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Interfaces with Other Disciplines

A decomposition of profit loss under output price uncertainty

Jean-Philippe Boussemart[a,1], David Crainich[b,1], Hervé Leleu[b,*]

[a] University of Lille 3 and IÉSEG School of Management (LEM-CNRS), 3, rue de la Digue, 59000 Lille, France
[b] LEM-CNRS (UMR 8179) and IÉSEG School of Management, 3, rue de la Digue, 59000 Lille, France

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ABSTRACT

In this paper, firm profit loss is decomposed as the sum of two terms related to the output price uncertainty (price expectation error and risk preference), plus one extra term expressing technical inefficiency. We then describe the implementation of our theoretical model in a robust data envelopment analysis (DEA) framework, which allows an effective and separate estimation of each term of the decomposition. In addition, we offer an operational tool to reveal producers' risk preferences. A 2009 database of French fattening pig farms is used as an illustration. Our results indicate that risk preference and technical inefficiency are the main sources of profit loss.

1. Introduction

In agricultural activities, long production lags imposed by biological processes, coupled with high price volatility (primarily due to inelastic demands), means that output prices are unknown when production decisions are made. *Ex ante* production decisions may thus differ from choices that would have been made had producers known *ex post* output prices. As a result, price uncertainty is one source of profit loss, since it creates a gap between the observed profit and the profit made in a situation when full information is available.

Numerous studies have been dedicated to uncertainty (whether created by random input prices, random output prices, and/or random shocks to technologies) in agricultural economics. Models dealing with producers' behavior in the context of output price uncertainty were examined by Sandmo (1971), Just (1974), Chambers (1983) and Chavas and Holt (1990), among others. Stochastic technology was considered by Just and Pope (1978) and Chambers and Quiggin (2002), while Chavas and Holt (1996) incorporated both price risk and production risk. More recently, Chambers, Hailu and Quiggin (2011) showed how estimations of efficiency performances in crop productions can dramatically change when stochastic elements not under the control of the producers are ignored in the technology specification. On a sample of Dutch arable farms, Skevas, Lansink and Stefanou (2012) evaluated the impact of stochastic elements on crop production. They found that ignoring the dynamics of production and the variability in production conditions, farmers' performances are underestimated. Other studies inferred farmers' risk attitude from their production decisions. For example, Just and Pope (1991) used US potato supply data to determine whether or not the absolute, the partial, and the relative risk aversions were constant. Likewise, Chavas and Holt (1996) and Kumbhakar (2002), respectively, used US farmers' corn-soybean acreage decisions and Norwegian farmers' salmon production data to evaluate farmers risk aversion. The association between risk preference in the presence of output price uncertainty on the one hand, and technical or allocative inefficiency on the other, has also been previously examined. On the basis of the old idea of an inverse relationship between price uncertainty and allocative efficiency, Wu (1979) empirically investigated whether farmers allocate their resources more efficiently when prices are less random. His results, based on the small scale of Taiwanese family farms, strongly suggest that price and output uncertainty cause profit loss.

The present contribution complements the analysis proposed in these papers by developing a model that decomposes the *ex post* profit loss due to output price uncertainty into two terms: price misprediction and risk preference. Compared to the full information case where the profit is maximized, farmers' output is too high (resp. low) if the future output price they anticipate is higher (resp. lower) than the price at which they finally sell it. Therefore, price misprediction creates an *ex post* profit loss. In the same way, risk preferences lead to output decisions different than those that would have been made in the full information case (Sandmo, 1971). Again, this implies an *ex post* profit loss. Adding the technical inefficiency to the *ex post* profit loss due to price uncertainty, we obtain the difference between the profit firms make and the profit they could have made in the absence of output price risk.

* Corresponding author. Tel.: +33 (0)320545892; fax: +33 (0)320574855.
E-mail addresses: jp.boussemart@ieseg.fr (J.-P. Boussemart), d.crainich@ieseg.fr (D. Crainich), h.leleu@ieseg.fr (H. Leleu).
[1] Tel.: +33 (0)320545892; fax: +33 (0)320574855.

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This structure of decomposition is common in efficiency analysis literature, where the economic inefficiency is separated into technical and allocative inefficiencies. However, we cannot directly interpret the profit loss as profit inefficiency. We favor the term profit loss because allocative inefficiency is decomposed here as the sum of price expectation error and risk attitude.[2] While the former can be considered as inefficiency, it is not the case for the *ex post* loss of profit due to risk preference. This loss is mainly due to a human preference, which affects the economic behavior of the producer, but is not a suboptimal choice *per se*.[3] Therefore, a primary contribution of our model is that it considers allocative inefficiency as a consequence of price uncertainty and risk attitude, and not, as occurs in traditional profit inefficiency decomposition, as a residual (Färe, Grosskopf, & Lovell, 1985, 1994).

We then go on to describe the implementation of our theoretical model in a data envelopment analysis (DEA) framework, which allows the separate estimation of each term of the decomposition. DEA is particularly relevant with regard to measuring inefficiency in production. Since its theoretical beginnings, described in the studies of Debreu (1951) and Koopmans (1951), moving through the seminal paper of Farrell (1957), and then into its operationalization by Charnes, Cooper, and Rhodes (1978), DEA has proved useful in modeling the efficient frontier of a technology, and in measuring the various inefficiencies (profit, allocative and technical[4]) of observed production plans. As we introduce price expectation error and risk attitudes to the model, DEA allows us to measure the intensity of risk preference. However, while the DEA approach is appealing, since it imposes very few assumptions on the production set, its main drawback is the sensitivity of the frontier to outliers (Dervaux et al., 2009). We therefore adapted our model to the robust approach developed by Cazals, Florens, and Simar (2002). The latter is based on subsampling which computes partial frontiers instead of a usual full frontier and therefore allows for some outliers to be situated above the frontier. Impacts of outliers are therefore limited in the computation of inefficiency scores.

In order to show the applicability of our approach, we provide an empirical illustration, using a sample of 149 French pig producers, specialized in fattening units, followed via the database Gestion Tecnhico-Economique from the IFIP (Institut de la Filière Porcine). Our choice of this industry was motivated by two main reasons. First, the fattening process starts months before pigs are sold and the pig-meat price is fairly volatile,[5] meaning that output decisions must be made under price uncertainty. Second, unlike other agricultural activities or types of pig farms (breeder-fattener or breeder), pig fattening is not particularly subject to climatic risks, and mostly includes output price risk. This is why we consider that this is the only risk that affects their *ex ante* decision making. Pig farmers are also subject to several other risks[6] (technological risk, human resources risk, financial risks, legal and environmental risks, ...). In our model, their effects are captured in the technical inefficiency component. For instance, piglet death during the fattening process (an example of technological risk) results in an output reduction (at an *ex ante* given input choice) which is included in the technical inefficiency.

Our decomposition of the difference between the profits earned by pig producers and the profits they could have made in the absence of output price uncertainty offers two insights. First, it explicitly determines whether profit losses can be attributed to uncertainty, or to technical inefficiencies. Second, it identifies pig producers' risk attitude (whether they are risk-averse, risk-neutrals or risk-lovers), which is important information to possess when implementing risk management tools in this sector.

This paper is structured as follows. Section 2 decomposes the profit loss into three terms: price misprediction, risk preference, and technical inefficiency. Section 3 introduces distance functions representing the production technology. These functions enable the isolation of profit loss due to price uncertainty and technical inefficiency. Section 4 is devoted to estimation aspects. It introduces the robust DEA approach to empirically estimate the technology frontier from which the three terms of the expected profit loss can be derived. Section 5 presents the sample and the specification of the empirical technology, tests the model, and discusses the different components of the profit loss decomposition. Finally, we draw our conclusions in Section 6.

2. Profit loss decomposition

In this section, we show how *ex post* profit loss can be decomposed into three effects: (i) the loss resulting from output price uncertainty that may lead to inaccurate price anticipation; (ii) the loss resulting from preferences toward risk and; (iii) the technical inefficiency. Observe that terms (i) and (ii) are the consequences of the output price uncertainty, while term (iii) expresses the various inefficiencies related to the production process.

To make things simple, suppose that firms produce a single output y using a single input x. The production process is assumed to display variable returns to scale, so it can be represented by an increasing and concave function: $y = f(x)$ (with $f'(x) > 0$ and $f''(x) < 0$). The input and output markets are both competitive, so firms take the price of the input (denoted by w) and the price of the output (denoted by p) as givens. The output price is unknown when production decisions are made. If firms knew this price, they would maximize the following (full information) profit:

$$\Pi(p^0, w^0) = \max_{(y,x)}\{p^0 y - w^0 x : y \le f(x)\} \quad (2.1)$$

The first-order condition related to this program $\left(\text{given by } f'(x^*) = \frac{w^0}{p^0}\right)$ defines the production plan (y^*, x^*), such that $(y^*, x^*) = \arg\max \Pi(p^0, w^0)$ and the associated maximum profit is denoted by π^*. This occurs at E^* in Fig. 1. At this equilibrium, firms maximize profits since: (i) there is no technical inefficiency in the production process and; (ii) firms know the price at which the output will be sold. We attempt to explain the difference between this full information profit, and that resulting from the observed input and output (respectively denoted by x^o and y^o). This observed profit (denoted by π^o) is given by:

$$\pi^o = p^o y^o - w^o x^o \quad (2.2)$$

The *ex post* profit loss PL is defined as the difference between the full information profit and the observed profit:

$$PL = \Pi\left(p^o, w^o\right) - \left(p^o y^o - w^o x^o\right) = \pi^* - \pi^o \quad (2.3)$$

Three sources of *ex post* profit loss are considered. In addition to the technical inefficiency commonly computed, we consider the fact that firms could mispredict the price at which the output will be sold, and that they have risk preferences that may affect their output decisions. The following decomposition determines the three sources

[2] Note that other sources of allocative inefficiency (such as physical or financial constraints) may exist. They are not considered in this paper, but could be introduced.

[3] We argue that this has gone largely unnoticed in previous studies on efficiency even if Skevas, Stefanou, and Lansink (2014) accounted for farmers' risk preferences when measuring their productive performances. More specifically, with regards to producers' decisions on risk they considered the risk decreasing or increasing nature of inputs such as pesticide uses and their impacts on benefit levels. Compared to their study focused on production uncertainty, our papers focuses on the profit loss only due to output price uncertainty.

[4] Technical inefficiency is related to misuses of inputs and/or wastes in outputs. Allocative inefficiency results from a misallocation of inputs and/or outputs when a price system and an economic objective like profit maximization is introduced. The sum of technical and allocative inefficiencies defines the profit inefficiency.

[5] The mean of annual output price changes in absolute terms over a period of 50 years is around 9.5 percent for pig compared to 8.1 percent for wheat, 6.4 percent for cattle and 4.6 percent for poultry (see figure in Appendix A).

[6] See Just and Pope (2002) for a classification.