2483	-33.3653	-11.5682	5.677836	38.35915	-53.3519	36.95429
68	-100	-90.2375	-86.2768	-81.1495	-76.4071	-69.7917	-55.2733	-33.3885	-11.5726	5.918799	38.2622	-53.338	37.00055
69	-100	-90.2442	-86.267	-81.161	-76.4272	-69.8101	-55.284	-33.4217	-11.5739	6.073469	38.2808	-53.3277	37.0465
70	-100	-90.2478	-86.2632	-81.1715	-76.4542	-69.8161	-55.2986	-33.4817	-11.5786	6.241281	38.32136	-53.3165	37.09376
71	-100	-90.2489	-86.2645	-81.1887	-76.5276	-69.8089	-55.3294	-33.4864	-11.5829	6.629491	38.24247	-53.2797	37.18807
72	-100	-90.2512	-86.2779	-81.2123	-76.611	-69.8343	-55.3631	-33.514	-11.5862	7.346279	37.97715	-53.2636	37.26776
73	-100	-90.2518	-86.279	-81.2298	-76.6177	-69.8503	-55.4023	-33.6199	-11.5806	7.89701	38.08787	-53.2013	37.39711
74	-100	-90.2518	-86.279	-81.2383	-76.6178	-69.8756	-55.4035	-33.6199	-11.5808	7.862464	38.0831	-53.2099	37.39693
75	-100	-90.2533	-86.2894	-81.2364	-76.6176	-69.8746	-55.401	-33.6198	-11.5826	7.834977	38.08718	-53.2228	37.3836
76	-100	-90.2554	-86.3015	-81.3028	-76.6218	-70.0252	-55.4138	-33.6211	-11.5554	8.363574	37.96842	-53.1305	37.60509
77	-100	-90.2597	-86.3362	-81.3222	-76.6247	-70.149	-55.4175	-33.6218	-11.5476	8.652159	37.76448	-53.1037	37.71482
78	-100	-90.263	-86.3369	-81.4449	-76.6385	-70.2254	-55.421	-33.6222	-11.5313	8.798651	37.76078	-53.0642	37.83205
79	-100	-90.2992	-86.3375	-81.6336	-76.7811	-70.1868	-55.4306	-33.6243	-11.5317	10.17122	37.25537	-52.9385	38.14567
80	-100	-90.3001	-86.3494	-81.6537	-76.7973	-70.1979	-55.4312	-33.7397	-11.5312	10.4075	37.27713	-52.9465	38.16017
81	-100	-90.3365	-86.3814	-81.669	-76.9049	-70.2263	-55.4304	-33.8352	-11.5317	10.46924	37.3012	-52.9783	38.12436
82	-100	-90.3599	-86.3845	-81.6709	-76.9176	-70.2287	-55.4304	-33.8451	-11.5317	10.48623	37.30215	-52.9816	38.12261
83	-100	-90.3839	-86.3845	-81.6713	-76.9209	-70.2319	-55.4305	-33.8451	-11.5319	10.49196	37.29033	-52.9834	38.12413
84	-100	-90.4265	-86.3833	-81.6945	-76.995	-70.1768	-55.4368	-33.8498	-11.5299	11.26457	37.1213	-52.8915	38.33279
85	-100	-90.4337	-86.3899	-81.7082	-77.0285	-70.1519	-55.4395	-33.8734	-11.5616	11.64404	37.07966	-52.8529	38.42399
86	-100	-90.4139	-86.438	-81.7246	-77.1008	-70.1146	-55.4449	-34.2469	-11.5882	12.20194	37.08188	-52.7894	38.59693
87	-100	-90.4156	-86.5006	-81.7249	-77.0975	-70.136	-55.4454	-34.5656	-11.5715	12.22633	37.12526	-52.8106	38.59865
88	-100	-90.3966	-86.5057	-81.7258	-77.098	-70.0324	-55.4506	-34.6078	-11.5478	12.5481	36.72475	-52.7311	38.76575
89	-100	-90.3762	-86.5182	-81.6769	-77.0837	-69.8411	-55.4603	-34.6273	-11.5357	13.42478	37.46639	-52.5562	39.09905
90	-100	-90.4169	-86.5475	-81.6258	-77.0631	-69.7267	-55.4709	-34.6856	-11.5525	14.09299	39.87028	-52.3615	39.46549
91	-100	-90.5167	-86.629	-81.5981	-77.0627	-69.8944	-55.4741	-34.9913	-11.9075	14.14367	40.57353	-52.3438	39.55224
92	-100	-90.6091	-86.6246	-81.6174	-77.0109	-70.1451	-55.8953	-35.1621	-12.349	14.19995	40.61501	-52.3796	39.53594
93	-100	-90.6291	-86.6218	-81.5924	-77.0118	-70.0514	-55.6548	-35.1684	-12.357	14.90806	42.48974	-52.2517	39.78635
94	-100	-90.6271	-86.6248	-81.6967	-77.0007	-69.9614	-55.5187	-35.5261	-12.3864	15.83824	42.67745	-52.2661	39.79541
95	-100	-90.6007	-86.6473	-81.6828	-77.2936	-69.9507	-55.7005	-36.0216	-12.6196	14.71574	38.71111	-52.6119	39.19491
96	-100	-90.6094	-86.6457	-81.6701	-77.2737	-69.8383	-55.4813	-35.8403	-12.6534	15.86325	41.41479	-52.4626	39.48285
97	-100	-90.643	-86.651	-81.6643	-77.3524	-69.8268	-55.4816	-35.7779	-12.6566	16.30083	41.34277	-52.464	39.53211
98	-100	-90.5446	-86.696	-81.735	-77.325	-69.8957	-55.4781	-36.2277	-12.829	16.26598	41.49304	-52.5721	39.39843
99	-100	-90.4479	-86.7472	-81.7114	-77.2432	-69.9771	-55.4712	-37.0818	-13.0228	15.91148	40.06992	-52.7007	39.1623
100	-100	-90.4602	-86.6206	-81.6163	-76.6042	-69.4597	-55.2562	-36.0256	-13.0246	10.62286	42.27549	-53.3023	37.5297

Table 8. Summary statistics of land quality contribution under non-increasing returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-89.5374	-71.1916	-29.4739	-10.4713	-1.31685	-0.00461	0.100342	0.113138	1.205026	3.559575	14.63759	-14.8455	27.76198
32	-100	-76.9161	-22.2483	-8.05756	-1.08191	-0.00051	0.082804	0.087188	0.980293	3.427858	13.89432	-15.0087	29.28994
33	-100	-76.944	-18.4665	-6.441	-0.51233	-0.00103	0.059328	0.059328	0.712382	2.838904	12.11957	-13.7865	28.45723
34	-100	-74.3163	-17.6208	-5.63448	-0.22421	-0.00311	0.049163	0.049163	0.596915	2.655873	11.67434	-13.5089	28.21699
35	-100	-74.3255	-17.7656	-5.61936	-0.17121	-0.00108	0.046484	0.046484	0.595855	2.676901	11.6528	-13.485	28.21728
36	-100	-24.9293	-1.59108	-0.11535	-0.02854	-0.00019	0.018093	0.027141	0.250618	0.898565	3.209414	-7.47103	21.58088
37	-100	-19.3871	-1.19427	-0.09847	-0.02392	0	0.015315	0.022974	0.197325	0.776955	2.648945	-7.19647	21.18369
38	-100	-21.5519	-1.39841	-0.11853	-0.02163	-0.00024	0.015743	0.023616	0.17851	0.648418	2.207725	-6.72435	19.84525
39	-100	-19.7936	-1.76302	-0.14378	-0.02665	-0.00069	0.015785	0.023678	0.181458	0.703666	2.167022	-6.74748	19.68813
40	-100	-22.9345	-3.11674	-0.15995	-0.03712	-0.00015	0.020184	0.030277	0.210122	0.837107	2.558683	-6.89619	19.69729
41	-100	-23.8235	-3.23607	-0.16207	-0.03924	0	0.031843	0.047768	0.399369	1.116448	3.568501	-6.96347	19.81142
42	-100	-24.3986	-2.60842	-0.13663	-0.0356	0	0.012282	0.018423	0.22389	0.673652	3.423958	-7.07351	19.78391
43	-100	-22.649	-2.8483	-0.16042	-0.03624	0	0.00538	0.00807	0.070533	0.247493	1.972288	-7.28121	19.68204
44	-100	-22.7846	-2.8848	-0.16459	-0.03582	0	0.009533	0.014299	0.131236	0.489894	2.331891	-7.15583	19.39653
45	-100	-24.7989	-4.30304	-0.19675	-0.04341	-0.00015	0.022144	0.033218	0.210786	0.890527	2.503885	-7.28413	19.47835
46	-100	-24.9926	-5.19058	-0.30741	-0.04725	-0.00016	0.026769	0.040156	0.240025	1.040611	2.67605	-7.18235	19.11899
47	-100	-25.9407	-5.8942	-0.42942	-0.04972	-0.00025	0.032291	0.04844	0.274559	1.241067	3.232345	-7.22849	19.15306
48	-100	-26.0074	-4.67745	-0.39384	-0.04974	-0.00084	0.035756	0.053639	0.304144	1.339193	3.578258	-7.04845	18.99008
49	-100	-26.011	-4.92683	-0.47875	-0.04791	0	0.039648	0.059478	0.323504	1.37367	3.949388	-7.07036	19.02984
50	-100	-25.5766	-4.96491	-0.49576	-0.05038	0	0.0416	0.062406	0.356617	1.364712	4.134678	-7.08718	19.05697
51	-100	-26.9098	-5.38409	-0.82191	-0.05513	-0.00225	0.050793	0.0762	0.528462	1.691421	5.006601	-7.13678	19.02886
52	-100	-26.9983	-5.53636	-1.02991	-0.05672	-0.00126	0.052598	0.080185	0.551234	1.771542	5.267072	-7.17946	19.05398
53	-100	-27.5505	-5.58922	-1.09639	-0.05915	-0.00147	0.053397	0.087868	0.579997	1.8732	5.7544	-7.23781	19.11789
54	-100	-28.6516	-6.69447	-1.42639	-0.07175	-0.00358	0.061655	0.106007	0.642232	2.115	6.917345	-7.40822	19.26979
55	-100	-29.1522	-7.35477	-1.7257	-0.08953	-0.00362	0.065635	0.115626	0.687458	2.347811	7.54661	-7.48158	19.31202
56	-100	-29.846	-8.37765	-1.93897	-0.1488	-0.00067	0.06816	0.133576	0.777567	2.621466	8.747876	-7.60458	19.40133
57	-100	-30.5056	-9.53453	-2.45986	-0.34576	-0.0027	0.072112	0.143052	0.854765	2.982714	10.24208	-7.8019	19.52004
58	-100	-30.5948	-10.0049	-3.04046	-0.48545	-0.00172	0.073781	0.148734	0.850154	3.200122	11.12633	-7.9408	19.58618
59	-100	-30.7642	-10.2973	-3.26125	-0.66706	-0.00097	0.076539	0.150731	0.824021	3.251044	11.69538	-8.0254	19.6003
60	-100	-33.1584	-11.5325	-4.18858	-1.21201	0	0.076415	0.156896	0.834998	3.271935	12.94721	-8.78852	20.68714
61	-100	-33.7188	-12.1804	-5.15542	-1.81439	-0.00081	0.074319	0.160184	0.794932	3.129396	14.05921	-9.06347	20.73801
62	-100	-32.0225	-12.3994	-5.04445	-1.85845	-0.00071	0.069036	0.152303	0.718941	2.947222	14.06524	-8.77758	20.15478
63	-100	-31.9719	-12.3774	-5.02764	-1.72081	0	0.067742	0.145504	0.708417	2.859118	13.9064	-8.66467	19.96563
64	-100	-31.5387	-10.9617	-4.26468	-0.74548	-0.00017	0.073882	0.161761	0.798564	2.988155	11.98344	-8.12153	19.59201
65	-100	-29.5845	-10.5375	-3.87403	-0.51294	-0.00131	0.072111	0.15499	0.756947	2.909372	11.54673	-7.87047	19.14644
66	-100	-28.8059	-10.3588	-3.7848	-0.45779	-0.00054	0.071157	0.15156	0.733512	2.848998	11.30726	-7.75867	18.90589
67	-95.9624	-17.5384	-6.52438	-2.30089	-0.20235	0.000523	0.071573	0.143446	0.778904	2.849163	10.11704	-4.45898	12.5967
68	-100	-18.0225	-6.68363	-1.98555	-0.14872	0	0.06662	0.1376	0.787466	2.65959	9.93906	-4.52655	12.77949
69	-100	-18.1696	-6.49569	-1.80099	-0.1475	0.000529	0.065735	0.13646	0.778363	2.609309	9.919563	-4.52067	12.83445
70	-100	-17.8592	-6.25797	-1.57135	-0.08773	0.00156	0.067141	0.132014	0.786235	2.571168	9.84201	-4.39854	12.6531
71	-100	-17.1077	-6.0368	-1.33496	-0.07422	0.001521	0.069593	0.128363	0.779521	2.570111	9.844806	-4.32271	12.59825
72	-27.6097	-0.14873	0	0	0	0	0	0	0	0.890486	9.717161	-0.10443	2.639486
73	-100	-16.903	-5.21711	-1.2437	-0.0575	0.001264	0.068167	0.118434	0.884076	2.553811	9.781793	-4.13785	12.34271
74	-100	-16.9229	-5.017	-1.24409	-0.06022	0.00086	0.067755	0.118039	0.883341	2.548504	9.876934	-4.08549	12.2741
75	-100	-16.5172	-4.93473	-1.11723	-0.06021	0.0016	0.070983	0.118044	0.884934	2.551119	9.896397	-4.01912	12.18182
76	-100	-16.2118	-4.71317	-0.9348	-0.06138	0.000774	0.066739	0.107935	0.73195	2.459882	9.397079	-3.92911	12.08368
77	-100	-15.4943	-4.56864	-0.77749	-0.06526	0.000589	0.0655	0.098266	0.657116	2.325074	8.907094	-3.82917	11.92323
78	-100	-15.5122	-4.57237	-0.60562	-0.06105	0.002035	0.061591	0.092401	0.639094	2.260888	8.595145	-3.77503	11.85312
79	-100	-15.1428	-4.71867	-0.50544	-0.05154	0.000133	0.050722	0.076093	0.60238	2.416142	7.842058	-3.73288	11.78702
80	-100	-14.701	-4.71503	-0.34503	-0.0535	0.000863	0.048588	0.072891	0.554242	2.394721	7.682144	-3.64644	11.65515
81	-100	-14.0992	-4.42512	-0.31083	-0.04896	0.000116	0.048186	0.072287	0.54264	2.385079	7.649136	-3.54399	11.51312
82	-100	-14.053	-4.38353	-0.30965	-0.04908	0.000353	0.048114	0.07218	0.546989	2.385639	7.643546	-3.52666	11.48951
83	-100	-14.0315	-4.38376	-0.31022	-0.04935	0.000257	0.047957	0.071944	0.534771	2.384262	7.629877	-3.51975	11.48161
84	-100	-14.1489	-4.39257	-0.31664	-0.04862	0.001848	0.041809	0.06272	0.552475	2.243002	7.238628	-3.51648	11.46888
85	-100	-14.0828	-4.58133	-0.29291	-0.04749	0	0.039058	0.058593	0.513692	2.28806	7.333389	-3.49456	11.43979
86	-100	-13.5133	-3.6862	-0.27106	-0.04953	0	0.029496	0.044248	0.4931	1.853154	7.249034	-3.44211	11.262
87	-100	-13.1171	-3.49084	-0.23527	-0.05114	0.000235	0.026789	0.040186	0.456323	1.810093	7.24882	-3.29558	11.05581
88	-100	-12.5071	-3.03105	-0.2271	-0.05009	0.001288	0.019232	0.028849	0.375133	1.618383	6.754161	-3.31323	11.02795
89	-100	-12.6515	-2.78664	-0.21354	-0.05273	0.001088	0.00761	0.011415	0.319806	1.329824	6.226139	-3.38333	11.02575
90	-98.3497	-12.6774	-3.08103	-0.2038	-0.05709	0	0	0	0.258178	0.876919	6.407549	-3.44723	10.9541
91	-98.3497	-11.424	-2.64552	-0.19909	-0.0494	0	0	0	0.241512	0.843204	6.433027	-3.2055	10.60104
92	-98.3497	-10.0036	-2.1009	-0.18614	-0.04537	0	0	0	0.128787	0.944447	6.428226	-2.93628	10.26185
93	-98.3497	-10.1194	-2.18403	-0.17683	-0.03439	0	0	0	0.02372	0.74884	6.230639	-2.97375	10.2747
94	-98.3497	-8.86463	-1.95508	-0.15885	-0.02644	0	0	0	0.006464	0.748726	6.277399	-2.72993	10.01184
95	-98.3497	-4.12084	-0.40794	-0.05858	0	0	0	0	0	0.488455	4.468694	-1.86862	9.005406
96	-98.3497	-3.75753	-0.34106	-0.05507	0	0	0	0	0	0.613098	5.854644	-1.81514	8.991748
97	-98.3497	-2.9421	-0.20403	-0.02968	0	0	0	0	0	0.792984	6.972254	-1.56639	8.844363
98	-98.3497	-2.55318	-0.13393	0	0	0	0	0	0	0.623384	8.037977	-1.44382	8.764872
99	-98.3497	-2.0366	-0.11605	0	0	0	0	0	0	0.715929	7.187842	-1.38259	8.746149
100	-98.3497	-1.97951	-0.08822	0	0	0	0	0	0	0.428312	6.405565	-1.38758	8.768594

Table 9. Summary statistics of land size contribution to yield difference under non-increasing returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-75.8204	-21.4916	-14.5615	-1.04513	0	0	0	0	0.328334	8.143351	196.6479	-2.34972	22.21395
32	-75.8246	-21.3934	-13.2094	-1.02606	0	0	0	0	0.617087	8.157519	196.6479	-2.18325	22.24799
33	-75.829	-21.3309	-13.2255	-1.03614	0	0	0	0	0.219841	7.371395	196.6479	-2.28751	22.24859
34	-75.8307	-21.2994	-13.2314	-1.04447	0	0	0	0	0.243582	7.375145	196.6479	-2.29753	22.25453
35	-75.8311	-21.2632	-13.233	-1.04779	0	0	0	0	0.241054	7.375657	196.6479	-2.30006	22.25405
36	-75.8342	-23.0646	-13.582	-1.08498	0	0	0	0	0.049863	7.374466	196.6479	-2.58138	22.45848
37	-75.8349	-23.069	-13.5469	-1.09101	0	0	0	0	0.070293	7.126792	196.6479	-2.61663	22.46577
38	-75.8348	-23.0654	-13.5156	-1.09544	0	0	0	0	0.018555	6.276778	196.6479	-2.70976	22.4231
39	-75.8348	-23.0637	-13.7083	-1.09278	0	0	0	0	0.06552	6.276778	196.6479	-2.70297	22.42292
40	-75.8337	-23.0568	-13.7885	-1.08588	0	0	0	0	0.054409	6.276778	196.601	-2.70602	22.42352
41	-75.8309	-23.0459	-13.8028	-1.07069	0	0	0	0	0.030768	6.276778	195.89	-2.70213	22.39806
42	-75.8356	-23.0685	-13.9777	-1.09943	0	0	0	0	0.066913	6.276778	195.5402	-2.7233	22.38348
43	-75.8373	-23.065	-14.0223	-1.10614	0	0	0	0	0.04366	6.276778	196.6479	-2.71063	22.40241
44	-75.8363	-23.0585	-14.0206	-1.10064	0	0	0	0	0.034836	5.454741	196.2602	-2.86583	22.12964
45	-75.8332	-23.0366	-13.8536	-1.07991	0	0	0	0	0.042361	5.480384	196.4711	-2.84082	22.11753
46	-75.8321	-23.0275	-13.8619	-1.07757	0	0	0	0	0.042756	5.573008	196.4668	-2.84721	22.11181
47	-75.8308	-22.9118	-13.8636	-1.06994	0	0	0	0	0.037688	5.66165	196.3612	-2.83765	22.09917
48	-75.83	-22.7713	-13.8633	-1.06462	0	0	0	0	0.036146	5.684626	196.2094	-2.84576	22.10264
49	-75.829	-22.5662	-13.858	-1.05865	0	0	0	0	0.036553	5.692846	195.976	-2.84227	22.09232
50	-75.8285	-22.4749	-13.8545	-1.05579	0	0	0	0	0.036959	5.762518	195.8528	-2.83981	22.08691
51	-75.8263	-22.4494	-13.845	-1.04208	0	0	0	0	0.025344	6.196833	195.2446	-2.82708	22.05831
52	-75.8257	-22.458	-13.8252	-1.03708	0	0	0	0	0.018309	6.276778	195.0832	-2.81976	22.051
53	-75.8244	-22.4663	-13.8157	-1.02956	0	0	0	0	0.016729	6.275785	194.71	-2.81128	22.03679
54	-75.8215	-22.5261	-13.8014	-1.01217	0	0	0	0	0.018309	6.251428	193.8046	-2.78812	22.00314
55	-75.82	-22.5536	-13.8342	-1.00213	0	0	0	0	0.018309	6.196308	193.311	-2.77622	21.98466
56	-75.8171	-22.3072	-13.8062	-0.9834	0	0	0	0	0.018309	6.114593	193.0993	-2.75038	21.96588
57	-75.8135	-22.0179	-13.7941	-0.96176	0	0	0	0	0.021042	6.276778	192.8052	-2.71511	21.94755
58	-75.8108	-21.8217	-13.7869	-0.94982	0	0	0	0	0.02113	6.276778	192.7295	-2.69312	21.93742
59	-75.8087	-21.6925	-13.7584	-0.94256	0	0	0	0	0.020728	6.276778	192.7049	-2.67869	21.93106
60	-75.8042	-21.0794	-14.0562	-0.92769	0	0	0	0	0.025282	6.276778	192.5711	-2.63924	21.90891
61	-75.7999	-20.849	-13.9728	-0.86381	0	0	0	0	0.031573	6.335232	192.5337	-2.60307	21.89698
62	-75.7994	-21.3676	-13.9847	-0.88471	0	0	0	0	0.02217	6.377788	191.5751	-2.61364	21.88273
63	-75.7997	-21.4435	-13.9885	-0.89753	0	0	0	0	0.021813	6.382039	191.4304	-2.61995	21.88367
64	-75.807	-21.7154	-13.9604	-0.94251	0	0	0	0	0.028986	6.41425	192.6076	-2.67562	21.90637
65	-75.8081	-22.0858	-13.9031	-0.94846	0	0	0	0	0.018143	6.405903	192.5168	-2.69218	21.90843
66	-75.8087	-22.2394	-13.8797	-0.95155	0	0	0	0	0.013744	6.402045	192.4905	-2.70614	21.90784
67	-75.8128	-22.6223	-13.8306	-0.97587	0	0	0	0	0	5.453126	193.685	-2.95051	21.73596
68	-75.8139	-22.6682	-13.4858	-0.98373	0	0	0	0	0	5.392213	194.0337	-2.95348	21.76387
69	-75.8144	-22.777	-13.2396	-0.9863	0	0	0	0	0.003939	5.352411	194.1875	-2.953	21.7667
70	-75.8154	-22.8802	-13.0779	-0.98951	0	0	0	0	0.007896	5.287229	194.436	-2.96085	21.77645
71	-75.816	-22.977	-13.0799	-0.99323	0	0	0	0	0.00733	5.217981	194.6465	-2.96921	21.78122
72	-75.8386	-23.0968	-19.019	-1.12151	0	0	0	0	0	4.97799	194.8866	-3.32868	21.95961
73	-75.8176	-22.9856	-13.201	-1.0043	0	0	0	0	0.004924	5.211115	195.2082	-2.98667	21.79775
74	-75.8177	-22.9863	-13.2199	-1.00455	0	0	0	0	0.007435	5.211333	195.2261	-2.9875	21.79965
75	-75.8177	-22.9871	-13.2318	-1.00455	0	0	0	0	0.007436	5.211153	195.217	-2.98998	21.7998
76	-75.8194	-22.9931	-13.2812	-1.01586	0	0	0	0	0.014636	5.206796	195.7908	-3.00253	21.81311
77	-75.8212	-22.9987	-13.4146	-1.02581	0	0	0	0	0.012409	5.204171	196.3323	-3.01475	21.82716
78	-75.8221	-23.002	-13.4184	-1.03277	0	0	0	0	0.016585	5.161648	196.6479	-3.01871	21.83713
79	-75.8248	-23.0109	-13.4773	-1.05168	0	0	0	0	0.007786	5.199483	196.6479	-3.03757	21.83908
80	-75.8255	-23.0127	-13.6028	-1.05478	0	0	0	0	0.006792	5.199907	196.6479	-3.04453	21.84094
81	-75.8258	-23.013	-13.7311	-1.05529	0	0	0	0	0.003838	5.200193	196.6479	-3.05078	21.84105
82	-75.8258	-23.0131	-13.7448	-1.05542	0	0	0	0	0.00362	5.200089	196.6479	-3.05162	21.84108
83	-75.8258	-23.0132	-13.7469	-1.05561	0	0	0	0	0.003501	5.199944	196.6479	-3.0519	21.84136
84	-75.8273	-23.0183	-13.753	-1.06648	0	0	0	0	0.005032	5.163049	196.6479	-3.06059	21.84224
85	-75.828	-23.0206	-13.786	-1.07139	0	0	0	0	0.009286	5.142199	196.6479	-3.06509	21.84208
86	-75.8306	-23.0529	-13.9832	-1.08139	0	0	0	0	0.017223	5.141475	196.6479	-3.07915	21.8472
87	-75.8317	-23.0563	-14.0531	-1.08581	0	0	0	0	0.01557	5.084079	196.6479	-3.09266	21.84769
88	-75.8335	-23.0653	-14.0743	-1.09784	0	0	0	0	0.015005	4.989345	196.6479	-3.10238	21.84578
89	-75.8363	-23.08	-14.0885	-1.11203	0	0	0	0	0.016296	4.98296	196.6479	-3.11504	21.84326
90	-75.8382	-23.0891	-14.1349	-1.12151	0	0	0	0	0.00837	4.927395	196.6479	-3.11951	21.81382
91	-75.8386	-23.0913	-14.2761	-1.12151	0	0	0	0	0.002433	4.87494	196.6479	-3.14396	21.81022
92	-75.8386	-23.0937	-14.332	-1.12151	0	0	0	0	0.004713	4.822737	196.6479	-3.16567	21.8045
93	-75.8386	-23.0937	-14.3687	-1.12151	0	0	0	0	0.009122	4.735602	196.6479	-3.16881	21.79942
94	-75.8386	-23.0961	-14.3218	-1.12151	0	0	0	0	0.00577	4.668985	196.6479	-3.18764	21.79187
95	-75.8386	-23.0968	-16.3071	-1.12151	0	0	0	0	2.22E-14	4.80745	196.6479	-3.24436	21.8066
96	-75.8386	-23.0968	-16.4924	-1.12151	0	0	0	0	0.00134	4.816078	196.6479	-3.25486	21.78282
97	-75.8386	-23.0968	-17.5131	-1.12151	0	0	0	0	0.001414	4.807302	196.6479	-3.27582	21.76344
98	-75.8386	-23.0968	-17.5324	-1.12151	0	0	0	0	0.002478	4.714627	196.6479	-3.27985	21.74613
99	-75.8386	-23.0968	-17.5324	-1.12151	0	0	0	0	0.00407	4.700253	196.6479	-3.27238	21.75133
100	-75.8386	-23.0968	-17.5324	-1.12151	0	0	0	0	0.007375	4.803176	196.6479	-3.25606	21.72564

Table 10. Summary statistics of other inputs contribution to yield difference under non-increasing returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-100	-89.7845	-85.8946	-80.8594	-75.0947	-66.681	-51.1774	-31.5152	-8.0631	14.47892	189.5771	-49.7768	41.52108
32	-100	-89.4973	-85.8717	-80.6004	-74.874	-66.0746	-51.761	-27.5906	-7.89475	13.82443	262.6922	-48.6573	44.00934
33	-100	-89.5931	-85.8697	-80.675	-75.1899	-66.2385	-52.4316	-29.428	-8.22729	15.4682	264.6308	-49.0954	43.77909
34	-100	-89.639	-85.8664	-80.686	-75.1687	-66.2414	-52.7751	-29.1032	-8.23287	16.05971	265.3722	-49.0632	43.87326
35	-100	-89.6368	-85.8669	-80.6874	-75.2263	-66.2422	-52.7344	-29.0982	-8.19635	16.17772	265.6011	-49.0556	43.89228
36	-100	-89.7387	-86.0427	-81.0421	-76.0701	-67.8939	-55.6075	-32.8115	-11.6617	18.61248	98.91955	-51.0961	40.64922
37	-100	-89.8533	-86.0434	-81.036	-76.2192	-67.8626	-55.3308	-33.0945	-11.664	18.69693	98.91126	-51.1752	40.46878
38	-100	-89.904	-86.0855	-81.1059	-76.219	-67.8833	-55.3194	-32.8423	-11.4766	18.66132	98.91254	-51.1728	40.50046
39	-100	-89.8945	-86.0842	-81.2678	-76.219	-68.5812	-55.3753	-33.7021	-11.481	18.64033	98.91266	-51.2409	40.52194
40	-100	-89.8777	-86.0984	-81.2667	-76.0776	-68.6774	-55.2599	-33.86	-11.5305	17.41151	98.92578	-51.3121	40.34979
41	-100	-89.8907	-86.1164	-81.2717	-76.0663	-68.7308	-55.2514	-33.8874	-11.5736	15.36149	98.96057	-51.4477	40.10126
42	-100	-89.8978	-86.076	-81.3484	-76.0858	-68.955	-55.2682	-33.9065	-11.4535	18.82048	98.90221	-51.1116	40.82999
43	-100	-89.8996	-86.0607	-81.3337	-76.0819	-68.6728	-55.2728	-33.9059	-11.4413	18.86986	98.88162	-51.0258	40.92178
44	-100	-89.8985	-86.0636	-81.3432	-76.0841	-68.722	-55.0479	-33.9062	-11.4333	18.71241	98.89401	-51.0579	40.83767
45	-100	-89.8944	-86.0633	-81.3829	-76.0794	-68.6639	-55.0352	-33.9005	-11.4815	17.72208	98.93163	-51.231	40.44635
46	-100	-89.8925	-86.0646	-81.3707	-76.0782	-68.6831	-55.2546	-33.6385	-11.4901	16.38655	98.94543	-51.3061	40.30991
47	-100	-89.8907	-86.0671	-81.3684	-76.0785	-68.715	-55.2473	-33.3518	-11.4862	15.45366	98.9619	-51.3754	40.16193
48	-100	-89.8898	-86.0684	-81.3808	-76.079	-68.7485	-55.2433	-33.8932	-11.4817	15.14803	98.97224	-51.4413	40.08384
49	-100	-89.8885	-86.0756	-81.3858	-76.0802	-68.7946	-55.2388	-33.8899	-11.4794	14.83892	98.98386	-51.4922	39.99557
50	-100	-89.8878	-86.0811	-81.3888	-76.0808	-68.8175	-55.2367	-33.8876	-11.4769	14.68463	98.98968	-51.5148	39.95241
51	-100	-90.1812	-86.2531	-81.3416	-76.0838	-68.9223	-55.2256	-33.8864	-11.3153	13.19553	99.01711	-51.6417	39.75728
52	-100	-90.1652	-86.2539	-81.3114	-76.0844	-68.9519	-55.2217	-33.8859	-11.3061	12.9871	99.02503	-51.6797	39.68383
53	-100	-90.1273	-86.2553	-81.2921	-76.0861	-69.0117	-55.2182	-33.8859	-11.2936	12.79157	99.04031	-51.7423	39.56497
54	-100	-90.0415	-86.2086	-81.1343	-76.0902	-69.1073	-55.2162	-33.7403	-11.2991	11.6411	99.07639	-51.8845	39.27618
55	-100	-89.9988	-86.1763	-81.2161	-76.092	-69.1342	-55.2129	-33.623	-11.3796	10.74527	99.09551	-51.9673	39.12247
56	-100	-89.9357	-86.1573	-81.1663	-76.0988	-69.1722	-55.2042	-33.2812	-11.3994	10.01881	99.1314	-52.1063	38.82463
57	-100	-89.8721	-86.0705	-81.1142	-76.1153	-69.0204	-55.1938	-32.7521	-11.3732	9.022929	99.175	-52.2666	38.4717
58	-100	-89.8948	-86.0598	-81.1112	-76.0596	-68.9395	-55.1804	-32.5003	-11.3582	7.945297	99.19993	-52.3543	38.26257
59	-100	-89.9153	-86.0408	-81.1037	-76.0283	-68.882	-55.1527	-32.3281	-11.33	7.371874	99.21504	-52.4059	38.1289
60	-100	-89.7273	-86.0092	-81.0775	-75.7653	-67.7047	-53.1106	-30.8607	-10.703	5.826408	164.0903	-51.4993	39.8883
61	-100	-89.7183	-85.942	-81.0518	-75.5906	-67.5532	-53.0334	-30.4138	-10.9332	5.866326	164.1309	-51.5703	39.67159
62	-100	-89.7395	-85.9014	-81.0434	-75.677	-67.4377	-54.0448	-31.0178	-11.0423	6.145339	164.1293	-51.7001	39.62272
63	-100	-89.7373	-85.9001	-81.08	-75.6464	-67.4024	-54.0461	-30.8968	-11.0491	6.292103	164.1229	-51.712	39.64121
64	-100	-89.7434	-86.0323	-81.0914	-76.0082	-67.8704	-54.0708	-31.4879	-11.0806	6.538125	164.0514	-51.7449	39.55694
65	-100	-89.7454	-86.0304	-81.0955	-76.0288	-68.526	-54.0779	-31.6124	-11.3584	7.240562	164.0336	-51.788	39.56218
66	-100	-89.8459	-86.0284	-81.1001	-76.0371	-68.5397	-54.0824	-31.6712	-11.3562	7.611573	164.0239	-51.7996	39.58352
67	-100	-90.1284	-86.2882	-81.5725	-76.3703	-69.5287	-55.2785	-33.999	-11.8505	6.445133	37.46467	-53.6052	36.67574
68	-100	-90.1147	-86.3056	-81.6596	-76.3857	-69.3657	-55.5831	-33.5294	-11.4616	6.04079	37.6848	-53.5399	36.79403
69	-100	-90.1103	-86.3112	-81.6613	-76.3866	-69.3676	-55.6117	-33.5274	-11.4673	6.028321	37.79721	-53.487	36.86191
70	-100	-90.1356	-86.3417	-81.6634	-76.3848	-69.6997	-55.6648	-33.5242	-11.4715	6.369668	38.00353	-53.4705	36.96098
71	-100	-90.1416	-86.3477	-81.6648	-76.383	-69.6999	-55.7345	-33.5207	-11.4757	6.634596	37.8081	-53.456	37.02819
72	-100	-90.7518	-86.868	-82.0796	-77.6361	-71.147	-55.8264	-38.426	-13.909	18.20697	47.09519	-52.8001	40.06923
73	-100	-90.164	-86.5624	-81.6674	-76.7336	-69.9338	-55.791	-33.6499	-11.4865	7.286421	37.50945	-53.4205	37.21033
74	-100	-90.164	-86.5624	-81.6674	-76.7338	-69.9797	-55.7908	-33.6502	-11.4867	7.333562	37.52955	-53.4315	37.21835
75	-100	-90.1798	-86.5625	-81.6674	-76.7338	-69.98	-55.7909	-33.6502	-11.4867	7.441261	37.57102	-53.4438	37.21867
76	-100	-90.1872	-86.5655	-81.6693	-76.7394	-70.2891	-55.7915	-33.6569	-11.4969	8.194564	37.3292	-53.3802	37.40807
77	-100	-90.2075	-86.5668	-81.6711	-76.7517	-70.522	-55.791	-33.941	-11.5058	8.570195	37.37162	-53.328	37.57255
78	-100	-90.2653	-86.5676	-81.708	-76.7876	-70.6096	-55.7882	-33.9436	-11.512	8.895719	37.35946	-53.2927	37.68175
79	-100	-90.2669	-86.5698	-81.7221	-77.0228	-70.6765	-55.7792	-34.1013	-11.5289	10.6452	36.87789	-53.1826	37.96885
80	-100	-90.2672	-86.5702	-81.7253	-77.0374	-70.6799	-55.7775	-34.4796	-11.8326	10.70786	37.02602	-53.1774	38.01697
81	-100	-90.2673	-86.5793	-81.733	-77.1438	-70.6861	-55.7772	-34.778	-11.8338	10.72072	37.18327	-53.1933	38.02373
82	-100	-90.2673	-86.5848	-81.7413	-77.1465	-70.6872	-55.7772	-34.7781	-11.8298	10.72298	37.19281	-53.1963	38.02554
83	-100	-90.2673	-86.5849	-81.7428	-77.1512	-70.688	-55.7773	-34.7785	-11.8292	10.72854	37.19286	-53.1966	38.02915
84	-100	-90.2887	-86.5861	-81.7526	-77.2125	-70.7286	-55.7722	-34.794	-11.8264	10.8908	36.87522	-53.1339	38.1865
85	-100	-90.3087	-86.5987	-81.7535	-77.2766	-70.7504	-55.7701	-34.7968	-11.8174	10.99237	36.75916	-53.1103	38.25606
86	-100	-90.372	-86.6644	-81.7567	-77.4491	-70.745	-55.7622	-34.8061	-11.7046	11.56196	36.96049	-53.0301	38.46805
87	-100	-90.4008	-86.6692	-81.7583	-77.4766	-70.7582	-55.7612	-34.8088	-11.8869	12.07286	37.18008	-53.0307	38.52508
88	-100	-90.3565	-86.6528	-81.7445	-77.479	-70.6819	-55.7662	-34.8162	-11.9466	12.67636	37.00276	-52.9482	38.69157
89	-100	-90.3377	-86.6351	-81.7517	-77.483	-70.5665	-55.7739	-34.8275	-11.962	13.85747	36.82538	-52.8214	38.94066
90	-100	-90.3361	-86.6108	-81.7588	-77.477	-70.2889	-55.4559	-34.4215	-12.0668	13.98776	37.62965	-52.6113	39.17918
91	-100	-90.3976	-86.5996	-81.7619	-77.5128	-70.5298	-55.8258	-34.9071	-12.219	14.04457	38.29141	-52.5862	39.31211
92	-100	-90.4602	-86.5829	-81.7677	-77.5132	-70.7115	-55.8264	-35.3194	-12.219	15.00901	38.627	-52.5976	39.37362
93	-100	-90.4601	-86.6119	-81.7804	-77.5135	-70.6644	-55.8264	-35.3223	-12.219	15.16961	39.52055	-52.5591	39.44018
94	-100	-90.5248	-86.6182	-81.801	-77.5139	-70.6646	-55.8264	-36.2395	-12.219	15.275	39.56159	-52.5824	39.46644
95	-100	-90.5915	-86.7553	-82.0316	-77.528	-70.8412	-55.8264	-36.5124	-12.8802	18.13392	41.49436	-52.628	39.66747
96	-100	-90.6366	-86.7563	-82.118	-77.5185	-70.8972	-55.8264	-36.4939	-12.8802	18.133	40.49047	-52.6489	39.66674
97	-100	-90.6003	-86.7593	-82.1113	-77.5191	-70.9351	-55.8264	-37.3127	-12.8802	17.94691	41.21991	-52.6827	39.71564
98	-100	-90.5558	-86.761	-82.0753	-77.5209	-70.9351	-55.8264	-37.3127	-13.2891	16.8974	41.4202	-52.7192	39.71555
99	-100	-90.5079	-86.7628	-82.0696	-77.5771	-70.9351	-55.8264	-37.3127	-13.2497	16.44964	42.67303	-52.7331	39.72423
100	-100	-90.4538	-86.7117	-82.0707	-77.508	-70.8215	-55.8264	-37.3127	-13.2403	16.44342	45.66762	-52.7224	39.73291

Table 11. Summary statistics of land quality contribution under variable returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	0	0	0	0	0	0	0	57.8616	95.9237	138.8852	601.1863	40.97519	73.48994
32	0	0	0	0	0	0	0	89.76464	119.0327	163.0921	622.5985	53.09077	86.25707
33	-100	-48.5169	-40.5055	-33.7552	-26.5897	0	13.70358	22.91571	33.09926	44.06256	246.203	-3.79698	42.2455
34	-100	-53.909	-45.6812	-37.0788	-30.2128	0	10.19829	15.94088	23.21435	31.45699	344.559	-8.79361	41.82523
35	-100	-55.137	-46.8652	-38.0285	-31.4818	0	7.735254	13.35132	19.64149	26.92227	142.6181	-11.2781	36.97383
36	-100	-79.6694	-68.09	-52.2124	-17.8792	0	3.03988	9.582034	14.48556	21.85982	146.4548	-20.0244	43.63874
37	-100	-79.2496	-65.9916	-50.8366	-14.3756	0	4.613642	10.21868	15.74251	23.71426	166.3025	-18.4278	43.14417
38	-100	-77.2859	-59.6929	-46.8644	-13.7725	0	2.682827	14.55327	19.57465	29.43754	142.9665	-15.5737	43.46375
39	-100	-73.9534	-58.609	-39.6845	-12.3257	0	4.138719	16.51555	21.45417	33.32345	358.3906	-13.2588	46.6612
40	-100	-71.3635	-55.3132	-32.0193	-12.0555	0	6.128717	17.19427	22.60909	35.51783	212.3379	-11.8349	44.78666
41	-100	-70.3726	-53.6463	-26.5056	-11.3658	0	5.14145	16.29883	21.39066	32.67011	120.5208	-11.7994	42.11873
42	-100	-69.7626	-52.5533	-24.8706	-10.0609	0	5.074186	16.092	21.6382	32.55738	117.4736	-11.0771	41.99364
43	-100	-69.9658	-50.5061	-24.2642	-9.89592	0	5.429638	15.60202	21.12196	31.95625	226.2427	-10.581	42.27121
44	-100	-69.8171	-51.0482	-23.9071	-9.78028	0	6.234004	14.49868	19.30118	31.50082	330.1324	-10.2824	44.57658
45	-100	-69.1795	-49.6302	-22.835	-8.89979	0	5.685231	13.78788	19.2249	30.79922	267.0823	-10.1974	42.64422
46	-100	-73.6319	-54.5762	-23.0338	-8.69812	0	5.747747	14.13552	19.78031	30.10559	253.3014	-10.7782	43.4721
47	-100	-73.8278	-54.2399	-22.0353	-9.58093	0	4.766326	13.57973	18.826	29.37763	225.4374	-11.1342	42.2735
48	-100	-73.926	-52.1779	-20.9013	-9.34018	0	4.719201	13.41069	18.4919	28.70913	233.9652	-10.9423	42.36285
49	-100	-74.2339	-50.3682	-20.862	-9.07729	0	4.490194	12.63343	17.57088	27.31577	202.2579	-11.4601	41.20507
50	-100	-74.4006	-47.0874	-20.5778	-8.77232	0	4.825865	11.88554	17.08419	26.68852	188.7031	-11.7162	40.71931
51	-100	-74.5455	-42.3408	-19.9973	-8.62913	0	4.789218	12.39083	17.05692	26.67389	178.5431	-11.3389	40.30494
52	-100	-74.6664	-39.4185	-20.4774	-7.73557	0	4.7452	12.4621	16.3374	25.76791	161.4772	-11.3513	39.67955
53	-100	-74.626	-38.7004	-20.3158	-7.51839	0	4.759166	12.51192	16.36833	25.89562	159.1272	-11.2004	39.64664
54	-100	-74.4687	-36.9842	-19.5589	-7.25342	0	4.692585	13.21564	17.04009	26.49558	157.1947	-10.7971	39.71628
55	-100	-74.383	-36.3959	-19.372	-7.15286	0	4.720584	13.1712	17.4487	26.66129	154.5984	-10.4312	39.41712
56	-100	-73.6864	-36.1903	-19.0758	-7.54558	0	4.881339	13.18207	17.73872	27.40616	151.0418	-9.97276	39.019
57	-100	-73.9356	-33.5659	-18.6861	-7.38063	0	5.058879	13.4641	18.24179	28.16417	152.9172	-9.54102	39.33073
58	-100	-73.2515	-32.8062	-18.309	-6.96632	0	4.931753	13.79312	18.78286	28.99588	150.701	-9.08503	39.42021
59	-100	-100	-33.0328	-18.3869	-7.1693	0	4.175864	12.92361	18.29413	28.40085	141.576	-11.9944	43.64952
60	-100	-100	-31.94	-18.1747	-7.45755	0	3.832702	12.1348	18.41118	29.32154	135.9175	-12.0187	43.60592
61	-100	-100	-32.6387	-18.0735	-7.30325	0	4.080999	12.62392	18.69116	29.21706	129.6084	-11.8261	43.73817
62	-100	-100	-31.1887	-17.1431	-7.27661	0	3.995767	12.54135	18.08686	28.51303	132.2003	-11.3477	42.86748
63	-100	-100	-30.3273	-17.3584	-7.18006	0	4.024971	12.10186	18.05173	28.73445	132.708	-10.9422	42.25312
64	-100	-100	-31.992	-17.2129	-6.62845	0	3.884442	13.10787	17.75137	27.66244	112.0949	-10.6068	41.23286
65	-100	-100	-30.713	-16.1514	-6.0998	0	3.624149	12.61454	17.21635	27.0355	111.1575	-10.1729	40.25364
66	-100	-100	-29.5399	-15.774	-6.00931	0	3.762002	12.09075	16.21878	25.393	109.0942	-10.3096	39.25839
67	-100	-43.6871	-23.3238	-11.3924	-4.13816	0	4.507183	11.36783	16.08755	24.36317	133.6521	-5.59154	33.42693
68	-100	-45.4255	-23.7163	-12.3943	-4.83157	0	3.90923	10.91395	15.49579	23.27488	122.2827	-6.39978	33.04121
69	-100	-45.808	-23.4171	-12.6388	-4.85356	0	3.781073	10.89521	15.41549	22.73556	116.3833	-6.53195	32.59602
70	-100	-44.7487	-23.6499	-12.1654	-5.30706	0	3.235504	10.21084	14.85853	21.48923	105.5552	-6.91	31.76328
71	-100	-47.2875	-23.777	-13.0618	-5.73201	0	3.080559	10.15808	14.53386	21.12569	100.2539	-7.65893	32.07951
72	-100	-45.6937	-23.7105	-12.9245	-5.70309	0	3.283118	10.32372	14.95202	21.31404	101.1433	-7.31433	31.93456
73	-100	-47.5359	-23.4758	-12.7716	-5.66132	0	3.427264	10.47864	15.03393	20.93337	99.09847	-7.28403	32.01598
74	-100	-45.4532	-23.2064	-12.6746	-5.55224	0	3.34661	10.72288	15.32477	20.91318	98.25285	-7.03623	31.79348
75	-100	-46.9763	-23.0553	-13.0287	-5.33563	0	3.458179	11.23843	16.00832	21.70557	98.7745	-6.94913	32.35023
76	-100	-45.8338	-23.1143	-12.4951	-4.77412	0	4.041752	11.49915	16.50977	22.40727	95.84295	-6.57099	32.479
77	-100	-50.2395	-23.8983	-12.66	-4.99945	0	4.189945	10.84778	15.40576	21.84898	86.48265	-7.3961	32.84827
78	-100	-49.4921	-24.1696	-11.353	-4.10622	0	2.782642	6.409602	8.995459	14.35122	136.4329	-8.95736	31.25775
79	-100	-50.0515	-25.1708	-11.6853	-4.42117	0	2.384433	5.629531	8.26586	13.0199	129.9427	-9.81612	30.9633
80	-100	-50.2047	-25.0922	-10.7225	-4.06575	0	2.751474	5.343379	7.84077	12.34453	122.9502	-9.90119	30.88056
81	-100	-50.6826	-25.236	-10.6123	-3.85011	0	2.152055	4.43536	6.733262	11.0805	105.3911	-10.487	30.15926
82	-100	-49.7152	-24.9565	-10.4529	-3.80213	0	1.988519	4.3831	6.67173	10.97651	104.3832	-10.309	29.79314
83	-100	-50.5839	-25.2971	-10.4565	-3.90074	0	1.9926	4.382495	6.673188	10.97611	105.6232	-10.4752	30.0551
84	-100	-49.9585	-25.498	-10.2379	-3.94104	0	2.208944	3.946047	6.180615	9.794081	105.7192	-10.5397	29.60391
85	-100	-50.6088	-26.0406	-10.3342	-4.12668	0	1.969346	3.546206	5.634982	9.359668	96.15457	-11.1026	29.59027
86	-100	-50.456	-25.9383	-9.74193	-3.37687	0	2.071202	3.229845	5.150146	8.929346	190.401	-10.4357	30.64877
87	-100	-50.0929	-25.8093	-9.89934	-3.59109	0	1.826457	2.45687	4.186569	7.644163	130.333	-11.0862	29.12949
88	-100	-48.516	-26.346	-9.93488	-3.96999	0	0.987423	1.556567	3.053342	5.934018	107.1395	-11.5327	27.81344
89	-100	-50.0568	-27.0964	-9.86951	-3.5738	0	0.710045	1.148227	2.799783	5.336794	118.6361	-11.9499	28.16195
90	-100	-50.3843	-27.8257	-10.0807	-3.0031	0	0.269916	0.612871	2.194172	4.238295	119.399	-12.3514	28.00651
91	-100	-47.4949	-26.3295	-10.2201	-2.54542	0	0.198179	0.425663	1.70601	3.999048	100.5112	-12.0506	27.06235
92	-100	-45.7888	-24.6718	-9.34383	-2.07041	0	0.195369	0.424349	1.71282	4.175832	104.2021	-11.5757	26.89959
93	-100	-44.3722	-24.3982	-8.43108	-1.68734	0	0.165826	0.357078	1.581308	3.926673	143.1039	-11.168	27.2674
94	-100	-43.8119	-23.4143	-8.50775	-1.54442	0	0.108306	0.236458	1.462797	3.651947	149.1794	-11.0262	27.38416
95	-100	-33.8927	-13.1207	-4.45895	-0.54054	0	0	0	0.419389	2.686294	95.2887	-8.80417	23.93597
96	-100	-33.4455	-12.3179	-3.49202	-0.29673	0	0	0	0.381409	2.529003	96.41691	-8.44089	23.39208
97	-100	-28.9266	-8.94369	-2.59367	-0.05755	0	0	0	0.192379	2.202262	92.95978	-7.55966	22.51689
98	-100	-27.0753	-6.05152	-1.57682	-0.05666	0	0	0	0.193133	2.327199	78.33857	-6.8702	22.1423
99	-100	-24.5721	-4.29202	-0.8477	0	0	0	0	0.084432	1.887581	58.88524	-6.43512	21.15766
100	-100	-23.4961	-2.74814	-0.44225	0	0	0	0	0.045991	1.828263	41.2526	-6.04146	20.46618

Table 12. Summary statistics of land size contribution to yield difference under variable returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-86.2322	-6.63908	-2.23892	0	0	0	0	0	0.539429	8.273663	217.3474	0.346979	17.07911
32	-85.6027	-9.86747	-2.89623	-0.00068	0	0	0	0.025473	1.285431	8.610118	250.5537	0.019169	19.55267
33	-100	-15.8383	-6.43586	-0.43473	-0.15716	0	0	0	0.751009	7.774249	273.7238	-2.01541	23.4606
34	-100	-16.5834	-7.5668	-0.62104	-0.20794	0	0	0.003417	0.705421	7.978218	272.4398	-2.01279	23.14941
35	-100	-16.7465	-7.73579	-0.6536	-0.17413	0	0	0.006683	0.765968	7.978218	271.8382	-2.08424	23.1722
36	-100	-36.4112	-14.8092	-1.64091	0	0	0	0	0.822813	7.18194	318.8213	-7.5669	32.66301
37	-100	-33.6254	-14.4919	-1.64091	0	0	0	0	0.684846	7.315341	318.8635	-7.59697	33.11537
38	-100	-33.0118	-13.1577	-1.70589	-0.06606	0	0	0	0.656835	7.430752	319.423	-7.42999	33.10915
39	-100	-32.7488	-12.9428	-1.73625	-0.10138	0	0	0.002504	0.700346	7.857657	319.8392	-7.18033	32.97475
40	-100	-32.177	-12.9444	-1.65478	0	0	0	0.000275	0.75443	7.864747	319.8747	-6.87147	32.35764
41	-100	-30.593	-12.688	-1.78538	0	0	0	0	0.754046	7.451363	319.6151	-6.22448	31.09535
42	-100	-30.428	-11.9831	-1.78538	0	0	0	0.001501	0.812103	8.78352	319.8009	-5.63226	30.96877
43	-100	-30.189	-11.9116	-1.78538	0	0	0	0	0.798933	8.78352	319.7623	-5.52852	30.36912
44	-100	-30.3238	-11.9785	-1.87232	-0.12905	0	0	0.0062	0.683413	7.419919	104.2582	-6.37626	24.56085
45	-100	-30.3887	-12.1313	-1.92497	-0.20433	0	0	0.008371	0.695145	7.731624	103.6977	-6.23018	24.08075
46	-100	-29.7446	-9.6813	-0.54596	0	0	0	0	0.468565	7.112683	102.3223	-5.95794	24.03765
47	-100	-26.429	-11.2184	-0.60001	0	0	0	0	0.479735	7.317288	102.241	-5.72086	23.54232
48	-100	-26.0868	-11.1615	-0.53518	0	0	0	0	0.474392	7.656955	102.144	-5.62025	23.55577
49	-100	-25.7256	-11.1472	-0.51656	0	0	0	0	0.423937	7.117791	102.0047	-5.56565	23.46931
50	-100	-25.6037	-11.1465	-0.50377	0	0	0	0	0.420758	7.125361	102.0047	-5.53669	23.43032
51	-100	-28.3883	-12.0285	-0.61652	0	0	0	0	0.324485	7.122473	102.0047	-5.76109	23.71936
52	-100	-28.645	-12.2419	-0.62393	0	0	0	0	0.377691	6.878073	109.638	-5.76051	23.74167
53	-100	-28.4095	-12.0106	-0.62317	0	0	0	0	0.378355	6.869535	109.638	-5.7415	23.71324
54	-100	-27.8724	-11.8669	-0.62498	0	0	0	0	0.345224	6.86855	109.638	-5.7001	23.66188
55	-100	-25.535	-12.1461	-1.04312	0	0	0	0	0.273385	7.116047	109.638	-5.44116	22.92228
56	-100	-25.299	-12.0145	-0.62786	0	0	0	0	0.265487	7.114813	109.638	-5.27735	22.54898
57	-100	-25.087	-11.9675	-0.8801	0	0	0	0	0.275985	7.154866	109.638	-5.24141	22.52591
58	-100	-26.5932	-11.8838	-1.08879	0	0	0	0	0.270595	6.974647	109.638	-5.31899	22.56504
59	-100	-22.3277	-7.38359	0	0	0	0	0	0.028059	3.068636	91.25484	-4.20841	17.24694
60	-100	-23.6518	-8.8995	-0.00989	0	0	0	0	0.033344	3.075817	90.79714	-4.68496	17.68881
61	-100	-23.3558	-8.88773	-0.00317	0	0	0	0	0.038298	2.937494	90.51217	-4.64434	17.6187
62	-100	-24.1535	-9.58337	-0.01563	0	0	0	0	0.032004	2.916889	90.48344	-4.68358	17.65877
63	-100	-24.2009	-9.5721	-0.02575	0	0	0	0	0.03712	3.226025	90.29227	-4.58238	17.8151
64	-100	-22.8007	-9.11889	-0.09045	0	0	0	0	0.236539	3.492877	89.22319	-4.3365	18.03346
65	-100	-22.9046	-9.50742	-0.2474	0	0	0	0	0.272579	3.874074	88.87562	-4.37284	18.08129
66	-100	-23.6368	-10.24	-0.38549	0	0	0	0	0.066553	3.414296	88.78868	-4.68569	18.21905
67	-100	-26.0258	-12.1072	-0.71628	0	0	0	0	0.091988	5.003512	89.18003	-5.11785	18.83622
68	-100	-25.5263	-11.8298	-0.73756	0	0	0	0	0.084297	4.467375	90.19728	-5.06849	18.7142
69	-100	-24.3257	-11.2363	-0.50465	0	0	0	0	0.082417	4.062927	90.36757	-4.77132	18.30826
70	-100	-23.8425	-10.8063	-0.60518	0	0	0	0	0.09829	3.827399	91.71974	-4.68169	18.15386
71	-100	-23.7063	-9.75141	-0.25161	0	0	0	0	0.101734	3.800277	92.28768	-4.61958	18.10958
72	-100	-23.4506	-10.7231	-0.6312	0	0	0	0	0.105589	4.270609	92.361	-4.74872	18.612
73	-100	-23.2014	-10.5264	-0.59079	0	0	0	0	0.100888	4.159103	92.43397	-4.48978	18.02335
74	-100	-22.8791	-10.3451	-0.51859	0	0	0	0	0.098113	4.159791	92.63949	-4.42642	17.99344
75	-100	-22.4995	-10.026	-0.39048	0	0	0	0	0.114079	4.734366	92.38836	-4.26251	17.91563
76	-100	-22.3085	-10.0307	-0.34382	0	0	0	0	0.098663	4.789629	91.30389	-4.26747	17.83831
77	-100	-22.097	-10.193	-0.31704	0	0	0	0	0.085857	3.819927	91.13566	-4.27798	17.72282
78	-100	-22.2089	-10.9603	-0.21987	0	0	0	0	0.073937	4.081461	90.15081	-4.67064	18.27818
79	-100	-22.3163	-11.5897	-0.26406	0	0	0	0	0.090961	3.906074	90.02947	-4.74035	18.31556
80	-100	-22.3072	-11.6113	-0.27523	0	0	0	0	0.053167	3.458774	89.14279	-4.7744	18.29875
81	-100	-22.1924	-11.0715	-0.18373	0	0	0	0	0.057705	3.464061	90.00412	-4.67338	18.19026
82	-100	-22.1659	-11.0571	-0.17352	0	0	0	0	0.05647	3.454864	90.12848	-4.67161	18.19263
83	-100	-22.1661	-11.0582	-0.17373	0	0	0	0	0.056468	3.452247	90.13	-4.67471	18.19413
84	-100	-22.1603	-11.1765	-0.17229	0	0	0	0	0.079067	3.250601	89.89535	-4.70142	18.21929
85	-100	-22.1663	-11.6855	-0.17695	0	0	0	0	0.082067	3.138558	89.99506	-4.71609	18.23397
86	-100	-22.4401	-12.0471	-0.39129	0	0	0	0	0.118235	3.226226	88.83326	-4.80003	18.38353
87	-100	-22.4331	-12.0016	-0.64896	0	0	0	0	0.111067	3.453336	88.48078	-4.63457	18.6739
88	-100	-22.5887	-12.078	-0.35607	0	0	0	0	0.119953	3.423741	88.83603	-4.70109	18.68088
89	-100	-22.6608	-12.0621	-0.27451	0	0	0	0	0.104723	3.333063	88.25337	-4.8681	19.12524
90	-100	-23.1494	-12.0403	-0.54205	-0.02447	0	0	0	0.060999	3.591342	87.74283	-5.07805	19.37699
91	-100	-23.3802	-12.958	-0.25337	-0.00941	0	0	0	0.061594	3.617823	87.46837	-5.14074	19.29244
92	-100	-23.4292	-12.9593	-0.26396	-0.00775	0	0	0	0.045981	3.337498	86.1332	-5.17592	19.25106
93	-100	-23.4462	-12.9734	-0.28575	-0.00267	0	0	0	0.046647	3.413399	84.73347	-5.19069	19.25523
94	-100	-23.1867	-12.3591	-0.24327	0	0	0	0	0.021734	3.340624	83.63361	-5.15964	19.22084
95	-100	-24.0735	-13.0302	-0.26117	0	0	0	0	0.008523	3.244198	89.69686	-5.07533	19.56389
96	-100	-24.1234	-13.0302	-0.36822	0	0	0	0	0.008523	3.194495	89.44347	-5.10117	19.51714
97	-100	-24.0621	-13.0316	-0.35045	0	0	0	0	0.008523	3.4365	87.90394	-5.00205	19.06019
98	-100	-24.1147	-13.685	-0.44583	0	0	0	0	0.008523	3.31787	86.21387	-5.12268	19.18436
99	-100	-24.5647	-13.7136	-0.44951	0	0	0	0	0.012579	2.940412	83.07275	-5.11079	19.21809
100	-100	-24.8133	-13.8923	-0.47428	0	0	0	0	0.004962	2.942763	86.76323	-5.28783	18.8497

Table 13. Summary statistics of other inputs contribution to yield difference under variable returns to scale in correspondence of different percentiles of reference vectors of inputs and outputs

Ref. percentile	Min	10%	20 %	30 %	40 %	Median	60 %	70 %	80 %	90 %	Max	Mean	St.Dev.
31	-100	-100	-85.8602	-74.1333	-63.5118	-53.0167	-42.0423	-27.7067	-2.80959	29.29118	187.027	-41.9399	51.60001
32	-100	-100	-87.4633	-75.1442	-67.762	-58.4314	-47.6233	-32.5886	-5.59968	31.67689	204.8811	-43.3746	53.31351
33	-100	-100	-89.1197	-78.9319	-72.4496	-63.6413	-47.6579	-30.0243	-8.63071	13.33324	143.5284	-48.9204	46.26454
34	-100	-100	-88.877	-80.35	-74.548	-65.5561	-50.1761	-30.4135	-9.87701	13.06406	132.9883	-50.2531	45.12271
35	-100	-100	-88.7837	-80.8662	-74.9855	-65.834	-51.4909	-30.6495	-10.9262	12.83506	129.579	-50.631	44.77376
36	-100	-100	-88.2797	-80.5212	-72.794	-60.9005	-41.8998	-17.7256	0	16.34133	95.26412	-46.935	44.8939
37	-100	-100	-88.0254	-80.6099	-73.3348	-60.7926	-39.7923	-16.7816	0	16.29367	96.45067	-46.9755	44.48936
38	-100	-100	-87.7478	-79.8619	-72.2446	-60.3573	-38.8942	-15.4669	0	16.62944	101.4713	-46.3738	44.80843
39	-100	-100	-87.5516	-79.3794	-71.6134	-60.9919	-39.541	-14.5239	0	17.81449	104.5132	-45.8445	45.21962
40	-100	-100	-86.7973	-78.9919	-70.7814	-60.1409	-38.9298	-14.0259	0	17.95144	107.4711	-45.3319	45.11103
41	-100	-100	-87.3539	-79.2431	-71.7546	-61.5382	-40.9369	-14.8725	0	17.28314	107.6583	-46.1413	44.83012
42	-100	-100	-87.6599	-79.2342	-71.3707	-61.1815	-42.7911	-16.6617	0	17.46349	108.3353	-46.3995	44.68683
43	-100	-100	-87.5249	-79.2511	-72.372	-61.2004	-43.0459	-16.7744	0	17.06988	108.0733	-46.5327	44.47106
44	-100	-100	-88.8432	-80.9858	-73.2425	-64.7294	-47.362	-20.1138	0	15.82524	106.488	-48.5537	43.97925
45	-100	-100	-88.5248	-80.8842	-73.8261	-64.6236	-47.1229	-20.0935	-0.17616	15.59661	106.7145	-48.5656	43.85002
46	-100	-100	-88.0936	-80.1682	-73.5537	-62.4804	-45.7339	-20.1544	-0.63879	17.89751	146.6107	-47.1467	45.96529
47	-100	-100	-88.1014	-80.2592	-73.6264	-62.7538	-46.4198	-20.8676	-1.00178	17.89433	145.9727	-47.5337	45.72422
48	-100	-100	-88.4693	-80.4522	-73.8199	-63.1329	-46.7402	-20.8718	-1.76949	17.30849	145.305	-47.8649	45.49803
49	-100	-100	-88.284	-80.6438	-74.2526	-63.6387	-47.355	-20.822	-1.76078	17.52203	144.1881	-48.1597	45.2676
50	-100	-100	-88.3141	-80.7293	-74.0992	-63.9136	-47.662	-21.2027	-1.81317	17.29511	143.5695	-48.2902	45.17727
51	-100	-100	-88.3581	-80.9708	-74.1306	-64.925	-47.9699	-21.1563	-1.79096	16.65677	143.7367	-48.556	44.98886
52	-100	-100	-88.9495	-81.2784	-74.8435	-65.389	-50.1559	-22.3015	-2.71373	16.35971	142.8595	-49.0967	44.69118
53	-100	-100	-88.9091	-81.3656	-74.8017	-65.3244	-50.0604	-22.4512	-2.6505	16.4362	143.1444	-49.0685	44.70456
54	-100	-100	-88.8806	-81.0664	-74.6736	-65.0753	-49.8161	-22.6443	-2.91971	16.62294	144.0541	-48.936	44.781
55	-100	-100	-88.5614	-81.4602	-74.6779	-65.0456	-50.7345	-22.8059	-4.08749	15.78139	147.1628	-49.089	44.80314
56	-100	-100	-88.4311	-81.5908	-74.6855	-64.8419	-50.9778	-23.2248	-5.03678	15.90678	148.0327	-49.3017	44.5755
57	-100	-100	-88.8243	-81.6055	-74.5525	-64.9659	-51.0368	-23.6907	-5.52095	14.87716	149.2065	-49.4945	44.56864
58	-100	-100	-89.0185	-81.5421	-74.5122	-64.8009	-50.9555	-24.3484	-5.38464	14.83512	149.8307	-49.4918	44.45759
59	-100	-94.8973	-86.2086	-77.8667	-69.4981	-56.958	-29.5625	-6.54072	0	8.336477	74.15583	-44.6393	42.0769
60	-100	-94.7249	-85.9041	-77.7777	-69.2125	-56.1166	-28.2624	-6.34813	0	8.423615	74.90298	-44.4222	42.01944
61	-100	-94.6879	-85.8741	-77.7217	-68.9903	-56.0963	-28.9834	-6.29956	0	8.655702	76.0238	-44.4018	42.02219
62	-100	-95.4591	-86.6922	-78.7177	-70.5622	-60.0106	-31.7917	-7.91869	0	8.826221	74.72719	-45.6737	42.19266
63	-100	-95.2415	-86.5751	-78.7296	-70.5806	-60.2863	-32.313	-8.5297	0	9.749194	74.12775	-45.7169	42.19527
64	-100	-95.6486	-86.9556	-79.0835	-71.4349	-61.5679	-36.0077	-12.1459	0	8.106655	70.37303	-47.0609	41.46089
65	-100	-96.125	-87.3966	-79.5198	-72.3094	-63.0046	-40.7479	-15.6647	0	9.154653	77.43689	-47.8421	41.67993
66	-100	-96.1885	-87.7111	-79.9854	-73.019	-64.4236	-40.9799	-15.1117	0	9.870885	65.10763	-48.0307	41.89872
67	-100	-95.8834	-88.4201	-81.6348	-74.6411	-67.5087	-49.8512	-25.2197	-3.20928	11.75314	56.9106	-51.2163	40.84752
68	-100	-95.7153	-88.3218	-81.7523	-74.825	-67.6241	-49.6991	-25.4167	-2.80825	12.44943	57.27351	-51.1868	40.91162
69	-100	-96.5141	-88.2757	-81.8172	-75.0907	-67.8107	-49.7544	-25.6044	-1.98948	12.13098	57.27302	-51.1711	41.1177
70	-100	-96.8484	-88.2447	-81.8506	-74.9854	-67.7596	-49.9451	-25.429	-1.51477	12.33993	58.54104	-51.1486	41.35778
71	-100	-96.8726	-88.2709	-81.8822	-75.0762	-67.8622	-50.0637	-25.6277	-0.60785	14.16487	58.26162	-51.0643	41.55015
72	-100	-96.9948	-88.35	-81.9113	-75.1007	-68.1579	-51.3711	-25.2745	-3.39355	14.37085	59.30946	-51.3027	41.57215
73	-100	-97.2531	-88.4444	-82.0928	-75.3282	-68.623	-51.6559	-25.812	-3.47315	14.6808	59.65173	-51.5121	41.63973
74	-100	-97.2401	-88.455	-82.3558	-75.3376	-68.5213	-51.5771	-25.419	-2.98322	14.89529	60.71924	-51.3857	41.8057
75	-100	-97.2284	-88.5181	-82.3903	-75.3877	-68.3344	-51.4413	-25.185	-2.02057	16.27526	62.25668	-51.1443	42.1184
76	-100	-98.1274	-88.5448	-82.6897	-75.8115	-69.0911	-51.9225	-26.0377	-2.64797	16.79715	60.9454	-51.543	42.12869
77	-100	-98.7026	-88.5915	-82.7444	-76.222	-68.7592	-52.1679	-26.1149	-3.53874	15.8497	58.60881	-51.6676	41.98446
78	-100	-98.2886	-89.2088	-83.7366	-77.6654	-70.9694	-55.652	-30.6495	-7.68073	13.88972	50.1862	-53.6536	40.5698
79	-100	-97.5393	-89.3295	-84.1928	-77.8551	-71.5541	-56.6039	-31.1814	-8.6565	14.3363	48.09267	-53.9197	40.51471
80	-100	-98.3487	-89.4912	-84.43	-78.0344	-71.762	-57.0747	-31.44	-8.97662	14.36862	46.98428	-54.1134	40.56084
81	-100	-98.7848	-89.4887	-84.5186	-78.3041	-71.9127	-57.3717	-31.7937	-9.44592	14.30532	46.43044	-54.2661	40.55337
82	-100	-98.7852	-89.4939	-84.5206	-78.3097	-71.9007	-57.3772	-31.8881	-9.45927	14.33306	46.53297	-54.2567	40.56896
83	-100	-98.7852	-89.5461	-84.5233	-78.3473	-71.9008	-57.3773	-31.8958	-9.45913	14.33235	46.52215	-54.2525	40.56318
84	-100	-98.7915	-89.5294	-84.6761	-78.6749	-71.9371	-57.7998	-31.9693	-9.93559	13.81432	45.07128	-54.4313	40.51771
85	-100	-98.7958	-89.4726	-84.7558	-78.8067	-72.0516	-58.0419	-32.097	-10.1877	13.39904	44.34682	-54.5287	40.49207
86	-100	-97.3598	-89.3642	-84.9382	-78.8201	-72.0432	-58.5711	-32.1665	-10.6716	12.29103	42.58546	-54.6172	40.45365
87	-100	-97.0522	-89.2275	-84.9763	-78.6966	-72.1952	-58.4087	-32.5198	-11.088	11.78421	41.5262	-54.5801	40.45064
88	-100	-97.0796	-89.3199	-85.0999	-78.8125	-72.5165	-58.7581	-33.0138	-11.4734	13.27114	40.00362	-54.8007	40.3011
89	-100	-97.2872	-89.3697	-85.3171	-78.9937	-72.771	-58.9511	-33.363	-11.6933	14.50029	38.34707	-54.9689	40.39068
90	-100	-97.1342	-89.3783	-85.3617	-79.0933	-72.9039	-59.1999	-33.6125	-11.4873	15.04201	36.82604	-54.9713	40.43498
91	-100	-96.3256	-89.3597	-85.318	-79.1882	-72.9313	-59.4695	-33.5872	-10.7684	15.70132	36.47555	-54.8571	40.65297
92	-100	-96.1404	-89.6142	-85.4554	-79.2468	-72.946	-59.5376	-33.3715	-10.511	15.88627	35.65899	-54.8964	40.74081
93	-100	-96.7719	-89.6167	-85.469	-79.253	-72.9599	-59.4809	-33.3512	-10.4297	15.91207	35.28902	-54.8899	40.7968
94	-100	-96.805	-89.14	-85.3967	-79.1825	-72.9789	-59.7338	-33.2812	-9.64148	16.67404	35.73215	-54.69	40.95224
95	-100	-95.9987	-89.6004	-85.5831	-80.0513	-74.0383	-60.8062	-35.2344	-11.0437	17.59926	106.7394	-54.6468	42.28653
96	-100	-96.0507	-89.4615	-85.5565	-79.9938	-73.848	-61.3841	-35.8687	-12.2544	17.677	108.9397	-54.7371	42.26377
97	-100	-95.894	-89.2321	-85.6982	-79.9569	-74.0949	-60.1199	-36.8061	-12.9009	17.67251	107.5684	-54.6717	42.28097
98	-100	-95.7498	-89.1951	-85.8092	-80.2465	-74.2291	-60.2847	-36.7533	-14.18	17.66766	105.1104	-54.6523	42.23678
99	-100	-95.2646	-89.1546	-85.5288	-80.1513	-74.0453	-59.7732	-36.685	-14.6099	17.36875	104.0873	-54.6293	42.01855
100	-100	-95.3128	-88.9421	-85.342	-80.2497	-74.0874	-59.7732	-36.6	-14.6067	17.36875	100.0225	-54.6266	42.02259

Table 14. Tests for equality of observed yields distribution and counter factual distributions: test by Li, Maasoumi, and Racine (2009) of integrated squared density difference under different returns to scale at the median level

Null hypothesis	CRS Tn	CRS p-value	NIRS Tn	NIRS p-value	VRS Tn	VRS p-value
$y_1/l_1 = y_1^I/l_1$	72.6824	0.000	58.4876	0.000	92.7071	0.000
$y_1/l_1 = y_1^E/l_1$	-28.0267	0.279	-26.9965	0.322	-60.1376	0.089
$y_1/l_1 = y_1^L/l_1$	-9.2267	0.724	-0.7495	1	0.5935	0.9475
$y_1/l_1 = y_1^Q/l_1$	-39.1165	0.354	-39.0964	0.35	4.2780	0.901
$y_1/l_1 = y_1^{IL}/l_1$	72.2510	0.000	69.4647	0.000	89.6234	0.000
$y_1/l_1 = y_1^{IQ}/l_1$	75.2886	0.000	60.4098	0.000	62.7195	0.000
$y_1/l_1 = y_1^{QL}/l_1$	78.8345	0.000	73.946	0.000	82.5379	0.000

Note: The tests statistics are Tn. They are performed on the observed yield against counter factual distributions indicated. For constant and non-increasing returns to scale the amount of units useful for this exercise is 443 while for variable returns to scale the amount of units is 403 with reference the median level. Equality is rejected if p-value is smaller than the significance level desired.

Table 15. Tests across returns to scale for equality of distributions (counter factual and observed yields): test by Li, Maasoumi, and Racine (2009) of integrated squared density difference at the median level

Distribution	CRS vs NIRS Tn	CRS vs NIRS p-value	CRS vs VRS Tn	CRS vs VRS p-value	NIRS vs VRS Tn	NIRS vs VRS p-value
y_1/l_1	-0.9707	1	-5.833	0.927	-5.833	0.927
y_1^I/l_1	3.8122	0.1325	-3.9411	0.051	-9.014	0.656
y_1^E/l_1	1.9715	0.925	-59,9877	0.3955	-60.889	0.347
y_1^L/l_1	8.7414	0.763	5.061	0.599	-4.3919	0.862
y_1^Q/l_1	-0.3074	0.999	52.5195	0.403	52.5174	0.404
y_1^{IL}/l_1	1.8888	0.1365	-1.8827	0.017	-6.6776	0.699
y_1^{IQ}/l_1	2.2412	0.771	2.6959	0.2475	-2.0262	0.897
y_1^{QL}/l_1	0.7957	0.8435	-0.2356	0.218	-3.2456	0.7905

Note: The tests statistics are Tn. For constant and non-increasing returns to scale the amount of units useful for this exercise is 443 while for variable returns to scale the amount of units is 403. Equality is rejected if p-value is smaller than the significance level desired.

Table 16. Tests for equality of observed yields distribution and counter factual distributions: test by Li, Maasoumi, and Racine (2009) of integrated squared density difference under different returns to scale at the mean level

Null hypothesis	CRS Tn	CRS p-value	NIRS Tn	NIRS p-value	VRS Tn	VRS p-value
$y_1/l_1 = y_1^I/l_1$	60.3772	0.000	62.2517	0.000	65.1694	0.000
$y_1/l_1 = y_1^E/l_1$	-26.9913	0.1345	-24.6082	0.055	-58.0400	0.013
$y_1/l_1 = y_1^L/l_1$	-11.3779	0.731	-7.8012	0.6745	-9.6793	0.5095
$y_1/l_1 = y_1^Q/l_1$	-39.4264	0.139	-1.2041	0.4955	2.0790	0.582
$y_1/l_1 = y_1^{IL}/l_1$	63.9487	0.000	67.8881	0.000	74.8112	0.000
$y_1/l_1 = y_1^{IQ}/l_1$	70.1965	0.000	66.8617	0.000	68.184	0.000
$y_1/l_1 = y_1^{QL}/l_1$	74.5181	0.000	75.3272	0.000	80.6204	0.000

Note: The tests statistics are Tn. They are performed on the observed yield against counter factual distributions indicated. For constant and non-increasing returns to scale the amount of units useful for this exercise is 443 while for variable returns to scale the amount of units is 411. Equality is rejected if p-value is smaller than the significance level desired.