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Abstract

We focus on a simple framework on wheat producer behaviour in a context of price output uncertainty. More precisely, we establish a relationship between *ex post* output price level and allocative inefficiency that allows to characterize farmers' risk preferences. Given this analysis, the connection between risk aversion and other socioeconomic variables (such as degree of output specialisation, total asset, debts, farmer's age…) can furthermore empirically be explored. This relationship is empirically tested on an unbalanced panel including about 650 wheat producers located in the French Department of Meuse over 1992-2003.

Keywords: producer behaviour, price uncertainty, allocative inefficiency, risk aversion, agriculture
JEL classification: D81, D21, D61, Q12

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1. Introduction

Price uncertainty - a standard attribute of agricultural activities - is well known as being one of the causes of allocative inefficiency. Because of long production lags imposed by biological processes, the final output price is usually unknown *ex ante* when producers make decisions. In addition, several characteristics of agricultural markets - such as inelastic demand, homogenous output, large number of small competitive producers - generate high price volatility even in case of slight supply changes. By these means, production risk due to climatic conditions or pest infestations leads to price uncertainty. As an additional source of price uncertainty, agricultural policy can also play a significant role in farm operations. For instance with the recent successive CAP reforms, European farmers have experienced a transition from a high subsidised output price system to a less sheltered and more risky context (international market prices, gradual uncoupling of local subsidies from production, …).

Models dealing with producer behaviour in a context of output price uncertainty are considered in Sandmo (1971) or Chambers (1983) while risk production analysis with stochastic technology have been developed by Just and Pope (1978) or Chambers and Quiggin (2002), among others. In the present paper we focus on a simple framework which associates allocative inefficiency with risk preferences when producers face price output uncertainty. More precisely, we establish that a relationship between output price level and allocative inefficiency allows to characterize risk preferences. Given this analysis, the connection between risk aversion and other socioeconomic variables (such as degree of output specialisation, total asset, debts, farmer's age…) can furthermore empirically be explored.

A wide range of papers in agricultural economics investigated risks preferences.[1] One of the most interesting conclusions of these analyses was that the dispersion of risk preferences is always significant even within relatively homogeneous groups of farmers. However, there are fewer empirical studies dealing with the joint estimation of technical or allocative inefficiency and risk aversion in the presence of output price uncertainty. For instance, on a panel of 28 Norwegian salmon farms, Kumbhakar (2002) showed that the degree of risk aversion - which varied substantially across producers and time - might bias parameter estimates on technology (technical change, input elasticity…). Based on the old idea of an inverse relationship between price uncertainty and allocative efficiency (Johnson, 1947), Wu (1979) empirically investigated whether farmers allocate their resources more efficiently when prices are less random. His results based on small scale of Taiwanese family farms strongly suggest that price and output uncertainty cause profit inefficiency.

Our analysis goes beyond the commonly known connection between allocative inefficiency and price volatility. We develop a simple model that bridges allocative inefficiency and *ex post* output price levels to characterize producers' risk aversion. This relationship is empirically tested on an unbalanced panel containing about six hundred wheat producers located in the French Department[2] of Meuse. The production technology is defined with one output (wheat per hectare) and three inputs (fertilizer, pesticide and seed) and the period of analysis (1992-2003) covers the two main CAP reforms.

Some restrictive features of such a model must be noted. First, we assume that all farm operations are decided before the resolution of uncertainty. Second, opportunities of risk management strategies are not considered with a mono-output profit function. Actually, output shares depend on multiple and complex factors mainly related to relative price movements and crop rotations set by agronomical constraints which are undetected in our data. Although these effects might play an important role, such simplifications are necessary in a first attempt to measure the basic features of risk aversion. Unlike most empirical papers analyzing production choices under uncertainty, we favour a non parametric approach to estimate the allocative inefficiency. A strength of our approach is that no *a priori* restrictive functional forms such as Cobb-Douglas or quadratic functions have to be specified

[1] See G. Moschini and D.A. Hennessy (2001) for a review of selected empirical issues.
[2] Territorial administrative division.

This paper is structured as follows. The next section first offers an intuitive and graphical overview of the connection between allocative inefficiency and output price levels under different risk preferences. This relationship is then formally derived within a mean-variance framework. Section 3 introduces distance functions representing technology and allowing to separate technical and allocative components from overall productive inefficiency. Section 4 discusses the sample, presents the empirical inefficiency scores, and tests the panel econometric model to characterize risk preferences of French wheat producers. Conclusions and extensions appear in Section 5.

2. Linking allocative inefficiency and risk-aversion

We first develop an intuitive and graphical overview of the connection between allocative inefficiency and output price levels under different risk preferences. In a second step, we formally derive the results within a mean-variance framework.

2.1. A graphical overview

Before embarking on a formal presentation of the models, we begin with graphical illustrations of our approach that links allocative inefficiency and risk-aversion. In Figure 1, the situation of a single input (*x*)/single output (*y*) farm displaying variable returns to scale (VRS) technology *T(x,y)* is depicted. The farmer has to make a decision on the optimal quantity of input/output in case he faces a known input price (p_x) and a uniformly distributed output price (p_y) over the interval [p_0, p_1]. Allocations (x_0, y_0) and (x_1, y_1) are the optimal solutions under certainty when the prices are respectively p_0 and p_1. Under uncertainty and risk-neutrality, the farmer will chose the production plan (x_{rn}, y_{rn}) corresponding to a shadow price equal to the mean output price $(p_0 + p_1)/2$.

The choice of the production plan is *ex ante* and one output price ($\tilde{p}_y$) will be made at the end of the period. If $\tilde{p}_y$ is different from the mean output price $(p_0 + p_1)/2$ then allocative inefficiency arises (Fig. 2). We notice that the allocative inefficiency increases if the achieved output price departs from the mean output price in both directions. Higher allocative inefficiency is expected for either high or low achieved price. We therefore do not expect, over an observed sample, the allocative inefficiency to be positively or negatively related to the realized output price under risk neutrality.

The picture is different when risk aversion is taken into account (Fig. 3). A risk averse producer produces less output than the risk neutral producer since he does not like the loss associated to potential low achieved output prices. As for the risk neutral farmer, allocative inefficiency arises as far as the achieved output price departs from the shadow price at the *ex ante* chosen production plan. However, under the assumption of a uniform price distribution[3], the majority of observed output prices are likely to be higher than the shadow price. On a sample of risk averse farmers, it is therefore intuitive that the allocative inefficiency increases along with the achieved output price since risk-aversion leads to lower output levels. Finally, Figure 4 illustrates the case of risk-loving producers. By symmetry to the risk aversion case, risk-loving farmers choose higher levels of output compared to risk neutral producers. Therefore, the allocative inefficiency increases (resp. decreases) along with decreasing (resp. increasing) achieved output price.

As a conclusion, we have illustrated how the allocative inefficiency is related to the achieved output price when producers choose a production plan under price uncertainty and exhibit different risk preferences. Therefore, on an observed sample, allocative inefficiencies are expected to be positively (resp. negatively, not) related to *ex post* output prices when producers are risk averse (resp. loving, neutral).

[3] The uniform distribution assumption is too strong for our results and a symmetric distribution around the mean will suffice.

Figure 1. Choice of production under risk neutrality and price uncertainty

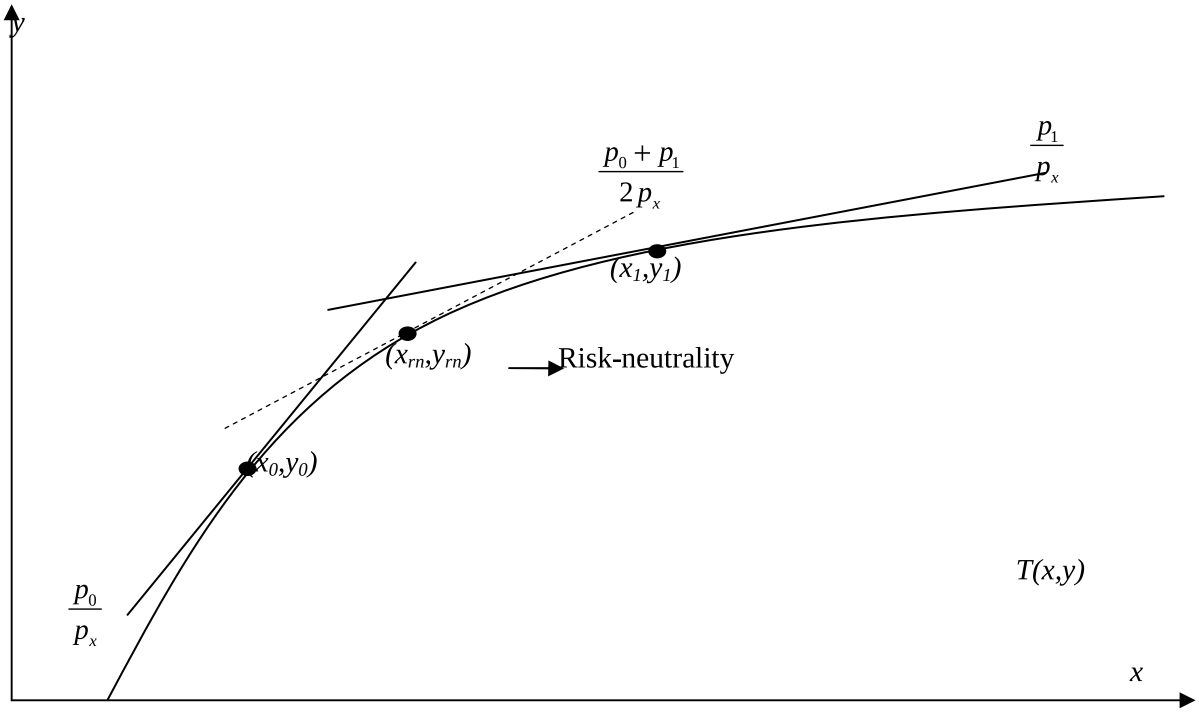


Figure 2. Allocative inefficiency for a risk neutral producer under price uncertainty

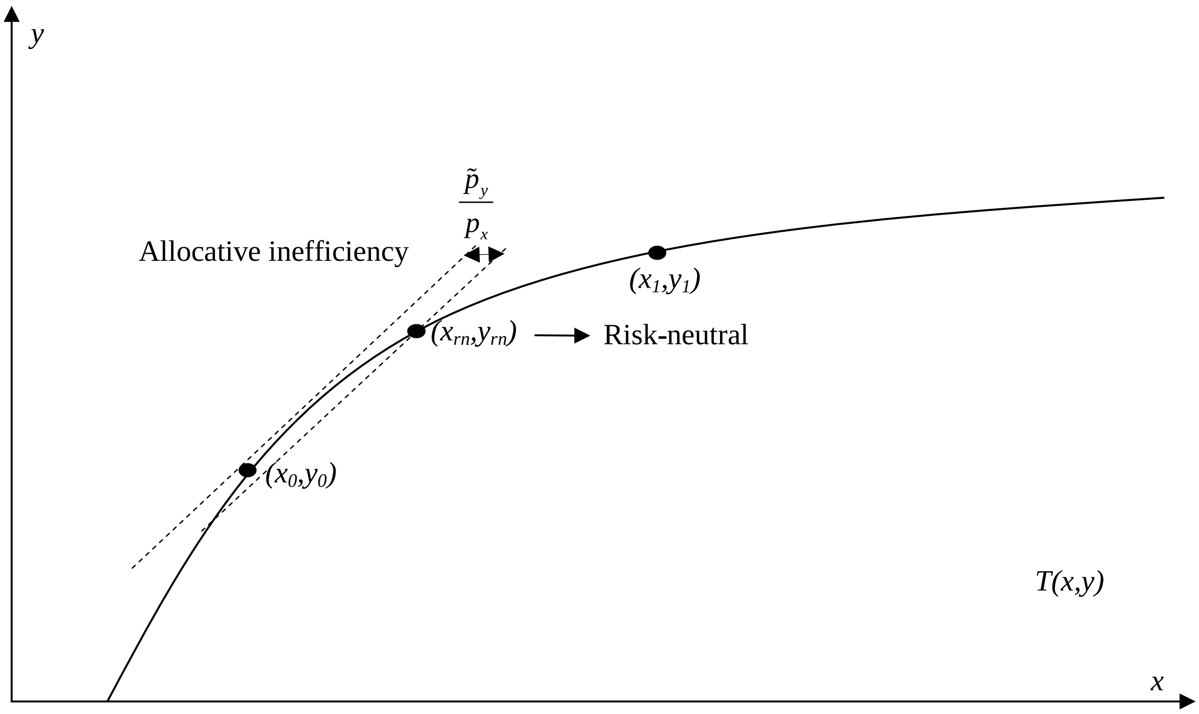


Figure 3. Allocative inefficiency for a risk averse producer under price uncertainty

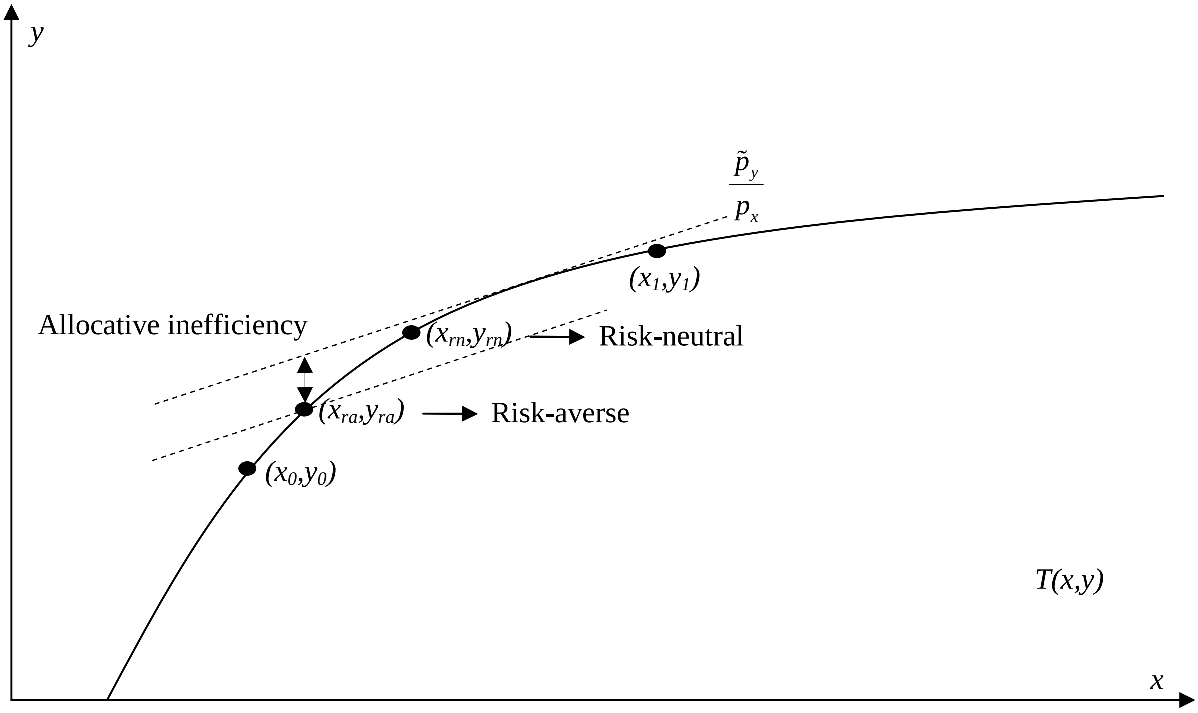
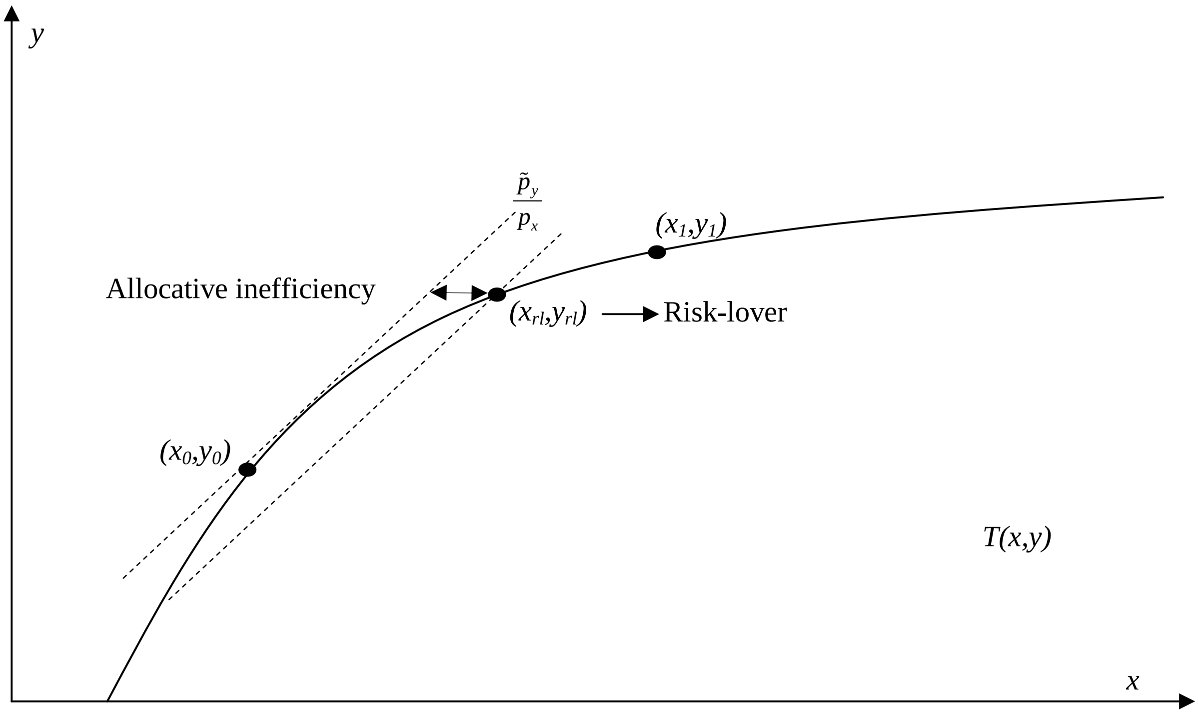


Figure 4. Allocative inefficiency for a risk lover producer under price uncertainty



2.2. A stylized model

Beyond this intuitive graphical description we now formally derive the results within a mean-variance framework. We consider the following simple model. Farmers produce a single output (y) using a single input (x). The production process they face displays variable (decreasing) returns to scale and is represented by the following concave function: $y = \sqrt{x}$.

The input and output markets are both considered as being competitive so that farmers take the price of the input (p_x) and the price of the output (p_y) as given. We suppose first that there is no risk surrounding farmers' decisions. The output is considered as being their decision variable. Their maximization program can thus be written as follows (where π^C denotes the profit made under certainty):

$$\underset{y}{Max}\ \pi^C = p_y y - p_x y^2$$

Give this framework the output produced (y^C) and the profit made ($\pi^C(y^C)$) under certainty are given by: $y^C = \frac{p_y}{2p_x}$ and $\pi^C(y^C) = \frac{p_y{}^2}{4p_x}$.

Let us now introduce risk into the model. We suppose that the only risk farmers face is related to the price at which they sell the output once it is produced. The distribution of the price of the output is supposed to be continuous and uniform between p_0 and p_1. No other sources of risk (such as a technological risk) are considered.

If farmers are risk neutral, their maximization program (where $E(\pi^{RN})$ denotes the expected profit the farmers get in case of risk neutrality) can be written:

$$\underset{y}{Max}\ E(\pi^{RN}) = \frac{1}{p_1 - p_0}\int_{p_0}^{p_1}(p_y y - p_x y^2)dp_y$$

The output produced under risk neutrality (denoted y^{RN}) is given by:

$$y^{RN} = \frac{p_1 + p_0}{4p_x}$$

The output is different from the one produced under certainty only if the average expected price differs from p_y. Let us indeed notice that $y^{RN} = y^C = \frac{p_y}{2p_x}$ as long as $p_y = \frac{p_1 + p_0}{2}$.

We model farmers' behaviour under risk using the mean-variance model. Given our assumptions, the expected value of the profit made by farmers and the variance of this profit are the following:

$$E(\pi) = \frac{1}{p_1 - p_0}\int_{p_0}^{p_1}(p_y y - p_x y^2)dp_y = \frac{y}{2}(p_0 + p_1 - 2p_x y)$$

$$\sigma^2(\pi) = \frac{1}{p_1 - p_0}\int_{p_0}^{p_1}(p_y y - p_x y^2 - E(\pi))^2 dp_y = \frac{y}{12}(p_0 - p_1)^2$$

It is interesting to note that a higher output necessarily increases the variance of the profit farmers face. This makes clear that the most risk averse of them are less output prone. Indeed, in the mean variance model the evaluation of the profit distribution (denoted $V^{RA}(\pi)$) is given by:

$$V^{RA}(\pi) = E(\pi) - k\sigma^2(\pi) = \frac{y}{2}(p_0 + p_1 - 2p_x y) - k\frac{y}{12}(p_0 - p_1)^2$$

where k denotes farmers' risk aversion since it expresses how much they dislike the variance of the distribution of the profit[4]. A negative value of k indicates that farmers are risk lovers while they are risk neutral if $k = 0$ (they only consider the mean profit when making decisions in that case).

Farmers' maximization program (where $V^{RA}(\pi)$ denotes the utility they get from their profit under risk aversion) thus becomes:

$$\underset{y}{Max}\ V^{RA}(\pi) = \frac{y}{2}(p_0 + p_1 - 2p_x y) - k\frac{y}{12}(p_0 - p_1)^2$$

The solution of this maximization problem gives the optimal value of the output (y^{RA}):

$$y^{RA} = \frac{3(p_0 + p_1)}{k(p_0 - p_1)^2 + 12p_x}$$

We notice that $y^{RA} = y^{RN}$ when farmers are risk neutral ($k = 0$). The higher (resp. lower) k the lower (resp. higher) y^{RA} since - as noticed earlier - a lower (resp. higher) output reduces (resp. increases) the variance of the distribution of the profit which is - beside the mean profit - something that risk averse (resp. risk-loving) farmers appreciate.

Let us define the shadow price of y^{RA} as the certain price that would lead farmers to the production of y^{RA} units of output. This shadow price is denoted p_y^{SP} and defined by:

$$p_y^{SP} = \frac{6p_x(p_0 + p_1)}{k(p_0 - p_1)^2 + 12p_x}$$

The more risk averse producers are, the lower the output and therefore the lower the shadow price associated with that output ($\frac{\partial p_y^{SP}}{\partial k} < 0$).

The allocative inefficiency (AI) is defined in our model as the difference between the profit made at the price p_y under certainty (complete information) and the profit made at the same price p_y in case the output decision is made under incomplete information *i.e.* before that price is known.

$$AI = \pi^C(y^C) - \pi^C(y^{RA}) = p_y y^C - p_x(y^C)^2 - (p_y y^{RA} - p_x(y^{RA})^2) = \frac{((k(p_0 - p_1)^2 + 12p_x)p_y - 6(p_0 + p_1)p_x)^2}{4p_x(k(p_0 - p_1)^2 + 12p_x)^2}$$

[4] In the mean variance model the risk is only characterized by the variance of the distribution. Agents are therefore supposed not to care about the higher moments of the distribution (skewness, kurtosis,…).

Therefore we obtain $AI = f(p_y, k, p_0, p_1, p_x)$ and we notice that allocative inefficiency is a quadratic function of the realized output price.

This allocative inefficiency stems from two elements: the preference towards risk (aversion or love) and the misprediction of the average price. It can indeed be seen that there is no allocative inefficiency in case of risk neutrality and if the average price farmers face was correctly foreseen ($AI = 0$ if $k = 0$ and $p_y = \frac{p_1 + p_0}{2}$).

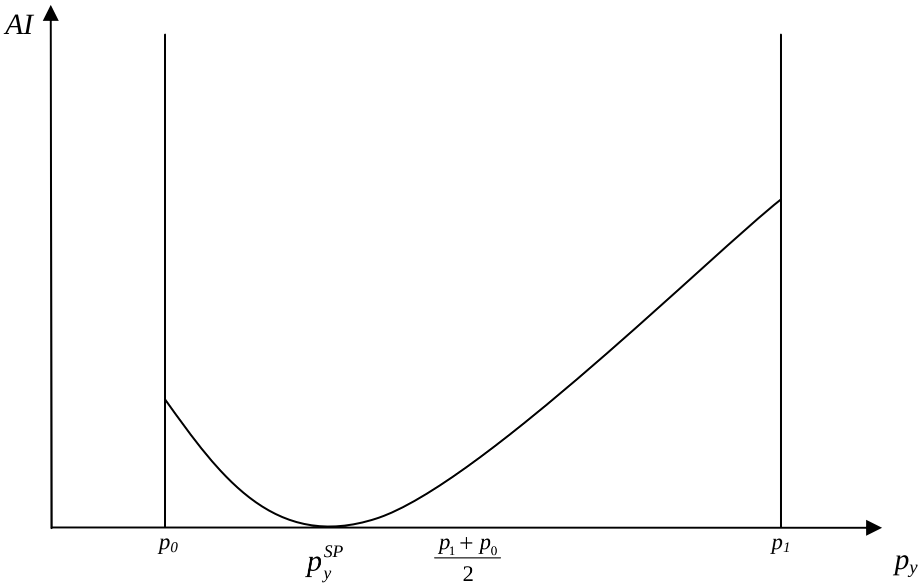
The variation of the allocative inefficiency with the output price is given by:

$$\frac{\partial AI}{\partial p_y} = \frac{p_y}{2p_x} - \frac{6(p_0 + p_1)p_x}{2p_x(k(p_0 - p_1)^2 + 12p_x)} = \frac{p_y - p_y^{SP}}{2p_x} \text{ so that } \begin{cases} \frac{\partial AI}{\partial p_y} > 0 \Leftrightarrow p_y > p_y^{SP} \\ \frac{\partial AI}{\partial p_y} = 0 \Leftrightarrow p_y = p_y^{SP} \\ \frac{\partial AI}{\partial p_y} < 0 \Leftrightarrow p_y < p_y^{SP} \end{cases}$$

It can be shown from this expression that the variation of the allocative inefficiency with the output price is directly related to the difference between the price farmers face *ex post* and the shadow price. This is shown on figure 5 that represents the allocative inefficiency of a risk averse farmer ($p_y^{SP} < \frac{p_1 + p_0}{2}$).

By definition of the shadow price AI is always positive (except in case of risk neutrality) and $\frac{\partial AI}{\partial p_y}$, positive (resp. negative) when the price farmers face is higher (resp. lower) than the shadow price. Moreover $\frac{\partial AI}{\partial p_y}$ is linear since its slope is constant ($\frac{\partial^2 AI}{\partial p_y^2} = \frac{1}{2p_x}$).

Figure 5. Allocative inefficiency and *ex post* output price (risk aversion case)



The intuition behind the figure is the following. If the price a single farmer faces turns out to be p_y^{SP}, there is no inefficiency since the farmer has produced under incomplete information what he would have produced had the information been known. The more the price moves away (on both sides) from the shadow price, the higher the difference between the current output and the one that would have been produced under complete information and thus the higher the allocative inefficiency.

We can infer farmers' average risk aversion from our data and this theoretical analysis. If the price that farmers face is distributed symmetrically around the mean price ($\frac{p_1 + p_0}{2}$), one can expect that $\frac{\partial AI}{\partial p_y} > 0$ on average since the price falls more often above the shadow price than below. Using the same argument, one can infer that:

$$\frac{1}{n}\sum_{i=1}^{n}\frac{\partial AI_i}{\partial p_{y,i}} = 0 \Rightarrow \text{The } n \text{ farmers are risk neutral on average}$$

$$\frac{1}{n}\sum_{i=1}^{n}\frac{\partial AI_i}{\partial p_{y,i}} < 0 \Rightarrow \text{The } n \text{ farmers are risk lovers on average}$$

Of course the analysis does not say anything about the individual risk aversion since $\frac{\partial AI}{\partial p_y}$ could be negative for an individual farmer despite the fact that the shadow price is lower than the average expected price if the price this farmer faces is close to p_0.

The above analysis enables us to define whether the farmers (or some subgroups of farmers) taken from our sample are risk averse on average. It also enables us to compare the average risk aversion of some subgroups of farmers since:

$$\frac{\partial^2 AI}{\partial p_y \partial k} = \frac{3(p_0 - p_1)^2 (p_0 + p_1)}{(k(p_0 - p_1)^2 + 12 p_x)^2} > 0$$

This last inequality means that $\frac{\partial AI}{\partial p_y}$ increases with risk aversion (k). So that we can conclude that subgroups of farmers with a higher average risk aversion have lower average shadow prices and a higher values of $\frac{\partial AI}{\partial p_y}$. The same holds for risk-loving subgroups of farmers ($\frac{\partial AI}{\partial p_y}$) falls when risk love falls).

3. Measuring allocative inefficiency using distance functions

In section 2, we have presented both a graphical overview and a formal model to analyze the link between allocative inefficiency and output price. Notice that we have always assumed a rational producer with choices on the frontier of the technology. However in the empirical work, to take into account heterogeneity and exogenous factors in farms' production, we allow for technical inefficiency (producing below the frontier). We therefore need to compute the allocative inefficiency net of the technical inefficiency. The following non parametric framework allows for the estimation of both types of inefficiencies.

Suppose that the sector under analysis is populated by K firms. Let $x^k \in R_+^N$ and $y^k \in R_+^M$ respectively denote input and output vectors for firm *k* (*k* = 1..., *K*). Let T be a production set satisfying the core Shephard axioms (Shephard, 1953); in particular, we consider a convex technology T satisfying free disposability of inputs and outputs. As noted above, we adopt the standard assumption that all firms face the same technology, *T*. Under variable returns to scale, the firm level technology can be represented by:

$$T_{VRS} = \Big\{(x,y):\ x \in R_+^N,\ y \in R_+^M,\ \sum_{k=1}^{K} y_m^k z^k \geq y_m,\ m=1,...,M, \\ \sum_{k=1}^{K} x_n^k z^k \geq x_n,\ n=1,...,N, \sum_{k=1}^{K} z^k = 1, z^k \geq 0,\ k=1,...,K\Big\}, \quad (1)$$

where x_i and y_j denote the i^{th} and j^{th} elements of x and y, respectively.

Given the above technology definition, we now present the directional distance function which is used to determine the inefficiency in the technology use. The function $\vec{D}_T : (R_+^N \times R_+^M) \times (-R_+^N) \times R_+^M \longrightarrow R_+$ defined by:

$$\vec{D}_T(x,y;g_x;g_y) = \sup_{\lambda}\Big\{ \lambda \in R_+ :\ \left(x+\lambda \cdot g_x, y+\lambda \cdot g_y\right) \in T \Big\}, \quad (2)$$

is the directional distance function in the direction $\left(g_x;g_y\right)$. An analysis of the properties of the directional distance function can be found in Chambers et al. (1996). Note that $\left(x,y\right) \in T \iff \vec{D}_T\left(x,y;g_x;g_y\right) \geq 0$. Thus, the production set can be derived from the directional distance function.

We use observed production plans as the direction of translation when computing inefficiency using the directional distance function (Briec, 1997); i.e., $(g_x, g_y) = \left(-x^k, y^k\right)$, where *k* indexes firms. The technical inefficiency of a particular firm k is defined by $\vec{D}_T\left(x^k, y^k; -x^k, y^k\right)$, which can be computed by solving a linear program (LP).[5] For example, under the assumption of a variable return to scale technology the linear programming problem to solve is:

$$\begin{aligned} \vec{D}_{T_{VRS}}\left(x^k, y^k; -x^k, y^k\right) &= \max_{z,\lambda^k} \ \lambda^k \\ s.t. \ \sum_{k'=1}^{K} z_{k'} y_{k'm} &\geq y_m^k + \lambda y_m^k \quad \forall m = 1,\cdots,M \\ \sum_{k'=1}^{K} z_{k'} x_{k'n} &\leq x_n^k - \lambda x_n^k \quad \forall n = 1,\cdots,N \\ \sum_{k'=1}^{K} z_{k'} &= 1 \\ z_{k'} &\geq 0 \quad \forall k' = 1,...,K \end{aligned} \quad (3)$$

We now turn to the definitions of profit and allocative inefficiencies. Let $(p,w) \in R_+^{M+N}$ denote an input-output price vector. The profit function is defined by:

$$\Pi(p,w) = \sup_{x,y}\left\{w.y - p.x : (x,y) \in T\right\} \quad (4)$$

[5] The calculation of inefficiency using LPs is commonly referred to a data envelopment analysis (DEA).

Profit inefficiency in the direction of g as defined by Chambers et al. (1998) is:

$$PI(x, y, p, w; g) = \sup\left\{\lambda \in R : w.(y + \lambda g_y) - p.(x + \lambda g_x) \leq \Pi(p, w)\right\} \tag{5}$$

This measure can be interpreted as the difference between the profit function and the observed profit of the firm. Indeed, it can be shown that:

$$PI(x, y, p, w; g) = \frac{\Pi(p, w) - w.y + p.x}{w.g_y - p.g_x} \tag{6}$$

By definition, the allocative inefficiency is the difference between the profit and the technical inefficiency:

$$AI(x, y, p, w; g) = PI(x, y, p, w; g) - D_T(x, y; g) \tag{7}$$

The profit inefficiency of a particular firm is defined by $PI(x^k, y^k, p^k, w^k; x^k, y^k)$. We first compute $\Pi(p^k, w^k)$ by solving a linear program (8) and then apply equation (6). For example, under the assumption of a variable returns to scale technology the linear programming problem to solve is:

$$\begin{aligned}
&\Pi(p^k, w^k) = \max_{z, \tilde{x}^k, \tilde{y}^k} \sum_{m=1}^{M} w_m^k \tilde{y}_m^k - \sum_{n=1}^{N} p_n^k \tilde{x}_n^k \\
&s.t. \sum_{k'=1}^{K} z_{k'} y_{k'm} \geq \tilde{y}_m^k \quad \forall m = 1, \cdots, M \\
&\sum_{k'=1}^{K} z_{k'} x_{k'n} \leq \tilde{x}_n^k \quad \forall n = 1, \cdots, N \\
&\sum_{k'=1}^{K} z_{k'} = 1 \\
&z_{k'} \geq 0 \quad \forall k' = 1, \ldots, K
\end{aligned} \tag{8}$$

4. Empirical analysis of farmers' attitudes to risk

This section first describes the data used, the technology specification and the allocative inefficiency scores. The equation linking allocative inefficiency and output price levels to characterize producer risk aversion is then econometrically tested.

4.1. Sample description and technology specification

This study uses farm accountancy figures from an unbalanced panel data related to 650 farms over the 1992-2003 period. Located in the French Department of Meuse, these farms mainly produce cereals, livestock and milk: 41% are specialized cattle and dairy farms, 18% focus on cash crops and 41% are mixed. Other outputs yield only marginal revenues. General descriptive statistics of the sample are detailed in Table 1.

Farms use on average a total cultivated area of 177 hectares. The sample however contains some heterogeneity in size with a standard deviation higher than 80 hectares and an interval of variation of 671 hectares. Figures are more homogenous over the time period showing a slight increasing size. Wheat cultivated area represents around 24% of total surface and follows the same time-trend. The average of gross margin attains 744 euros per hectare with an annual growth rate of 4.4%. Some annual variations are quite significant especially during the 2003 drought.

Table 1: General Descriptive Statistics (period 1992-2003)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Number of observations	624	647	658	685	662	669	669	657	650	623	614	595
Total area (hectares)												
Mean	157	165	172	175	178	178	179	181	181	185	187	189
Std. Dev.	82	86	89	92	94	95	96	98	97	99	99	101
Min	47	50	47	44	53	48	48	42	47	40	47	40
Max	733	720	718	718	718	718	717	717	716	708	708	708
Wheat area (hectares)												
Mean	37	35	38	42	44	45	46	42	46	43	45	43
Std. Dev.	29	26	27	29	30	33	33	34	33	31	32	31
Min	1.8	1.9	1.5	1.4	2.8	1.7	2.9	1.1	2.3	2.0	0.5	1.8
Max	307	201	236	208	231	284	316	298	232	235	242	229
Gross Margin (euros/hectare)												
Mean	840	750	781	845	962	700	725	722	650	664	652	634
Std. Dev.	140	131	117	119	119	101	117	126	124	119	108	127
Min	331	319	382	346	574	161	260	261	149	241	301	209
Max	1328	1132	1200	1207	1486	1042	1076	1158	1054	1145	1377	1177

Table 2 presents the data used to estimate the production technology and the profit function. Wheat is produced from the following three inputs:

1. total expenses in fertilizer by hectare
2. total expenses on pesticide by hectare
3. total expenses on seeds by hectare

All these input variables are deflated using their respective price indices and expressed in constant Euros (year 2000). Wheat price in real terms (euros per quintal deflated by the general price index) is also used in the profit function. On average, fertilizer expenses are nearly 126 euros while pesticide and seed costs respectively reach 136 euros and 56 euros per hectare. Yield mean gets to 68 quintals per hectare. For these four variables, no significant increasing or decreasing trends can be found since annual values get around their total period average. Wheat price is around 16 euros per quintal and it decreased for the 11 years at an annual rate of 1.5%. Following a phase of downward trend (1992-1996), the output price volatility[6] among farmers within the same year significantly increased over the period 1997-2003.

Table 2: Descriptive statistics of the production technology and profit function variables

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Input variables												
Fertilizer (euros/hectare)												
Mean	135	117	115	130	144	139	131	121	113	137	123	112
Std. Dev.	36	33	28	34	34	36	36	37	33	34	30	32
Min	46	40	47	32	35	57	31	42	42	40	34	46
Max	260	267	228	262	280	304	304	324	268	269	239	241
Pesticide (euros/hectare)												
Mean	137	120	118	136	134	136	147	145	143	148	140	123
Std. Dev.	37	37	35	38	36	35	36	40	36	39	37	40
Min	16	2	6	11	28	16	16	14	12	5	13	14
Max	246	276	276	261	253	242	247	261	281	281	274	319
Seeds (euros/hectare)												
Mean	65	62	52	50	56	60	61	64	55	56	50	44
Std. Dev.	21	21	18	18	21	23	21	29	22	24	20	18

[6] Measured by the coefficient of variation (std/mean).

Min	29	9	5	14	18	17	20	18	13	14	13	13
Max	126	154	123	115	126	129	124	311	146	291	122	183
Output variables												
Wheat (quintal/hectare)												
Mean	66.7	67.7	62.9	65.4	78.5	65.1	73.0	71.8	70.5	64.7	70.2	57.5
Std. Dev.	7.3	9.0	7.6	7.9	8.5	7.0	9.3	9.4	9.7	9.9	9.1	10.1
Min	40.0	32.0	32.6	20.3	49.8	43.4	38.3	27.3	26.0	25.3	43.2	30.3
Max	89.8	89.0	90.6	95.3	113.6	88.6	101.0	94.3	97.3	91.1	93.5	88.2
Wheat Price (euros/quintal)												
Mean	17.7	15.6	17.0	17.8	16.6	15.9	14.6	14.7	13.7	15.6	13.8	16.1
Std. Dev.	1.0	1.1	0.8	1.0	0.7	0.9	0.9	1.0	1.0	1.3	1.1	1.9
Min	15.9	11.5	15.0	15.2	13.6	10.5	11.7	10.4	9.1	11.6	11.3	10.2
Max	24.6	22.5	19.8	28.1	19.7	20.6	19.2	25.7	21.2	28.3	24.2	26.0

4.2. Allocative inefficiency results

To account for a climatic effect, we estimate a specific variable return to scale technology per year. This implicitly integrates this risk into the time dimension of our analysis instead of computing a common benchmark on the whole of accumulated sample (650 farms over 12 years). We measured the technical inefficiency using the linear program (3). Allocative inefficiency levels are evaluated with the linear program (8).

Table 2 presents the allocative inefficiency scores. Over the period, allocative inefficiency reaches 30%. This implies that farms could improve their wheat gross margin per hectare by about the same percentage if their variable input expenditures were adjusted to the observed relative price levels.

Table 3: Allocative inefficiency scores in %

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Mean	29.0	23.6	27.8	27.4	38.2	29.1	25.4	36.9	29.0	23.6	27.8	27.4
Std. Dev.	17.1	15.0	23.1	30.1	33.0	30.6	18.4	36.3	17.1	15.0	23.1	30.1

4.3. Econometric Estimations

In section 2, the following relationship has been derived $AI = f(p_y, k, p_0, p_1, p_x)$. Given that homogenous price intervals and input prices were assumed among our sample, we can omit (p_0, p_1, p_x) in the specification since they will be captured by the constant in the model. Moreover, we complement the equation by farmers' economic characteristics assumed to lead to variations in risk attitude. In the particular case of the simple model developed previously, a quadratic functional form was highlighted between AI and p_y. As we cannot infer the exact relationship for general concave production technology, we adopt a flexible functional form in logarithmic terms. We therefore estimate the following equation:

$$AI_{i,t} = \beta Ln(p_{i,t}^{y}) + \gamma Ln(p_{i,t}^{y}) X_{i,t} + \omega D_t + \alpha_i + \mu_{i,t}$$

Where indices i and t are respectively related to individuals and time. $AI_{i,t}$ measures allocative inefficiency, $Ln(p_{i,t}^{y})$ is the achieved price of a quintal of wheat (in logarithm term) and $X_{i,t}$ is a vector of socio-economic variables such as subsidies per hectare of wheat, debt ratio, total assets, farmer's age… Thus γ measures the influence of X on the allocative inefficiency-price slope. Time-dummy variables D_t are introduced to take account of common year effects. Individuals effects α_i

allows to capture structural differences among farms and $\mu_{i,t}$ is an usual random term assumed to have zero mean and constant variance. Additionally, we assume it to be distributed independently and identically across producers and over time.

We retain four variables as having an influence on allocative inefficiency and risk behavior:

- Subsidies per hectare of wheat to capture the dependency of the farm on subsidies,
- Debt ratio to characterize financial position (measured by total debts on total assets),
- Total assets to assess wealth in the farm,
- Farmer's age.

The expected sign of $\frac{\partial AI}{\partial p_y}$ is positive in case of risk aversion while components of $\hat{\gamma}$ can be positive or negative with respect to their variables. In the literature, subsidies per hectare and the total assets have generally been associated positively with risk taking (see e.g. Shahabuddin et al. 1986). Risk aversion is thought to decrease as farmer' wealth increases and as output activities are more supported by agricultural policies. Inversely, we expect a positive effect for the debt ratio. Finally, it is usually assumed that younger farmers are more disposed to take risks than older ones (Moscardi and de Janvry, 1977).

Since we have panel data, we both estimate the fixed effect model (within estimators) and the random effect model (GLS estimators) complemented by the usual Hausman test. This test leads to favor the random effect model. As expected, a positive and highly significant effect of output prices on allocative inefficiency is found at the average point. All other marginal effects have the expected signs or are not significant. Beyond this global analysis, one can also be interested in comparing risk preferences among different farm types (specialized field crops, specialized cattle and dairy farms or mixed). Therefore, we run similar regression for each category. Results are listed in table 4. The main result is a significant difference in risk aversion between, on one hand, specialized field crops and mixed farms and, on the other hand, specialized cattle and dairy farms. Risk aversion is nearly twice as high for the latter group. As a result, it appears that livestock farmers are much risk averse in wheat production which is not in the core of their activities. Marginal effects of subsidies per hectare, indebtedness and farmer's age are either non significant or display the anticipated signs. Finally, in line with Binswanger's statistical results (1980), wealth measured by total assets do not affect risk aversion.

Table 4: Estimation results for all of farms and for each type of farms

	Overall	**Specialized field crops**	**Specialized cattle and dairy**	**Mixed**
Intercept	-4.3495*** (0.1059)	-	-6.0016*** (0.1884)	-
Ln(price)	1.7601*** (0.0398)	0.9906*** (0.0918)	2.3437*** (0.0717)	1.0768*** (0.0500)
Ln(price).subsidies	-0.0033*** (0.0004)	-0.0031** (0.0011)	-0.0046*** (0.0007)	-0.0021*** (0.0005)
Ln(price).debt	0.0173** (0.0061)	-0.0027 (0.0099)	0.0371** (0.0124)	0.0035 (0.0090)
Ln(price).assets	-1.062E-09 (9.72E-10)	3.960E-10 (2.42E-09)	-2.54E-09 (2.24E-09)	5.98E-10 (9.94E-09)
Ln(price).age	0.0004**	0.00176**	0.0006*	0.0005**

	(0.0002)	(0.0008)	(0.0003)	(0.0003)
Number of observations	7753	1381	3196	3176
Test d'Hausman (χ_2, df=15)	24.98	66.74	20.75	64.33
P-value	5.0%	0.0%	14.5%	0.0%
Estimator	GLS	Within	GLS	Within

Note: ***, **, *: statistical significant at the 1%, 5% and 10% levels, respectively. Standard deviations are in parenthesis. The coefficients of the time-dummy variables are not reported in this table.

5. Conclusion

It has long been suspected that price uncertainty may cause allocative inefficiency in output/input farm decisions. So far, most empirical studies have investigated whether farmers allocate their resources more efficiently when prices are less random. Beyond this commonly known connection between allocative inefficiency and price volatility, our analysis goes one step further by bridging allocative inefficiency and *ex post* output price levels. A contribution of our model is to typify producers regarding their risk preferences. We further propose a methodological approach first to estimate allocative inefficiency (net of technical inefficiency) and second to test for risk preferences within an econometric framework.

Our results strongly suggest that French farmers are risk averse in wheat production. In particular, their risk aversion is decreasing with their specialization in this crop activity. As several previous empirical works have shown, we find a negative influence of subsidies on risk aversion while a positive effect for the debt ratio and the farmer's age have been established.

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