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Decision tools for strategic planning and efficiency analysis in sow farms

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If a person is persistent, albeit hard to understand, will be intelligent, and even weak will become strong. Leonardo da Vinci (1452-1519)

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Abstract

The pig sector is very important in the European Union (EU). Catalonia is Spain first producing region, where Catalan swine production accounts for 34.3% of Catalan Agricultural Product Final. This thesis focuses on the continuing need to increase the productive efficiency of the producers in a very competitive sector. The thesis proposes models for an ex ante (before the start-up of productive activity or the implementation of the decision) and ex post (after the productive activity) assessment of the swine farm. We propose an: i) analysis of the efficiency and the variables that explain and ii) development and validation of a simulation model to evaluate different production strategies.

The literature review of economic models developed for swine farms shows that the use in the swine sector of strategic decision models in the literature published is still very limited. Given the competitiveness of the sector and its high efficiency, it began to try to characterize the efficient farms and their distinctive characteristics. It is shown that nonparametric methods (Data Envelopment Analysis or DEA) are more practical and intuitive than parametric methods. The farms analysed were highly efficient (over 90%), being more efficient farms producing piglets than pig producers. Among the inputs, the size of the farm, feed consumed and number of inseminations were the most determinants of efficiency.

To support farmers in decision-making and analysis of different production strategies, a Decision Support System was developed (DSS): AnaPorkDSS. The model integrated AnaPorkDSS uses economic and technical parameters based on Spanish farms. In all scenarios analysed, Net Present Value (NPV) of a farm in an integration contract exceeds the NPV not integrated. Furthermore, it shows how the herd structure of the sows produces a variability that can influence the economic viability of the farm.

In conclusion, decisions as enter into integration contracts *well negotiated*, maintain a stable sow herd and increased number of inseminations that increase prolificity, increase the efficiency of farms.

Resum

El sector porcí és molt important a la Unió Europea (UE). Catalunya és la primera regió productora d'Espanya, on la producció porcina catalana representa el 34,3% de la Producció Final Agrària Catalana. Aquesta tesi està centrada en la necessitat permanent d'incrementar l'eficiència productiva dels productors dins un sector molt competitiu. La tesi proposa uns models per una avaluació *ex ante* (abans de l'inici de l'activitat productiva o la implementació de la decisió) i *ex post* (després de l'activitat productiva) de la granja porcina. Per això es proposa: i) Anàlisi de l'eficiència i les variables que l'explicarien i ii) desenvolupament i validació d'un model de simulació per avaluar diferents estratègies productives.

La revisió bibliogràfica dels models econòmics desenvolupats per granges porcines demostra que l'ús al sector porcí de models de decisió estratègics publicats a la literatura és molt limitat. Donada la competitivitat del sector i la elevada eficiència, es va començar per intentar caracteritzar les explotacions eficients i els seus trets distintius. Es demostra com els mètodes no paramètrics (Anàlisi Envolvent de Dades o DEA) són més pràctics i intuïtius que els mètodes paramètrics. En conjunt, les granges analitzades van resultar molt eficients (més del 90%), destacant les granges productores de garrins sobre les de porcs. D'entre els inputs, la mida de la granja, pinso consumit i nombre d'inseminacions van ser els més determinants de l'eficiència.

Per recolzar als grangers en la seva pressa de decisions i en l'anàlisi de diferents estratègies productives, es va desenvolupar un Sistema de Suport a la presa de Decisions (DSS): AnaPorkDSS. El model integrat en AnaPorkDSS utilitza paràmetres econòmics i tècnics basats en granges espanyoles. En tots els escenaris analitzats, el Valor Actual Net (VAN) d'una explotació dins un contracte d'integració és superior al no integrat. A més a més, es demostra com l'estructura poblacional de les truges genera una variabilitat que pot condicionar la viabilitat econòmica de l'explotació.

En conclusió, decisions com entrar en contractes d'integració ben negociats, mantenir un cens de truges estable i l'augment del nombre d'inseminacions que augmentin la prolificitat, incrementen l'eficiència de les granges.

Resumen

El sector porcino es muy importante dentro de la Unión Europea (UE). Catalunya es la primera región productora de España, siendo la producción porcina catalana el 34,3% de la Producción Final Agraria Catalana. Esta tesis se centra en la necesidad permanente de incrementar la eficiencia productiva de los productores dentro de un sector muy competitivo. La tesis propone unos modelos para una evaluación ex ante (antes del inicio de la actividad productiva o la implementación de la decisión) i ex post (después de la actividad productiva) de la granja porcina. En base a lo anterior se propone: i) Análisis de la eficiencia y las variables que la explicarían y ii) desarrollo y validación de un modelo de simulación para evaluar diferentes estrategias productivas.

La revisión bibliográfica de los modelos económicos desarrollados para granjas porcinas demuestra que el uso dentro del sector porcino de modelos de decisión estratégicos publicados en la literatura es muy limitado. Dada la competitividad del sector y su elevada eficiencia, se empezó por intentar caracterizar las explotaciones eficientes y sus características distintivas. Se demuestra como los métodos no paramétricos (Análisis Envolvente de Datos o DEA) son más prácticos e intuitivos que los métodos paramétricos. En conjunto, las granjas analizadas resultaron muy eficientes (más del 90%), destacando las granjas productoras de gorrinos sobre las de cerdos. De entre los inputs, el tamaño de la granja, pienso consumido y número de inseminaciones fueron los más determinantes de la eficiencia.

Para apoyar a los granjeros en la toma de decisiones y en el análisis de diferentes estrategias productivas, se desarrolló un Sistema de Soporte a la toma de Decisiones (DSS): AnaPorkDSS. El modelo integrado en AnaPorkDSS utiliza parámetros económicos y técnicos basados en granjas españolas. En todos los escenarios analizados, el Valor Actual Neto (VAN) de una explotación dentro de un contrato de integración es superior al no integrado. Además, se demuestra como la estructura poblacional de las cerdas genera una variabilidad que puede condicionar la viabilidad económica de la explotación.

En conclusión, decisiones como entrar en contratos de integración bien negociados, mantener un censo de cerdas estable y el aumento del número de inseminaciones que aumenten la prolificidad, incrementan la eficiencia de las granjas.

Chapter 1

General Introduction

1 Introduction

The pig sector is very important in the European Union (EU). Catalonia is the first Spanish region in number of pigs produced, where swine production accounts for 34.3% of Catalan Final Agricultural Product. This sector has been industrialized for years, reducing the number of farms, but increasing capacity. Currently, within the EU and its regulatory framework, rather than maximizing overall production, it is more important to maximize the technical and economic production efficiency of farms.

Within the EU, pig production is concentrated in a number of countries, with Denmark, Germany, Spain, France, the Netherlands and Poland holding more than two thirds of the breeding pigs. The major production basin extends from Germany (namely from Nordhein-Westfalen & Niedersachen), to Belgium (Vlaams Gewest) and accounts for 30 % of EU sows. However, there are other important regions, such as Cataluña, Murcia (Spain), Lombardia (Italy), Bretagne (France) and some areas of central Poland and Northern Croatia (Eurostat, 2014).

This thesis analyses pig production focusing on sow farms and paying attention to the improvement of their technical and economic efficiency. To increase efficiency: i) farms must optimize production costs according to their individual position in the sector (given the limited influence on the selling prices) ii) and gain bargaining power within the supply chain making sound decisions.

i) Feed cost is the main cost of pig production farm in Europe (Nguyen et al., 2012). The year 2009 between 50 and 65% of the total cost of production in a sow farm was feed cost in Denmark, Germany, Spain, France and the Netherlands (Brossard, L. and Montagne, L., 2012). In the 2012-2013 periods this percentage was the 70% in Spain (Informe anual del sector porcí 2013, 2013). A problem for farms is the volatility of the feed cost, because it affects the profitability of farms. In the period 2009-2013 in Spain the price of feed for sows and feeder pigs increased by 40% in Spain (Informe anual del sector porcí 2013, 2013). Feed price increases in 2007 and 2008 also had a relatively large effect on producers and processors (European Commission, 2011).

ii) Producers tend to organise their activities in supply chains. Past studies have described the European meat industry to be less competitive than that of other competing countries. Production cost and productivity have been the major issues hindering its competitiveness. (European Commission, 2011). It is necessary to improve the relationships and interactions among different actors along the supply chain. This thesis analyses the position of individual farmers within the supply chain and the strategic decision of being integrated vertically. In Spain and other European countries vertical integration is very common (Evolución del mercado porcino UE y tendencias legislativas comunitarias para el sector porcino, 2013). European Commission (2011) considered Spain has a high level of vertical integration (between feed companies and farms 70% of total production) whilst in United Kingdom, the Netherlands, Poland and Germany vertical integration is still low. Since individual farmers are part of a competitive market with long term relations with other actors, their ability to enter in direct negotiations with retailers is very minimal because of their fragmentation. Farmers influence on the downstream industry is therefore very small. However, integration of farmers strengthen the bargaining position through vertically integrated companies and cooperatives, who can reach the costumers or negotiate with other processors or retailers. In recent years the vertical organization of meat supply chains has been among the most vividly discussed topics in agriculture and the food industry. Many authors hypothesize that contracts and vertical integration are paramount for the future competitiveness of pork production (Schulze et al., 2006). Individual farmers are needed of tools for economic analysis to value the impact on their own production of changes in the selling price or assessing vertical integration as an alternative decision.

Increased efficiency will enhance competitiveness and productivity of the farm. Evolución del mercado porcino UE y tendencias legislativas comunitarias para el sector porcino (2013) shows the importance of the competitiveness and productivity in the pig sector. The farmer competes with other pork producers (in the same country or abroad) but also with other meat producers (e.g. chicken). The farmer has to promote greater effectiveness and technical efficiency: i) improving piglets weaned per sow per year, piglet mortality and vaccinations, ii) investment in genetics, nutrition and health; iii) and a greater economic efficiency (cost control or financial analysis). Pork meat production had showed an economic cycle of less than two and half years, although nowadays this cycle is getting sharper and irregular as globalisation is progressing (Eurostat, 2014). This situation leads the producer to need financial tools to evaluate the building of a new farm, to expand or adapt the present one to the standards of animal welfare.

Following the necessity to improve economic and technical efficiency of sow producers, this thesis is focused on: the economic assessment before the start-up of the farm or to explore strategic decision like enter into integration contracts.

2 Research scope and objective

The objective of this Ph.D. thesis was to contribute to improve the production efficiency of the pig production, focused on sow farms and supporting strategic decisions regarding vertical integration. This has been achieved from two secondary objectives:

- Analysis of technical and economic efficiency assessing the most important variables affecting efficiency to evaluate different production strategies on sow farms.
- Proposal of a model for the strategic planning and embedded into a DSS.

The above objectives are formulated based in the following hypothesis:

- Parametric and non-parametric approaches are useful and equivalent to evaluate efficiency for a sample of pig farms.
- Specific DSS for strategic decisions, suitable and accessible for farm or multisite closed cycle, has not been developed yet.

Hence, the present thesis contributes to an analysis of pig farming in two situations: before the activity starts (ex ante) and after, when the activity is operating (ex post). The analysis should provide tools for better decision making to individual farmers and help to improve technical and economic efficiency.

Figure 1 shows the objectives of the thesis and how they are covered through the different chapters. After a general introduction (Chapter 1), the thesis begins with a review about the economic models published for sow farms until now (Chapter 2). The review intends to detect how efficiency in strategic models have been treated in literature and with which extension.

The first secondary objective was the evaluation of a sample of sow farms with parametric and non-parametric approach (Chapter 3). Data Envelopment Analysis (DEA) is the non-parametric mathematical programming approach to frontier estimation. This analysis evaluates the efficiency and the variables most determinants of efficiency. Additionally, this study compares results with other studies and determines whether the non-parametric approach is useful.

The second secondary objective was propos a DSS. In Chapter 4 a decision support system to evaluate pig production economics (AnaPorkDSS) based on a spreadsheet model has been developed to estimate net present value (NPV) with the pig production activity under Spanish conditions. A strategic planning application of AnaPorkDSS that allows the user to optimize and perform an economic analysis in a farrow-to-finish pig farm. This strategic model is evaluated by applying it to specific cases in Chapter 5. The aim is to support the decision making concerning the investment on the creation of a new farm and determining whether entering into integration contracts is or not convenient.

Figure 1. Detailed objectives of this research.

GENERAL OBJECTIVE
IMPROVE PRODUCTION EFFICIENCY AND SUPPORTING STRATEGIC DECISIONS REGARDING VERTICAL INTEGRATION

SECONDARY OBJECTIVES

SOW FARMS EFFICIENCY (CHAPTER 2 and 3)

1. to analysis technical and economic efficiency sow farms: parametric and non-parametric approach
2. to analysis efficiency sow farms:
   a) results and comparation with other published results
   b) assessing the most important variables affecting efficiency
   c) to determine if DEA is a practical tool for individual agents and small companies
3. modelling approaches: economic models developed

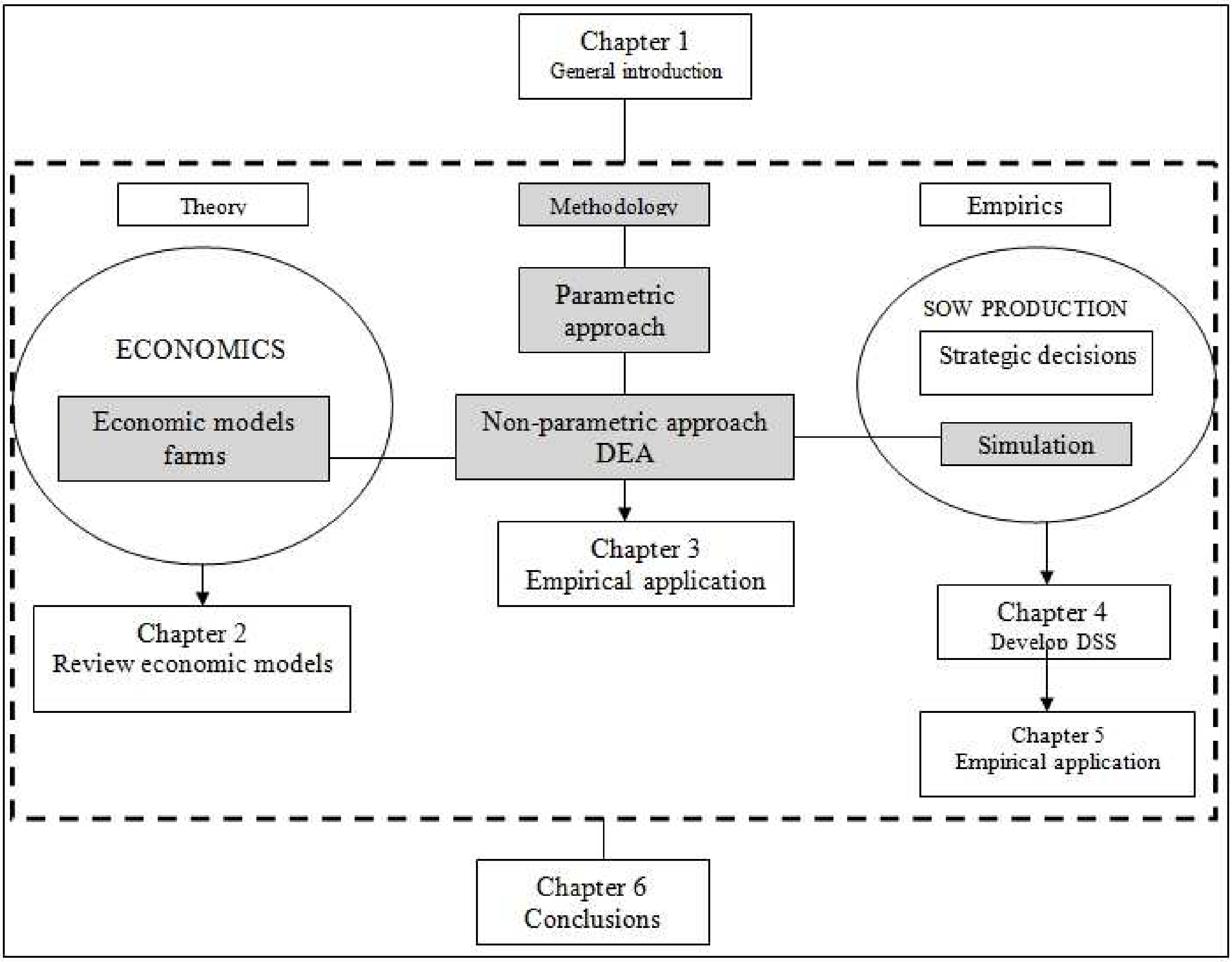
STRATEGIC PLANNING (CHAPTER 2, 4, 5)

1. to review economic models for sow farms developed
2. to design a DSS for strategic planning
   a) to design an economic model for the strategic planning
   b) to applicate the model to particular cases

3 Outline of the thesis

Figure 2 shows the plan of this research, highlighting the theoretical, methodological, and empirical compasses used to reach the results of this thesis. Chapter 1 is a general introduction showing the objectives, hypothesis and internal coherence and organisation. Chapter 2 is a review of the economic models for sow farms. Chapter 3, 4 and 5 are concerned with the evaluation and strategic planning in sow farm. The general conclusions are in the last chapter (Chapter 6).

Figure 2. Plan of this research.



Chapter 2 gives an assessment of the state of the art in the area of economic models for sow farms. The pig sector is characterized by a great variability of revenues and less in costs, high competitiveness, many family farms of small size and strict regulations. The pig sector is a very competitive sector and the use of strategic models to better plan their activities might represent substantial savings and increased efficiencies. These farms need appropriate economic model to decide entering into production contracts. In this chapter, a general outline is given of the framework in which these models can be used in on-farm decision support. Models available in the literature are studied to examine to what extent they are suitable for use for on-farm decision support. The structure of each single model and the differences/similarities between models are identified.

Chapter 3 presents the application of parametric and nonparametric approach to the analysis of the sow farms and an analysis of results. The parametric approach requires the definition of a specific functional form for the technology and for the inefficiency error term, using mathematical programming or econometric techniques. It can be subdivided into deterministic and stochastic models. Deterministic models envelope all the observations, identifying the distance between the observed production and the maximum functions, defined by the frontier and the available technology, as technical inefficiency. On the other hand, stochastic approaches allow distinguishing between technical efficiency and statistical noise.

DEA is a non-parametric approach to relative efficiency measurement which considers multiple inputs and outputs. If a suitable set of input-output data can be defined, DEA provides a measurement of relative technical efficiency which does not require inputs and outputs to be weighted according to a common weighting system.

This chapter presents the analysis of technical efficiency in sow farms vertically integrated into the same company comparing parametric and non-parametric approaches. Empirical data from Spanish sow farms classified into two groups depending on the final product, that is, farms producing weaned piglets or feeder pigs were available. This sample is representative of the Spanish farms, to be integrated and the final product. The analysis will draw conclusions applicable to the farms of the sector.

This study classified sow farms between efficient and inefficient, and the efficient were used as reference for inefficient. This study will help farmers to increase efficiency: help in making decisions to increase the size of the farm, control production costs or lead productive structures of reference. The results will show to the public administrations or technical a view of the sector in terms of technical or economic efficiency. This view can be used in the development of public and business policies in the sector. The study must analyse: i) The scale efficiency (farms in which efficiency gains would be expected by increasing the size), ii) quantifies margins improved efficiency farm iii) farm- specific factors affecting productive inefficiencies (i.e. production or feed) and iv) the efficiency of the pig sector in Spain and other European countries.

The objective of Chapter 4 was to develop a model to determine optimal strategy and compare alternative strategies. This model was embedded into a DSS to evaluate pig production economics (AnaPorkDSS). A DSS is an interactive system providing information, tools or models to help managers or professionals make decisions in semi structured or unstructured situations (Alter, 1996). The ability to invoke, run, change, combine and inspect models is a key capability in DSSs. The models in the DSS can be divided into strategic, tactical and operational models (Turban, 1990).

The proposed DSS solve part of the problem and help isolate places were judgement and experience is required. This DSS incorporate both data and models, are designed to assist managers (farmer) with their decision process in semi structured or unstructured tasks and support, rather than replace, managerial judgement. Economic and technical data are of Spanish farms. The strategic model shows economic results of these farms and will help the sow farmer in making strategic decisions. The objective of this DSS is to improve the quality of decision making by modelling all alternatives and by forecasting their contributions to the goals.

Traditional pig production was based on small familiar sow farrowing - to finish farms. The small farmer needs an ex-ante analysis to support the strategic decisions: i) creation of a new operation, ii) the decision of a new investment, iii) the extension of the operation or iv) to decide entering into production contracts. A DSS tool to be used in analysing complex pig production systems is necessary. This DSS will show detailed to economic and financial information based on our level and necessities to us. A model adapted to handle situations in all production regions where pig production is important. Developed software packages can help to manage the farm, and can be adapted to other production and purposes (Zoranovica and Novkovic, 2013). The AnaPorkDSS is written as a multipage spreadsheet model and is operated on a PC in a windows environment, accessible for all level of users. AnaPorkDSS is developed for especially for small family farms: i) Easy to use and ii) adapted to the specific necessities of the farm and environment (variables and key results). This chapter describes the model structure, input data requirements, and summarizes basic reports generated by the model. The model is capable of estimating NPV for a farrowing-to-finish farm producing pigs that are sold to the slaughterhouse. The application maximizes the NPV of the business along a given time horizon under different financial scenarios and expectation about future market prices. Incomes from sales are estimated for both fattened pigs and culled sows and boars. The analysis of the starting up of the activity is used to illustrate the usefulness of the AnaPorkDSS.

Within the strategic planning the aim of the Chapter 5 is to support the decision making concerning the investment on the creation of a new farm and decide whether entering into production contracts is or not convenient. The study is developed to address the recognised deficiency financial information on integration contracts. The integration contracts are the most important livestock contract modality of those signed today in Spain. In view of present world financial crisis, an economic analysis with and without external loans will be performed. The explicit incorporation of financial issues it is necessary to be used either by banks, credit agencies or governmental extension services to give advice to pig farmers evaluating investment projects, or by pig companies to value and grant the access to credit given the present scarcity.

Chapter 5 considered the strategic planning of a sow farm and compare alternative strategies. Strategic planning (also called strategic management) is a systematic process through which an organization agrees on – and builds commitment among key stakeholders to – priorities that are essential to its mission and are responsive to the environment (Allison and Kaye, 2005). Strategic planning guides the acquisition and allocation of resources to achieve these priorities (Barney and Hesterly, 2010).

Modern production is impossible without a detailed plan of production. Only well-organized farms can survive on the market. Current organizational and managing structure of a farm indicates the existence a level within the management hierarchy: Strategic and tactical level– Top management (Agricultural-Factory Farm (AFF) level) (Zoranovica and Novkovic, 2013). Planning at this level is done by the farmer.

Strategic planning on a sow-farm is important to ensure an acceptable return on the activity in the long term. In this context, an economic analysis is important for a decision maker or swine specialist involved in the setting up of a new farrowing –to– finish farm.

Finally, Chapter 6 ends with the main conclusions of the thesis and present further research.

4 References

Allison, M. and Kaye, J., 2005. Strategic planning for nonprofit organizations, 2nd edn. Hoboken, NJ: John Wiley & Sons, 1–30.

Alter, S., 1996. Information systems: a management perspective. The Benjamin/Cummings Publishing Company, Inc. Menlo Park, U.S.A. 728.

Barney, J.B. and Hesterly, W.S., 2010. Strategic management and competitive advantage: Concepts and cases, 3rd edn. Englewood Cliffs, NJ: Prentice Hall, 4–25.

Brossard, L. and Montagne, L., 2012. Overview of pig production in the European Union. CAPES-COFECUB n° Sv 687/10, Brazil, October 2012.

Evolución del mercado porcino UE y tendencias legislativas comunitarias para el sector porcino, 2013. Dirección General de producciones y mercados agrarios. Ministerio de Agricultura, Alimentación y Medio Ambiente., 2013.

http://www.asfac.org/fitxers/AVISOS/2014/Evolucion%20del%20mercado%20porcino.pdf (last access December 3rd, 2014).

European Commission, 2011. Study on the Competitiveness of the European Meat Processing Industry. . http://ec.europa.eu/enterprise/sectors/food/files/report_compmeat_en.pdf (last access September 2nd, 2015).

Eurostat, 2014. http://ec.europa.eu/eurostat/statistics-explained/index.php/Pig_farming_sector_-_statistical_portrait_2014 (last access October 3rd, 2015).

Informe Anual del Sector Porcí, 2013. Generalitat de Catalunya, Departament d'Agricultura Ramaderia, Pesca Alimentació i Medi Natural, Observatori del Porcí. http://agricultura.gencat.cat/web/.content/de_departament/de02_estadistiques_observatoris/08_observatoris_sectorials/04_observatori_porci/informes_anuals/fitxers_estatics/Informe-sector-porci-2013_GGP_UdL.pdf (last access October 3rd, 2015)

Nguyen, T.L.T., Hermansen, J.E. and Mogensen, L., 2012. Environmental costs of meat production: the case of typical EU pork production. Journal of Cleaner Production, 28, 168-176.

Schulze, B., Spiller, A. and Theuvsen, L., 2006. Vertical Coordination in German Pork Production:Towards more Integration. Paper presented at the 16th Annual World Forum and Symposium "Agribusiness, Food, Health, and Nutrition", IAMA Conference, June 10 – 13, 2006 in Buenos Aires, Argentina. www.uni-goettingen.de/de/kat/...pdf/1022_Paper%5B1%5D.pdf (last access December 15th, 2014).

Turban, E., 1990. Decision support and expert systems: management support systems. Macmillan Publishing Company. New York: 846.

Zoranovica, T. and Novkovic., N., 2013. Information System for Small Pig Farm. 6th International Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2013).Procedia Technology, 8, 544 – 549.

Chapter 2

Economic models for swine producers: a literature review

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Abstract

This paper gives an assessment of the state of the art in the area of economic models for the sow farms published from 1979 to 2015 (n54). This study is focused in the economic models. The models are classified by different criteria. So that it is easy to see similarities and differences between the models. We also found that the number of strategic models in the swine industry is still very limited (50% of the models). As the second component of production cost is the replacement of sows, most of tactical model consider sow herd dynamics. Judging by the numbers of published papers, we concluded that different economic measures have been used in literature to evaluate pig production. Most of papers were developed in standard software (69% of the models). A model develop in spreadsheet is easy to use for a pig farmer and this review reveals a lack of models developed in spreadsheet (13% of the models). Then some existing gaps in the literature that we believe should be addressed in the near future are identifying.

Keywords: swine producers; strategic model; economic model; software.

1 Introduction

The pig meat occupies the first place in meat production around the world, with Asia as the continent with a major production, followed by Europe. Europe produces a 25 % of the total production around the world. With 152 million pigs and a yearly production of about 23 million tons carcass weight the EU (European Union) is the world's biggest exporter.

The EU's main producer countries are Germany, Spain and France. They represent together already half of the EU's total production.
The EU has a self sufficiency of about 110% and exports about 12% of its total production. Main export destinations are Russia and East Asia, in particular China (European Commission, 2015a). Brossard and Montagne (2012) show that in 2011, some countries are big importers (as Slovenia and Bulgaria) and other big exporters (as Belgium and Denmark). In the EU the average price for pig carcasses for the period 2010-2014 range between 1.52 and 1.70 €/kg. The prices for 2015 range from 1.37 to 1.52 (€ / kg). Therefore market prices tend to decline (European Commission, 2015 b).

The evolution of the pig production in the EU from 2000 to 2011 is variable depending on the country. Some countries have increased (Germany 30%, Spain 20% or Denmark 15%), others have decreased (UK 12% or Poland 12%), and others have remained stable (Belgium and France). However the trend in the production in the EU-27 (27 countries members European Union) has increased by 9% from 2000 to 2011 (Brossard and Montagne, 2012).

This sector is heavily regulated by EU on pig welfare, animal health, environmental, or waste management.

Figure 1 shows the distribution of pig farms in EU. Pig farms are classified in four types based on the number of sows and "other pigs": i) Small fatteners (without sows and less than10 pigs), ii) Large fatteners (without sows and more than 400 pigs), iii) Large breeders (more than 100 sows and more than 400 pigs), and iv) Other farms (with sows and less than 400 pigs).

Figure 1. Distribution of pig farms by type of pig rearing: four types based on the numbers of sows and “other pigs” (adapted from Brossard and Montagne, 2012).

	Number of sows		
Number of “other pigs”	None	0-100	100-
0-10	**Small fatteners** Own consumption New members states (Bulgaria, Romania,..) 71.4 % Farms of EU 4.1 % “Other pigs” of EU	**Other** 27.2 % Farms 23.3 % 53.1 % sows	**farms** of EU “Other pigs”of EU of EU
10-400			
400-	**Large fatteners** Specialised fatteners 10 countries EU (Belgium, Denmark, Italy…) 0.8 % Farms of EU 36.5 % “Other pigs” of EU		**Large breeders** 0.6 % Farms of EU 36.0 % “Other pigs” of EU 46.9 % sows of EU

The modern piglet production system results in a specialization of the swine production industry characterized by a herd of sows in a continuous process of reproduction.

The European pig sector is characterized by a great variability of revenues and less in costs (basically feed cost), high competitiveness, many family farms of small size and strict regulations. The European pork industry is currently being rapidly redefined by new economic, ecological and social forces (Backus and Dijkhuizen, 2002). Brossard and Montagne (2012) indicate that the sector's development depends on the feed price and animal welfare regulation. Margin of benefit per kg of pig meat produced has been reduced in recent years (Rodríguez-Sánchez et al., 2010) and it is important that the industry produces a high quality product at the lowest possible cost (Dhuyvetter, 2000). Globalization, consumer concerns about environment, animal welfare, food safety, food quality technological developments, new science, and people involving social and cultural attitudes are transforming pork production (Trienekens et al, 2009).

According to Brossard and Montagne (2012), the EU pig market is characterized by:

a. Change from production oriented to market oriented

b. Critical consumers with wishes concerning way of production

c. Large market consisting of consumers with a relatively high income

d. High production costs compared to other areas.

This characterization produces concentration, abandonment and restructuring (Brossard and Montagne, 2012, Rodríguez-Sánchez, 2010). Traditional pig production was based on small familiar sow farrowing – to finish farms, but this is undergoing a rapid change (Perez et al. 2010). There has been a general reduction of the number of pork enterprises (in particular individual farms managed by a family) but incrementing the size and overall production (Balogh et al, 2009, Rodríguez-Sánchez, 2010).

A model can play an important role in this context of restructuring, change, globalization and high competitiveness. A model is defined as a simplified representation of a system (e.g. the farm or a part of it), which can be used to predict the effects of changes in the system (Dent and Blackie, 1979; Spedding, 1988). An economic model for swine farm predicts the financial effects of changes in the farm. Before a farmer start operating his farm, it is very important to have a business plan guiding the entrepreneur through the process of developing a strategic plan (Kaplan et al, 2008). This way, the farmer will be aware of financial needs like additional capital and hereafter if proceed, seeking for a loan. The farmer need to perform an economic analysis considering advanced features such as assets entered, tracking depreciation, calculating his net profit value or loss accurately, averaging his farming income and the tax effect. In this context, it is basic the explicit addition of financial aspects to evaluate investment projects.

These farms need appropriate tool to assist them in making decisions. This model should be appropriate to its structure: affordable, easy to use and accessible to a non-expert user.

The present review aims at determining current state of the art of economic models applied to the pig farm in an attempt to determine whether they are useful for the needs of the farmer.

Hence, we intend to do that (i) review the literature on planning models for pig farm and (ii) classifying the literature by different criteria.

1.1 Scope of the review

This paper gives an assessment of the state of the art in the area of economic pig models. Economic models meet three requirements: i) All or part of the model represents the activity of the individual producer (rearing farms, sow farms or fattening farms), ii) generates and evaluates economic performance (i.e. profit or income) and iii) the model is specific to the pig sector or highly applicable to the pig sector.

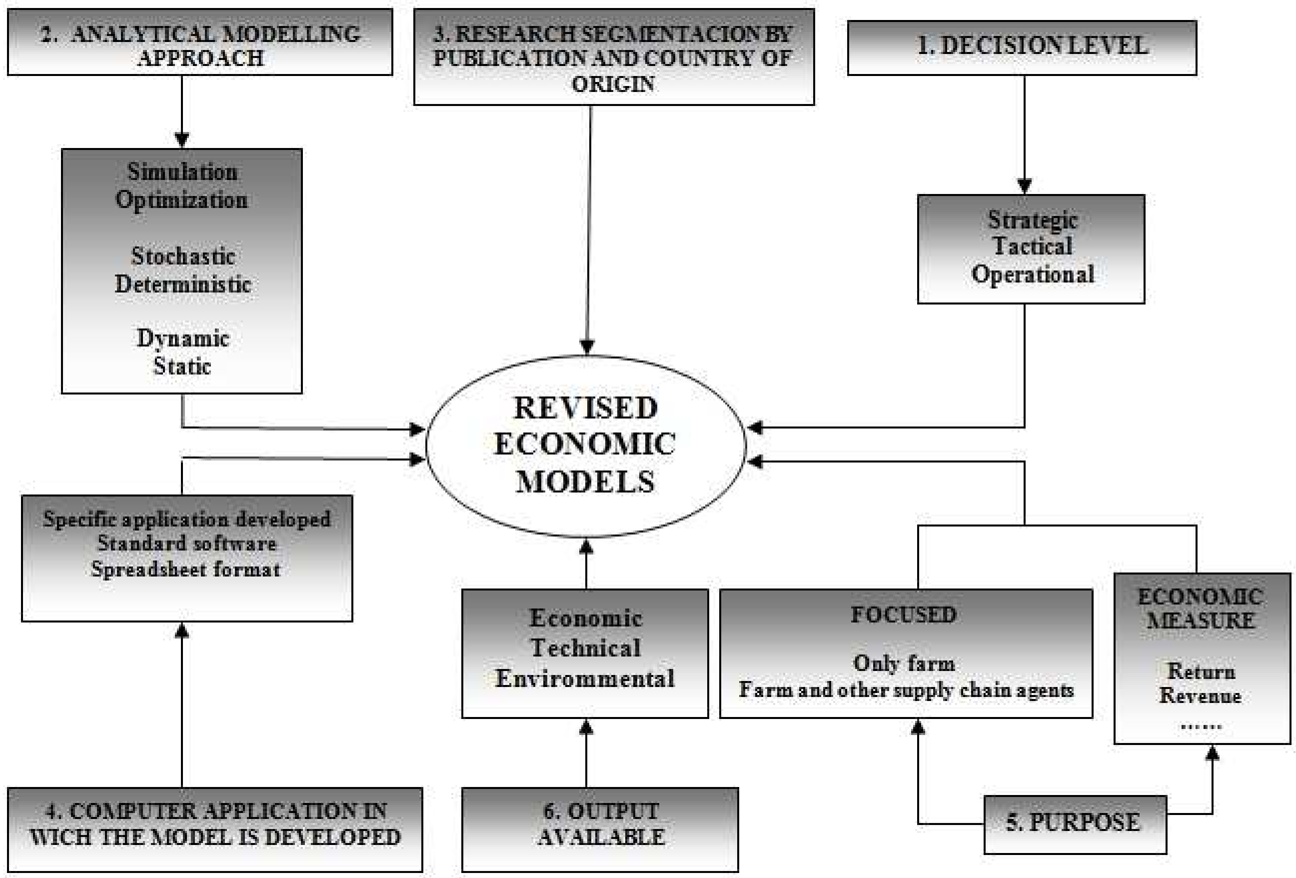
The scope of this review is basically one: economic models reviews that have been published in preprints, journal articles, books, thesis, reports or conference. We exclude patents.

1.2 Taxonomy

In view of the proposed classification of the literature done by Jalvingh (1992), Plà (2007) and Rodríguez-Sánchez et al. (2010), has been performed this review including six criteria used to organize and present this review. In this sense, as shown in Figure 2, we have proposed different taxonomies to classify the revised works and giving a multidimensional approach of each one. So that, the proposed taxonomy in this paper considers the following six classification criteria:

1. Decision level: regarding the scope of decisions there are three levels: strategic, tactical or operational corresponding to long, medium (year, season) and short time horizon (days, weeks) respectively (Jalvingh, 1992). Strategic decisions (i.e. invest in sow production, such a case is farm designing and sizing, determining the capacity of swine production facilities) are major choices of actions and influence whole or a major part sow farm. They have long-term implications on the production. Tactical decision (i.e. sow herd dynamics, housing facilities, and reproduction management) making helps to develop the ideas behind a basic strategy. Operational decision making (i.e. determining sows to inseminate, sows to replace and piglets to wean) focuses more upon the detailed operations of decision making, as opposed to tactical decisions.
2. Analytical modelling approach: considering the mathematical methods or mathematical relationships used to model and solve the problem within the context of pig farm.
3. Research segmentation by publication and country of origin: the scope of the publications where revised papers were published may be useful to understand the motivation of the research and the multidisciplinary approach. This review considers the country where the models were developed.
4. Computer application in which the model is developed: analysing whether it has developed a specific application or use existing software.
5. Purpose: models are classified based on the type of decision variables related to different activities: farm or consider other supply chain agents (i.e. slaughter). The nature of the economic measure (net present value, revenue, profit, cost, net worth, return, margin or other function).
6. Output available: considering calculations available, only economic or also technical and/or environmental calculations.

Figure 2. Classification criteria of the revised papers for this review.



1.3 Plan for this research

The aim is to access all the developed models with scientific content. So we searched papers from the main electronic bibliographical sources (Google Scholar, Scopus, Web of Science) using different keywords (see Table 1).

We have based our literature review on a selection of economic models of sow farms, published in English between 1979 and 2015. Models published before 1979 were not retained in our collection as economic planning is quite recent research question.

This keywords' set was difficult to be fixed because always there were listed many irrelevant papers. In the end, an individual examination paper by paper was necessary to make a final decision. Table 1 shows results.

Table 1. Results search.

Word to search All in title	Google Scholar	Scopus	Web of Science
Analysis hog production	17	3	13
Analysis pig optimization	2	0	1
Analysis pig production	101	40	109
Agricultural policy simulator	6	4	9
Bio economic model swine	2	3	3
Cost tactical	72	30	21
Culling policies sow	1	0	1
Culling strategies	17 (without words: "Cow;Dairy")	22	48
Economic model farm	76	45	178
Economic optimization pork production	3	2	2
Financial model farm	17	2	17
Gilt Replacement	12	20	74
Investment decisions hog	4	1	1
Management System Pigs	13	39	123
Management support pig production	3	0	1
Model pigs decisions	2	4	10
Model swine financial	1	1	1
Pig farm planning	3	4	11
Pig production system	117	144	322
Pig systems	497	1,494	141 (further topic: Economic)
Planning pig	24	11	70
Pork industry	215	58	221
Pork sector	70	18	51
Production and Farm Income	55	17	83
Programming model optimal pork	1	1	1
Simulation pork production	7	1	7
Swine Herd Population	2	5	9
Sow efficiency	32	34	289
Sow model	41	44	233
Sow replacement	31	23	45
Sows economy production	2	1	1
Swine replacement	26	10	25

In the end, we have based our literature review on a selection of fifty-four economic models. Forty-two reviewed models were published in journal, two in conference, two in congress or workshop, two in books, two in a discussion paper and four in other sources (bulletin, dissertation, project or online). These economic models meet all three requirements indicated in the scope of the review. This after defining our selection criteria, we analyse each model. A 'model' can be broadly defined as a finalised representation of reality (Legay, 1997). Both conceptual (i.e. theoretical) and implemented (i.e. software-integrated) models were considered for this analysis. We paid special attention to avoid taking several publications presenting the same model. When sub models were published separately from the whole published model of which they were a part, they were retained in our collection only if some characteristics of the sub models, according to our analysis grid, differed significantly from those of the whole model. When available, publications presenting the model were preferred to those aimed at evaluating this model or at presenting original results obtained from using this model. Only decision economic models are included. We aimed to be exhaustive in the list of models matching all our selection criteria.

Classifying the models from our collection or analysis was subject to some limitations as some part of the necessary information was sometimes missing in the papers. The data used for the model development (experimental data, data from case studies, observational data, data built with farmers and extensions, or any other kind of data) were not always described with much detail. Therefore it is difficult to classify the models in the different modalities of criterion used in this review. In all cases, the classifications and the analysis we retained were based on what we could assume on the only basis of what was written in the papers. The amount of details provided could greatly vary between the different works.

The organization of this paper is as follows: we first present some background about review of models in swine production (Section 2) those models used in the swine industry. In Section 3 we present economic models that have been developed for swine producer, and we classify them according to the different criteria presented in figure 2. Later on, in Section 4, we present some related studies focused on swine producer. In the last section we provide an outlook.

2 Economic models

2.1 Background

Jalvingh (1992) examined what extent existing models can be used on-farm decision support. This paper studied especially in a field of livestock management with a high number of published economic models, i.e. reproduction and replacement in dairy and sow herds. In this research the structure of each single model and the differences/similarities between models were identified. Jalvingh (1992) reviewed technical and/or economic calculations. The taxonomy used by Jalvingh (1992) was based on consider optimization versus simulation, deterministic versus stochastic and dynamic or static. Furthermore, some characteristics more related to the contents of the model were used in identifying the structure (i.e. country of origin or software support). This review summarized the existing literature from 1983 to 1990.

Plà (2007) survey the different sow models described (from 1983 to 2004), which made use of different mathematical methodologies, and were intended for sow herd management. Models were discussed depending on the mathematical approach, that is, simulation and optimisation.

Rodríguez-Sánchez et al. (2010) reviewed papers dealing with models (technical and/or economic) for planning activities in the Pork supply chain (farmers, slaughterhouses, wholesalers and retailers) published from 1983 to 2009. Particularly, those models using optimization and simulation methodologies were considered. The basic classification used is the Supply chain-agent studied in the model (pig farms, sow farms, fattening farms, slaughterhouse, wholesalers and distributors). Our study is focused in pig farms, sow farms and fattening farms (models incorporating these agents). Additionally, the structure of each single model and the differences/similarities between models were identified in Rodríguez-Sánchez et al. (2010).

3 Economic models for pig farms planning and modelling approaches

Table 1 shows list of papers and main objective.

Table 1. List of papers dealing with economic models.

Paper / book / study	Main objective
Kroes and Van Male (1979)	Analyses data on 15,000 services from 85 commercial pig farms to quantify the importance of the losses when a sow has to be culled too early.
Greene and Eidman (1980)	Describes and evaluates three feeder pig confinement systems by calculating annual enterprise budgets and monthly cash flows for each system and comparing the results.
Tess et al. (1983)	Construct a deterministic computer model to simulate biological and economic inputs and outputs for life cycle pork production. Parameters and relationships used were developed and verified by comparison with experimental results in the literature.
Dijkhuizen et al. (1986)	Design a computer model, PorkCHOP, to quantify the benefits of increased lifespan in swine breeding herds and to optimize the replacement decision for sows with poor productive and/or reproductive performance.
Macbeth and McPhee (1986)	Computer models of a number of systems for combining the Large White and Landrace pig breeds were developed.
Singh (1986)	A discrete stochastic simulation model of swine herd population dynamics is described. The model is homomorphic with the life cycle of hogs.
Pettigrew et al. (1987)	A dynamic, partially stochastic mathematical model describing the reproductive performance of a sow herd is presented.
Houben et al. (1990)	Economic comparison of insemination and culling policies in commercial sow herds, assessed by stochastic simulation with the lowest Retention-Pay-Off (an economic index which ranks sows on future profitability).
Faust et al. (1992)	A stochastic computer model was developed to simulate individual pigs in a hierarchical breeding system. The bio economic model was designed as a tool to facilitate the evaluation of selection, culling, and management strategies for a three-tiered breeding structure.
Jalvingh et al. (1992)	Present the TACT-swine simulation model (a tactical model planning for the individual farmer).
Boland et al. (1993)	Develop a simulation of three hog genotypes to determine how producer profits, economically optimal slaughter weights, and carcass component weights change under three pricing models.
Huirme et al. (1993)	A stochastic dynamic programming model, which runs on a personal computer, is introduced to determine the economic optimal replacement policy in swine breeding herds.
Backus et al. (1995)	Develop a computer-based simulation model that analyses the economic consequences of strategic plans (20 years) related to investment decisions in swine farming: replacement of existing pig farm buildings and buying others.
den Ouden, et al. (1997a, 1997b)	Dynamic linear programming was used to evaluate the development of pork chain concepts that take animal welfare concerns into account.
Kure (1997)	The problem of optimal slaughter pig marketing management is examined in more details and methods.
Udovc (1997)	Presents the decision support system KMETIJA (Farm) which is intended to be used by farmers, extension workers, decision makers and other subjects active in agriculture and rural areas. KMETIJA consists of three parts: data banks, simulation core and financial calculations. The simulation core consists of two sub models which are used to simulate farm's plant and animal production.
Meuwissen et al. (1999)	Present a model aimed at a financial analysis of a Classical Swine Fever outbreak. Financial consequences are calculated for affected parties, including governments

	(EU and national), farms, and related industries in the production chain.
Bailleul et al. (2000)	Develop a simplified growing pig model to determine the feeding management system that maximizes net return in commercial growing/finishing production systems. The model is mechanistic, deterministic, dynamic and aggregated at the whole-animal level.
Dhuyvetter (2000)	Examines the impact sow attrition rate has on the cost and returns of producing a weaned pig.
Krieter (2002)	Evaluates different production systems in pig farming including economic, animal welfare and environmental aspects with computer simulation. The computer model considers a vertically integrated system with farrowing, weaning, fattening and slaughtering stage as well as the transportation of pigs between theses stages.
Majewski et al. (2002)	Examine impacts of different rates of direct payments on production structures and farm incomes of Polish family farms after the accession to the EU.
Søllested and Kristensen (2002)	Present a sow replacement model that really uses methodological improvements in replacement models comprising multi-level hierarchical Markov processes and Bayesian updating.
Li et al. (2003)	An approach to the development of the economically optimal dietary concentration of Paylean, duration of the Paylean feeding and dietary lysine concentration for finishing hog production is presented.
Plà et al. (2003)	Develop a Markov decision sow model to represent the productive and reproductive lifespan of herd sows. The model precisely describes the herd structure at equilibrium based on actual farm data.
Stalder et al. (2003)	Determine with a net present value (NPV) the number of parities a sow must remain in the breeding herd of a breed-to-wean operation before the initial investment in her is profitable, and to evaluate the sensitivity of NPV to production, price received, and gilt replacement price.
Zonderland and Enting (2003)	Develop the farm model Pig Farm Manager for pig productions systems to calculate technical and economic consequences. The Pig Farm Manager estimates the effects of various farm designs as well as farm management on production, environmental and economical parameters. The Pig Farm Manager includes simulations for sow farms and finisher pig farms.
Happe et al. (2004)	Present the agent-based model AgriPoliS (Agricultural Policy Simulator) which simultaneously considers a large number of individually acting farms, product markets, investment activity, as well as the land market, and a simple spatial representation. AgriPoliS studies the interrelationship of rents, technical change, product prices, investments, production and policies, structural effects resulting from these, the analysis of the winners and losers of agricultural policy as well as the costs and efficiency of various policy measures.
Kristensen and Søllested, (2004)	A biological model of the replacement model is described in a previous paper and in this paper the optimization model is described. The model is developed as a prototype for use under practical conditions.
Brumm et al. (2005)	Develop a simulation model to use in evaluating economic impacts of increasing pig space allotments above those currently in use.
Odening et al. (2005)	This study applies the option-pricing theory is applied to an investment problem in hog production. A stochastic simulation model capable of pricing American-type options is developed.
Niemi (2006)	Examines the effect of production technology and changes in input and output prices on feeding and slaughter decisions.
Reimer (2006)	Provides an economic explanation regarding why the share of U.S. pork raised on company-owned farms with hired management (integration) is increasing relative to production through independently owned-and-operated contract growers (contracting). Develops a property rights model that shows how in certain circumstances production contracts do not transfer sufficient control over the use of production assets to intermediaries.
Rodriguez-Zas et al. (2006)	Use a dynamic programming model to find the optimal parity and net present value in breed-to-wean swine herds. The model included income and costs per parity weighted by the discount rate and sow removal rate.
Ferguson (2008)	Describes the key components of an integrated simulation model, Watson and how it

	has been applied within Nutreco Canada.
Lammers et. al (2008)	Analyses the impact of gestation housing system o weaned pig production cost
Lemke and Valle Zárate (2008)	Analyses developmental trends, and the driving forces behind them, in smallholder pig production systems in the marginalized mountainous areas of North-west Vietnam.
Ohlman and Jones (2008)	Determine the marketing strategy that maximizes expected annual profit.
Balogh et al. (2009)	The model allows the quantification of the number of pigs from given farms to slaughterhouses, the maximum sales revenue, the delivery threshold prices, and an analysis of the impact co-operative members exert on sales revenues.
Rutten-Ramos and Deen (2009)	Present a partial budget in Microsoft Excel to describe the long-term implications of voluntary culling programs on long-range parity distributions, expectations for annual productivity, and marginal financial differences.
Houska et al. (2010)	Marginal economic values for production and reproduction traits of pigs were estimated applying a bio-economic model to Hungarian commercial sow herds with integrated fattening of piglets.
Aramyan et al. (2011)	Presents a scenario analysis of the spatial allocation of pork supply chain activities in Europe. A mixed integer linear programming (MILP) model, which includes piglet production, fattening, slaughtering of pigs, processing of pork and pork consumption, is used to analyse the scenarios.
Ezcurra-Ciaurriz and Plà-Aragonés (2011)	Develop a decision support system to evaluate pig production economics (AnaPorkDSS) based on a spreadsheet model to estimate net present value and costs associated with the pig production activity under Spanish conditions.
Bernard et al. (2012)	Animal health and Welfare Planning (AHWP) was implemented on 50 organic pig farms in Austria (29 breeding and 21 fattening farms). The paper measure the impact of AHWP on economic data (gross margin) as well as potential effects on other areas such as animal health, welfare and farmers' perceptions.
Bono et al. (2012)	Develop a dynamic monitoring system for litter size at herd and sow level, with weekly updates. For this purpose, a modified litter size model, based on an existing model found in the literature, is implemented using dynamic linear models.
Hermesch et al. (2012)	Present PigEV that is a spreadsheet with a number of worksheets, which capture all of the assumptions and calculations required to derive economic values for traits of the growing pig and the sow. PigEV generates a summary table of economic values as well as multiple formatted tables of intermediate calculations and assumptions.
Rodríguez-Sánchez et al. (2012)	Deals with tactical planning decisions for breeding farms producing piglets through a linear optimization model.
Berevoianu et al. (2013)	Present a computer model to analyse economic information on the profitability and economic risk, available both in the vegetable farms and for the livestock sector.
Khamjan et al. (2013)	Demonstrates the use of a heuristic algorithm, pig size distribution, and pig growth to create a procurement plan. The performance of the developed procurement method is compared to the traditional practices of a company.
Seddon et al. (2013)	Describes the development of a novel spreadsheet-based financial simulation model that estimates the cost of pig production in five free-farrowing systems in comparison to standard sow housing in a farrowing crate.
Nadal-Roig and Plà (2014)	Present a multiperiod planning tool for multisite pig production systems based on Linear Programming The aim of the model is to help pig managers of multisite systems in making short-term decisions (mainly related to pig transfers between farms and batch management in fattening units) and mid-term or long-term decisions (according to company targets and expansion strategy).
Wen-cong et al. (2014)	Develop and test a method to determine the technical optimization to ameliorate waste treatment methods and gain insight into the relationship between technological options and the economic and ecological effects.
Gonzalez-Pena et al. (2015)	Compare the financial indicators (gross return, net profit, and cost) in a three-tier pig production system under one of two selection strategies: a traditional strategy including nine paternal and maternal traits and an advanced strategy that adds four semen traits.
Mbuthia et al. (2015)	A deterministic bio-economic model was developed and applied to evaluate biological and economic variables that characterize smallholder pig production

	systems in Kenya.
Nadal-Roig and Plà (2015)	Present the formulation and resolution of a stochastic mixed integer linear programming model for pig production planning. The aim of the model is to optimize the entire pig supply chain according to the number of farms operating for the same company or cooperative.

3.1 Decision Level

The classification of the revised papers according to the decision level is presented in Table 2. As it is shown, there are twenty seven papers dealing with strategic decisions, thirty-five related to tactical decisions and also ten at the operational level. While thirty six papers were devoted to one specific decision level, there are eighteen papers that combined decisions at different levels like strategic-tactical or tactical-operational. Most of the strategic models consider production or housing system, pig genotypes, integration contracts, pork supply chain and investment decisions.

Most of tactical model consider sow herd dynamics as was pointed by Jalvingh (1992) and Plà (2007). Moreover most of the published sow herd models are devoted to tackle the sow replacement problem which is one of the most important decisions in sow herd management and with a direct economic impact for the farmer (Kristensen, 1993). After feeding the second component of production cost is the replacement of sows (Rodríguez-Sanchez et al., 2010).

Table 2. Decision levels for the papers analysed.

Author	Decision level		
	Strategic	**Tactical**	**Operational**
Kroes and Van Male (1979)		X	
Greene and Eidman (1980)	X		
Tess et al. (1983)	X	X	
Dijkhuizen et al. (1986)		X	
Macbeth and McPhee (1986)	X		
Singh (1986)		X	
Pettigrew et al. (1987)		X	
Houben et al. (1990)			X
Faust et al. (1992)		X	
Jalvingh et al. (1992)		X	

Boland et al. (1993)	X	X	
Huirme et al. (1993)		X	X
Backus et al. (1995)	X		
den Ouden, et al. (1997a, 1997b)	X	X	
Kure (1997)			X
Udovc (1997)	X	X	
Meuwissen et al. (1999)		X	X
Bailleul et al. (2000)		X	
Dhuyvetter (2000)		X	
Krieter (2002)	X		
Majewski et al. (2002)	X		
Søllested and Kristensen (2002)		X	
Li et al. (2003)		X	X
Plà et al. (2003)		X	
Stalder et al. (2003)		X	
Zonderland and Enting (2003)	X	X	
Happe et al. (2004)	X	X	
Kristensen and Søllested, (2004)		X	
Brumm et al. (2005)	X		
Odening et al. (2005)	X		
Niemi (2006)	X	X	
Reimer (2006)	X		
Rodriguez-Zas et al. (2006)		X	
Ferguson (2008)		X	X
Lammers et. al (2008)	X		
Lemke and Valle Zárate (2008)	X	X	
Ohlman and Jones (2008)		X	X
Balogh et al. (2009)	X		
Rutten-Ramos, and Deen (2009)		X	
Houska et al. (2010)		X	
Aramyan et al. (2011)	X		
Ezcurra-Ciaurriz and Plà-Aragonès (2011)	X		
Bernard et al. (2012)	X		
Bono et al. (2012)		X	

Hermesch et al. (2012)		X	X
Rodríguez-Sánchez et al. (2012)		X	
Berevoianu et al. (2013)	X		
Khamjan et al. (2013)		X	X
Seddon et al. (2013)	X		
Nadal-Roig and Plà (2014)	X	X	
Wen-cong et al. (2014)	X		
Gonzalez-Pena et al. (2015)		X	X
Mbuthia et al. (2015)	X		
Nadal-Roig and Plà (2015)	X	X	

3.2 Analytical modelling approach

As shown in Table 3, most of the papers preferred simulation as modelling technique. From fifty-four works, thirty-two are included in this category being the larger. Therefore, simulation models are preferred, making it also possible to gain insight into the consequences of sub-optimum decisions Jalvingh et al. (1992). Simulation models are well suited to dealing with the variability and complex nature of livestock production (Plà, 2007). Only, two papers combined different methodologies either (simulation or optimization). Twenty two works applied stochastic approaches and applied deterministic approaches thirty one models. One paper combined stochastic and deterministic approach (Ezcurra-Ciaurriz and Plà-Aragonés, 2011). As shown in Table 3, most of the papers preferred static approach as modelling technique. From fifty-four papers, thirty-two are included in this category being the larger. The rest of papers used dynamic approach.

Special mention deserves the approach of Odening et al. (2005). Odening et al. (2005) applied option-pricing theory to an investment problem in swine production. Employ a numerical approximation procedure, which is based on stochastic simulation and dynamic programming. This is the first time that this option-pricing is applied in an agricultural context (Odening et al., 2005).

Table 3. Modelling approaches used by the analysed papers.

Author	Modelling approach of the reviewed works		
	Simulation / Optimization	**Stochastic / Deterministic**	**Dynamic / Static**
Kroes and Van Male (1979)	Simulation	Deterministic	Static
Greene and Eidman (1980)	Simulation	Deterministic	Static
Tess et al. (1983)	Simulation	Deterministic	Static
Dijkhuizen et al. (1986)	Optimization	Deterministic	Static
Macbeth and McPhee (1986)	Simulation	Deterministic	Dynamic
Singh (1986)	Simulation	Stochastic	Dynamic
Pettigrew et al. (1987)	Simulation	Stochastic	Dynamic
Houben et al. (1990)	Simulation	Stochastic	Dynamic
Faust et al. (1992)	Simulation	Stochastic	Static
Jalvingh et al. (1992)	Simulation	Stochastic	Dynamic
Boland et al. (1993)	Optimization	Deterministic	Static
Huirme et al. (1993)	Optimization	Stochastic	Dynamic
Backus et al. (1995)	Simulation	Stochastic	Static
den Ouden, et al. (1997a, 1997b)	Simulation / Optimization	Deterministic	Dynamic
Kure (1997)	Optimization	Stochastic	Dynamic
Udovc (1997)	Simulation	Deterministic	Static
Meuwissen et al. (1999)	Simulation	Deterministic	Dynamic
Bailleul et al. (2000)	Optimization	Deterministic	Dynamic
Dhuyvetter (2000)	Simulation	Deterministic	Static
Krieter (2002)	Simulation	Deterministic	Static
Majewski et al. (2002)	Optimization	Deterministic	Static
Søllested and Kristensen (2002)	Optimization	Stochastic	Dynamic
Li et al. (2003)	Simulation	Deterministic	Static
Plà et al. (2003)	Simulation	Stochastic	Dynamic
Stalder et al. (2003)	Simulation	Deterministic	Static
Zonderland and Enting (2003)	Simulation	Deterministic	Static
Happe et al. (2004)	Simulation / Optimization	Stochastic	Dynamic

Kristensen and Søllested, (2004)	Optimization	Stochastic	Dynamic
Brumm et al. (2005)	Simulation	Stochastic	Static
Odening et al. (2005)	Simulation	Stochastic	Dynamic
Niemi (2006)	Optimization	Stochastic	Dynamic
Reimer (2006)	Optimization	Stochastic	Static
Rodriguez-Zas et al. (2006)	Optimization	Stochastic	Dynamic
Ferguson (2008)	Simulation	Deterministic	Static
Lemke and Valle Zárate (2008)	Simulation	Deterministic	Static
Ohlman and Jones (2008).	Optimization	Stochastic	Dynamic
Yuan et al. (2008)	Simulation	Deterministic	Static
Balogh et al. (2009)	Optimization	Deterministic	Static
Rutten-Ramos, and Deen (2009)	Simulation	Deterministic	Static
Houska et al. (2010)	Simulation	Deterministic	Static
Aramyan et al. (2011)	Optimization	Deterministic	Static
Ezcurra-Ciaurriz and Plà-Aragonès (2011)	Simulation	Stochastic / Deterministic	Static
Bernard et al. (2012)	Simulation	Deterministic	Static
Bono et al. (2012)	Optimization	Stochastic	Dynamic
Hermesch et al. (2012)	Simulation	Deterministic	Static
Rodríguez-Sánchez et al. (2012)	Optimization	Stochastic	Dynamic
Berevoianu et al. (2013)	Simulation	Deterministic	Static
Khamjan et al. (2013)	Optimization	Stochastic	Dynamic
Seddon et al. (2013)	Simulation	Deterministic	Static
Nadal-Roig and Plà (2014)	Optimization	Deterministic	Static
Wen-cong et al. (2014)	Optimization	Deterministic	Static
Gonzalez-Pena et al. (2015)	Simulation	Deterministic	Static
Mbuthia et al. (2015)	Simulation	Deterministic	Static
Nadal-Roig and Plà (2015)	Optimization	Stochastic	Dynamic

3.3 Research segmentation by publication and country of origin

Reviewed papers were usually published in agricultural journals (thirty-eight papers). Twelve models (22% of the economic models) were published or presented in a project, conference, bulletin, discussion paper, workshop, dissertation, online or congress.

On the other hand, if we pay attention of the year of publication, clearly, the interest in economic models for swine producers is rather recent. Most of the economic models have been published this century (69% of the models). The increasing number of new variables and constraints affecting piglet production make difficult to explore all possible management alternatives to find the best one. For such a purpose of the development of good models is important (Rodríguez-Sánchez, 2012). So, the increment in references is expected to increase in the following years.

If the article does not say that the country has developed the model, it is considered the country of the university researcher. When the authors belong to universities from different countries model is from all countries. Countries where pig farming is a very important sector like USA (seven-teen models) and The Netherlands (ten models) have developed more models.

Table 4. Research segmentation by publication and country of origin.

Model	Journal	Type	Country of origin
Kroes and Van Male (1979)	Livestock Production Science	Agricultural	The Netherlands
Greene and Eidman (1980)	----	Bulletin	USA
Tess et al. (1983)	Journal of Animal Science	Agricultural	USA
Dijkhuizen et al. (1986)	Preventive Veterinary Medicine	Agricultural	The Netherlands and USA
Macbeth and McPhee (1986)	Agricultural Systems	Agricultural	Australia
Singh (1986)	Agricultural Systems	Agricultural	Denmark
Pettigrew et al. (1987)	Journal of Animal Science	Agricultural	USA
Houben et al. (1990)	Netherlands Journal of Agricultural Science	Agricultural	The Netherlands
Faust et al. (1992)	Journal of Animal Science	Agricultural	USA
Jalvingh et al. (1992)	Agricultural Systems	Agricultural	The Netherlands
Boland et al. (1993)	Studies in Agricultural Economics	Agricultural	Hungary
Huirme et al. (1993)	European Journal of Operational Research	Operational Research	The Netherlands
Backus et al. (1995)	Computer and Electronics in Agriculture.	Agricultural	The Netherlands
den Ouden, et al. (1997a, 1997b)	Livestock Production Science	Agricultural	The Netherlands
Kure (1997)	----	Dissertation	Denmark
Udovc (1997)	---	Conference	Slovenia

Meuwissen et al. (1999)	Preventive Veterinary Medicine	Agricultural	The Netherlands
Bailleul et al. (2000)	---	Book	Canada
Dhuyvetter (2000)	---	Conference	USA
Krieter (2002)	Arch. Tierz., Dummerstorf	Agricultural	Germany
Majewski et al. (2002)	Agrarwirtschaft	Agricultural	Poland
Søllested and Kristensen (2002)	Journal Swine Health Production	Agricultural	USA
Li et al. (2003)	Journal of Agricultural and Resource Economics	Agricultural	USA
Plà et al. (2003)	Agricultural Systems	Agricultural	Spain and Canada
Stalder et al. (2003)	Agricultural Systems	Agricultural	USA
Zonderland and Enting (2003)	---	Congress	The Netherlands
Happe et al. (2004)	----	Discussion Paper	Germany
Kristensen and Søllested, (2004)	Livestock Production Science	Agricultural	Denmark
Brumm et al. (2005)	---	Project	USA
Odening et al. (2005)	Agricultural Economics	Agricultural	Germany
Niemi (2006)	Agricultural and Food Science	Agricultural	Finland
Reimer (2006)	American Journal Agricultural Economy	Agricultural	USA
Rodriguez-Zas et al. (2006)	Journal Animal Science	Agricultural	USA
Ferguson (2008)	Advances in Pork Production	Agricultural	Canada
Lammers et. al (2008)	Applied Engineering in Agricultura	Agricultural	USA
Lemke and Valle Zárate (2008)	Agricultural Systems	Agricultural	Germany
Ohlman and Jones (2008)	Online	Online	USA
Balogh et al. (2009)	Journal of Agricultural and Applied Economics	Agricultural	USA
Rutten-Ramos, and Deen (2009)	American Society of Animal Science	Agricultural	USA
Houska et al. (2010)	Czech Journal of Animal Science	Agricultural	Hungary
Aramyan et al. (2011)	Journal on Chain and Network Science	Engineering and management	The Netherlands
Ezcurra-Ciaurriz and Plà-Aragonès (2011)	Proyecto Social: Revista de	Social sciences	Spain

	Relaciones Laborales		
Bernard et al. (2012)	Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie	Agricultural	Austria
Bono et al. (2012)	Livestock Science	Agricultural	Denmark
Hermesch et al. (2012)	----	Workshop	Australia
Rodríguez-Sánchez et al. (2012)	Livestock Science	Agricultural	Spain and Chile
Berevoianu et al. (2013)	----	Discussion Paper	Romania
Khamjan et al. (2013)	Computers & Industrial Engineering	Computer	Thailand
Seddon et al. (2013)	Livestock Science	Agricultural	United Kingdom
Nadal-Roig and Plà (2014)	Journal of Animal Science	Agricultural	Spain
Wen-cong et al. (2014)	Journal of Integrative Agriculture	Agricultural	China
Gonzalez-Pena et al. (2015)	Theriogenology	Agricultural	USA
Mbuthia et al. (2015)	Trop Anim Health Prod	Agricultural	Kenya
Nadal-Roig and Plà (2015)	---	Book	Spain

3.4 Computer application in which the model is developed

This section examines whether existing software, spreadsheet or a specific program developed was used (see Table 5). It is not considered specific program specific software program (i.e. program into Extend). They have developed ten specific applications and seven models are developed in spreadsheet.

The adoption of advanced tools is not clear (Kamp, 1999), in part due to complex models behind and more research oriented purpose. With the introduction of personal computers on farms in the 1990s (Huirme, 1990), the inclusion of models developed in spreadsheet is of interest for all level of users. A model develop in spreadsheet is easy to use for a pig farmer. The study reveals a lack of models developed in spreadsheet or other commercial software.

Table 5. Computer application of the model.

Author	Computer application		
	Specific application developed	Standard software	Spreadsheet format
Kroes and Van Male (1979)		X	
Greene and Eidman (1980)		X	
Tess et al. (1983)	X		
Dijkhuizen et al. (1986)	X		
Singh (1986)		X	
Macbeth and McPhee (1986)		X	
Pettigrew et al. (1987)		X	
Houben et al. (1990)		X	
Faust et al. (1992)		X	
Jalvingh et al. (1992)	X		
Boland et al. (1993)		X	
Huirme et al. (1993)		X	
Backus et al. (1995)		X	
den Ouden, et al. (1997a, 1997b)		X	
Kure (1997)		X	
Udovc (1997)	X		
Meuwissen et al. (1999)		X	
Bailleul et al. *(2000)*		X	
Dhuyvetter (2000)		X	
Krieter (2002)	X		
Majewski et al. (2002)		X	
Søllested and Kristensen (2002)			X
Li et al. (2003)		X	
Plà et al. (2003)		X	
Stalder et al. (2003)		X	
Zonderland and Enting (2003)	X		
Happe et al. (2004)	X		
Kristensen and Søllested, (2004)		X	

Brumm et al. (2005)			**X**
Odening et al. (2005)		**X**	
Niemi (2006)		**X**	
Reimer (2006)		**X**	
Rodriguez-Zas et al. (2006)		**X**	
Ferguson (2008)	**X**		
Lammers et. al (2008)		**X**	
Lemke and Valle Zárate (2008)			**X**
Ohlman and Jones (2008).		**X**	
Balogh et al. (2009)		**X**	
Rutten-Ramos, and Deen (2009)			**X**
Houska et al. (2010)	**X**		
Aramyan et al. (2011)		**X**	
Ezcurra-Ciaurriz and Plà-Aragonès (2011)			**X**
Bernard et al. (2012)		**X**	
Bono et al. (2012)		**X**	
Hermesch et al. (2012)			**X**
Rodríguez-Sánchez et al. (2012)		**X**	
Berevoianu et al. (2013)	**X**		
Khamjan et al. (2013)		**X**	
Seddon et al. (2013)			**X**
Nadal-Roig and Plà (2014)		**X**	
Wen-cong et al. (2014)		**X**	
Gonzalez-Pena et al. (2015)		**X**	
Mbuthia et al. (2015)		**X**	
Nadal-Roig and Plà (2015)		**X**	

3.5 Purpose

There is a variety of economic measures used related to the revised models. Table 6 displays the acronyms and corresponding meaning of the different economic measures considered for this review.

Table 6. Nomenclature used to classify the papers according the economic measures.

Notation	Economic measure
C	Cost
NPV	Net Present Value
M	Margin
P	Profit
RT	Return
RV	Revenue
O	Other

Table 7 use the acronyms introduced in Table 6. Forty one models were focused only on farm and thirteen consider the farm and other supply chain agents (slaughterhouse, wholesales or distributors). A scarce literature related to the farm and other supply chain agent models is found.

Economic measures are very different. The most common are return (twelve models), profit (twelve works) and cost (eleven works). Several models combine two or more economic results (Faust et al., 1992; Gonzalez-Pena et al.,2015; Lemke and Valle Zárate, 2008; Mbuthia et al., 2015; Odening et al., 2005; Udovc, 1997; Zonderland and Enting, 2003).

Table 7. Purpose of the models: focused on farm / farm and other agents and Economic measure.

Author	Focused		Economic measure						
	Only farm	Farm and other agents supply chain	C	NPV	M	P	RT	RV	O
Kroes and Van Male (1979)	X		X						
Greene and Eidman (1980)	X								X
Tess et al. (1983)	X								X
Dijkhuizen et al. (1986)	X								X

Macbeth and McPhee (1986)	**X**						**X**		
Singh (1986)	**X**						**X**		
Pettigrew et al. (1987)	**X**						**X**		
Houben et al. (1990)	**X**								**X**
Faust et al. (1992)	**X**		**X**				**X**		
Jalvingh et al. (1992)	**X**				**X**				
Boland et al. (1993)	**X**					**X**			
Huirme et al. (1993)	**X**			**X**					
Backus et al. (1995)	**X**								**X**
den Ouden, et al. (1997a, 1997b)		**X**	**X**						
Kure (1997)		**X**					**X**		
Udovc (1997)	**X**			**X**	**X**				
Meuwissen et al. (1999)		**X**							**X**
Bailleul et al. (2000)	**X**						**X**		
Dhuyvetter (2000)	**X**						**X**		
Krieter (2002)		**X**	**X**						
Majewski et al. (2002)	**X**								**X**
Søllested and Kristensen (2002)	**X**						**X**		
Li et al. (2003)	**X**						**X**		
Plà et al. (2003)	**X**					**X**			
Stalder et al. (2003)	**X**			**X**					
Zonderland and Enting (2003)	**X**		**X**			**X**			
Happe et al. (2004)		**X**				**X**			
Kristensen and Søllested, (2004)	**X**						**X**		
Brumm et al. (2005)	**X**						**X**		
Odening et al. (2005)		**X**		**X**				**X**	**X**
Niemi (2006)		**X**							**X**
Reimer (2006)		**X**							**X**
Rodriguez-Zas et al. (2006)	**X**			**X**					
Ferguson (2008)	**X**					**X**			
Lammers et. al (2008)	**X**		**X**						
Lemke and Valle Zárate (2008)	**X**				**X**			**X**	
Ohlman and Jones (2008).		**X**				**X**			
Balogh et al. (2009)		**X**						**X**	
Rutten-Ramos, and Deen (2009)	**X**							**X**	
Houska et al. (2010)	**X**					**X**			
Aramyan et al. (2011)		**X**							**X**
Ezcurra-Ciaurriz and Plà-Aragonès (2011)	**X**			**X**					
Bernard et al. (2012)	**X**				**X**				
Bono et al. (2012)	**X**								**X**
Hermesch et al. (2012)	**X**		**X**						
Rodríguez-Sánchez et al. (2012)	**X**					**X**			

Berevoianu et al. (2013)	X					X			
Khamjan et al. (2013)		X	X						
Seddon et al. (2013)	X		X						
Nadal-Roig and Plà (2014)	X				X				
Wen-cong et al. (2014)	X					X			
Gonzalez-Pena et al. (2015)	X		X			X	X		
Mbuthia et al. (2015)	X		X			X		X	
Nadal-Roig and Plà (2014)		X						X	

3.6 Output available

Twenty three works developed economic models and twenty eight technical and economic models. Two models (Aramyan et al., 2011 and Krieter, 2002) showed economic and environmental outputs. Finally Wen-cong et al. (2014) showed economic, technical and environmental outputs. This reveals a lack of models taking into account economic and environmental outputs.

Table 8. Model classified by outcome available.

Author	**Outcome available**		
	Economic	**Technical**	**Environmental**
Kroes and Van Male (1979)	X	X	
Greene and Eidman (1980)	X		
Tess et al. (1983)	X	X	
Dijkhuizen et al. (1986)	X		
Macbeth and McPhee (1986)	X	X	
Singh (1986)	X	X	
Pettigrew et al. (1987)	X	X	
Houben et al. (1990)	X	X	
Faust et al. (1992)	X		
Jalvingh et al. (1992)	X	X	
Boland et al. (1993)	X	X	
Huirme et al. (1993)	X	X	
Backus et al. (1995)	X		
den Ouden, et al. (1997a, 1997b)	X	X	

Kure (1997)	**X**	**X**	
Udovc (1997)	**X**		
Meuwissen et al. (1999)	**X**		
Bailleul et al. *(2000)*	**X**	**X**	
Dhuyvetter (2000)	**X**		
Krieter (2002)	**X**		**X**
Majewski et al. (2002)	**X**		
Søllested and Kristensen (2002)	**X**	**X**	
Li et al. (2003)	**X**		
Plà et al. (2003)	**X**	**X**	
Stalder et al. (2003)	**X**	**X**	
Zonderland and Enting (2003)	**X**	**X**	
Happe et al. (2004)	**X**	**X**	
Kristensen and Søllested, (2004)	**X**	**X**	
Brumm et al. (2005)	**X**		
Odening et al. (2005)	**X**		
Niemi (2006)	**X**	**X**	
Reimer (2006)	**X**		
Rodriguez-Zas et al. (2006)	**X**	**X**	
Ferguson (2008)	**X**	**X**	
Lammers et. al (2008)	**X**		
Lemke and Valle Zárate (2008)	**X**		
Ohlman and Jones (2008).	**X**	**X**	
Balogh et al. (2009)	**X**	**X**	
Rutten-Ramos, and Deen (2009)	**X**	**X**	
Houska et al. (2010)	**X**	**X**	
Aramyan et al. (2011)	**X**		**X**
Ezcurra-Ciaurriz and Plà-Aragonès (2011)	**X**		
Bernard et al. (2012)	**X**		
Bono et al. (2012)	**X**	**X**	
Hermesch et al. (2012)	**X**		
Rodríguez-Sánchez et al. (2012)	**X**	**X**	
Berevoianu et al. (2013)	**X**		

Khamjan et al. (2013)	X		
Seddon et al. (2013)	X		
Nadal-Roig and Plà (2014)	X		
Wen-cong et al. (2014)	X	X	X
Gonzalez-Pena et al. (2015)	X		
Mbuthia et al. (2015)	X	X	
Nadal-Roig and Plà (2015)	X		

4 Economic studies focused on individual swine producer other than economic models

Along the revision process, we had found papers dealing with other economic studies out of the scope of the present review. However, we judged the interest of this economic studies where the modelling technique or the relevance in the economic analysis of the individual producer. These papers were concerned in individual swine producer. Major characteristics of other economic studies are listed and presented in Table 9. Most of these studies showed economic results (Adegbite et al., 2010; Argilés Bosch and García Blandón, 2011; Baxter et al., 2011; Dial et al., 2007; Hermann et al., 2014; Heshmati et al., 1995; Kralik et al., 2006; Mbaso and Kamwana, 2013). These eight papers are not economic models. Pomar et al. (1991) shows only technical calculations, but indicates that economic efficiency may also be evaluated by adding monetary costs and values to the appropriate model input and output variables. Yuan et al. (2008) showed only technical results although presented a bio economic computer model to simulate biological and economic inputs and outputs. Pomar et al. (1991) and Yuan et al. (2008) are two models excluded from the scope of the review because they not calculated economic results.

As shows Table 9 two papers applied simulation approach and two papers developed a study based in a stochastic frontier production. The rest of the papers applied several techniques.

Table 9. Characteristics of other economic studies.

Paper / book / study	Main objective	Modelling technique	Publication	Country origin	Economic result
Pomar et al. (1991)	A dynamic herd simulation model for a swine production unit has been developed.	Simulation model	Journal of Animal Science	Canada	Economic efficiency may also be evaluated
Heshmati et al (1995)	Investigate the issues of technical efficiency, technical changes and bias in technical change in the Swedish pork industry.	A panel data and a stochastic frontier production model	European Journal of Operational Research	Sweden	Efficiency
Kralik et al. (2006)	Determines economic possibilities and to evaluate results of production systems, justifying their economic and social aspects.	Calculation of incomes and costs	Conference	Croatia	Profit
Dial et al. (2007)	Discusses how to establish financial information systems and report financial performance data for the benefit of the external stakeholders, which as stated above, often also includes owners.	Calculation of incomes and costs	Advances in Pork Production	USA	Several economic results
Yuan et al. (2008)	A bio economic computer model was constructed to simulate biological and economic inputs and outputs for life cycle swine production.	Simulation model	International Federation for Information Processing	China	--
Adegbite et al. (2010)	Examine the efficiency of pig production among government-assisted and non-assisted farmers in Lagos State, Southwest, and Nigeria.	Descriptive, budgetary and econometric (Stochastic Production Frontier) methods	Journal of Humanities, Social Sciences and Creative Arts	Nigeria	Net Farm Income and Gross Margin
Argilés Bosch and García Blandón (2011)	An empirical analysis, using a sample of farms, on the influence of size on cost behaviour under operational and tactical flexibility.	Cobb Douglas function and linear regressions	Estudios de Economía	Spain	Cost
Baxter et al. (2011)	Evaluate how well these farrowing systems meet the biological needs of the sow and her piglets. Furthermore, the physical and financial performances of these systems are summarised to present a balanced evaluation of alternative farrowing accommodation.	Welfare design index (WDI)	Animal	United Kingdom	Cost
Mbaso and Kamwana (2013)	Compares the profitability of three pig production systems; (1) feeder-pig system, (2) pig-finishing system and (3) farrow-to-finish system.	Calculation of incomes and costs	Livest Res Rural Develop	Malawi	Profits, returns on investment and breakeven points
Hermann et al. (2014)	Experimentally investigate and compare the investment behaviour of organic and conventional hog farmers. Examines the question of whether the investment behaviour depends on the framing of the investment possibility as organic or conventional.	An hypotheses is tested using a computer-based experiment	Conference	German	% Investment decisions

5 Discussion and outlook

This review analyses the strengths and weaknesses of published economic models of sow farms systems to support farmers in redesigning their whole systems. It is a first step towards building more efficient tools to help farmers to switch towards more sustainable farming systems. Although there are some reviews done by previous researchers regarding, there is no review focused on economic models that represent the activity of the rearing farm, sow farm or fattening farm.

Different conclusions can be drawn from the previous review. A first finding that can be drawn from the reviewed papers is that an enormous variation in structure is observed.

A second finding is that the number of strategic models in the swine industry is still very limited (50% of the models). The strategic models consider production or housing system, pig genotypes, integration contracts, pork supply chain and investment decisions.

Among the papers revised, most of them were focused in tactical and/or operational decisions. As the second component of production cost is the replacement of sows, most of tactical model considered sow herd dynamics.

Regarding modelling techniques and mathematical methods, simulation is the most dominant technique. As show Plà (2007), simulation models are well suited to dealing with the variability and complex nature of livestock production. 43% of the models use stochastic approximation and 57% of the papers us a deterministic approach. Most of the papers preferred static approach as modelling technique (56% of the models).

On the other hand, research projects dealing with economic models produce papers usually published in agricultural journals (70% of the models).

If we pay attention of the year of publication, clearly, the interest in economic models for swine producers is rather recent. As a consequence, the increment in references is expected to increase even more in the following years.

Most of papers were developed in standard software (69% of the models). Only seven models are developed in spreadsheet. A model develop in spreadsheet is easy to use for a pig farmer. In addition, the study reveals a lack of models developed in commercial software (i.e. spreadsheet).

A scarce literature related to the farm and other supply chain agent economic models is found (24% of the models). Economic measures are very different between the models. Although the common measures available of the papers were return (twelve models), profit (twelve works) and cost (eleven works). Twenty three works developed economic outputs specifically and only three models show economic and environmental outputs. This reveals a lack of models taking into account economic and environmental outputs.

Countries where pig farming is a very important sector like USA and The Netherlands have developed more models.

Along the revision process, we had found papers out of the scope of the present review. However, we considered the interest of these nine economic studies. Most of these studies showed economic results but were not economic models.

We advocate including farmers in the conceptual modelling process, using a participatory approach. To better support the sow farmers in their redesign processes, such conceptual models should be conceived at the farm scale and take the long term into account.

5 References

Adegbite, D.A., Okuneye, P.A., Adebambo, A.O., Odu, O., Shittu, A.M. and Adewuyi, S.A., 2010. Comparative analysis of production efficiency of government assisted and unassisted pig farmers in Lagos State. J. Hum. Soc. Sci. Crtv. Arts, 5(1), 1-16.

Aramyan, L.H., Hoste, R., van den Broek, W., Groot, J. , Soethoudt, H., Nguyen, T.L.T. , Hermansen, J. E. and van den Vorst, J.G.A.J., 2011. Towards sustainable food production: a scenario study of the European pork sector. Journal on Chain and Network Science, 11(2), 177-189.

Argilés Bosch, J. M. and García Blandón, J., 2011. The influence of size on cost behaviour associated with tactical and operational flexibility. Estudios de Economía. Vol. 38, N. 2, 419-455.

Backus, G.B.C., Timmer, G.T., Dijkhuizen, A.A., Eidman, V.R. and King, R.P., 1995. The impact of a decision support system for strategic pig farm planning on the advice of extension officers. Computers and Electronics in Agriculture, Volume 12, 1, 51-64 (14).

Backus, G. and Dijkhuizen, A.A., 2002. Kmkamp lecture: The future of the European pork chain. Allen d. Leman Swine Conference, Minessota, USA, 8-11.

Bailleul, P. J., Bernier, J.F., van Milgen, J., Sauvant, D. and Pomar, C., 2000. The utilization of prediction models to optimize farm animal production systems: the case of a growing pig model. Modelling nutrient utilization in farm animals, 379-392.

Balogh, P., Ertsey, I., Fenyves, V. and Nagy, L., 2009. Analysis and optimization regarding the activity of a Hungarian Pig sales and Purchased Cooperation. Studies in Agricultural Economics 109, 35-54.

Baxter, E.M., Lawrence, A.B. and Edwards, S.A., 2011. Alternative farrowing accommodation: welfare and economic aspects of existing farrowing and lactation systems for pigs. Animal, 6:1, 96–1.

Berevoianu, R., Cofas, E. and Vlad, C.M., 2013. Computer model used to calculate profitability and economic risk of farms. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 13, Issue 4.

Bernardi, F., Winckler, C., Eder, M. and Leeb, C., 2012. Economic evaluation of "Animal Health and Welfare Planning" on organic pig farms in Austria. Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie, Band 21(1), 135-143.

Boland, M.A., Preckel, P.V. and Schinckel, A.P., 1993. Optimal Hog Slaughter Weights Under Alternative Pricing Systems. Journal of Agricultural and Applied Economics, Volume 25, Issue 02 , 148-163.

Bono, C., Cornou, C. and Kristensen, A.R., 2012. Dynamic production monitoring in pig herds I: Modeling and monitoring litter size at herd and sow level. Livestock Science, 149, 289–300.

Brossard, L. and Montagne, L., 2012. Overview of pig production in the European Union. CAPES-COFECUB n° Sv 687/10, Brazil, October 2012.

Brumm, M., Burh, B., Holtkamp, D. and Kliebenstein, J., 2005. Economic Analysis of Pig Space: Comparison of Production System Impacts. Identification Number: 04177.

den Ouden, M., Nijsing, J.T., Dijkhuizen, A.A. and Huirme, R..B.M., 1997 a. Economic Optimization of pork production-marketing chains: I. Model input on animal welfare and cost. Livestock Production Science 48, 23-37.

den Ouden, M., Huirme, R..B.M., Dijkhuizen, A.A. and van Breek, P., 1997 b. Economic Optimization of pork production-marketing chains: I. Model outcome. Livestock Production Science 48, 39-50.

Dent, J.B. and Blackie, M.J., 1979. Systems Simulation in Agriculture. Applied Science Publishers, London.

Dhuyvetter, K.C., 2000. Attrition and Gilt Replacement: What does attrition cost and what is it worth to reduce? Pages 110-116 in Proc. Allen D. Leman Swine Conf., College of Vet. Med., Univ. Minnesota, St. Paul.

Dial, G.D., Roker, J.R. and McWilliams, S.A., 2007. Financial Management of Pig Businesses: Making Your Lenders, Investors & Partners Comfortable with Your Business Plans. Advances in Pork Production, Volume 18, 277.

Dijkhuizen, A. A., Morris, R.S. and Morrow, M., 1986. Economic optimization of culling strategies in swine breeding herds, using the "PorkCHOP computer program." Preveventive Veterinary Medicine, 4, 341-353.

European Commission, 2015 a. http://ec.europa.eu/agriculture/pigmeat/index_en.htm (last access March 17th, 2015).

European Commission, 2015 b. Committee for the Common Organisation of the Agricultural Markets 17 September 2015. http://agricultura.gencat.cat/web/.content/de_departament/de02_estadistiques_observatoris/11_sectors_agraris/sectors_ramaders/porci/fitxers_estatics/2015_porci.pdf (last access October 1st, 2015).

Ezcurra-Ciaurriz, X. and Plà-Aragonés, L.M., 2011. AnaporkKDSS: a decision support system to evaluate pig production economics. Proyecto Social: Revista de Relaciones Laborales, 14, 23-44.

Faust, M.A., Robinson, O.W. and Tess, M.W., 1992. A bioeconomic simulation model for a hierarchical swine breeding structure. Journal Animal Science, 70, 1760.

Ferguson, N.S., 2008. Application of an Integrated Management System to Improve Performance and Profitability in Finishing Pigs. Advances in Pork Production. Volume 19, 85.

Gonzalez-Pena, D. Knox, R.V. and Rodriguez-Zas, S.L., 2015. Contribution of semen trait selection, artificial insemination technique, and semen dose to the profitability of pig production systems: A simulation study. Theriogenology (article in press), 1-10.

Greene, D.D. and Eidman, V.R., 1980. An economic analysis of three confinement feeder pig production systems. Station Bulletin 534.

Grossman, S. and Hart, H., 1986. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. Journal of Political Economy, 691-719.

Happe, K., Balmann, A. and Kellermann, K., 2004.The agricultural policy simulator (AgriPoliS): an agent-based model to study structural change in agriculture (Version 1.0), Discussion paper // Institute of Agricultural Development in Central and Eastern Europe, No. 71, http://nbn-resolving.de/urn:nbn:de:gbv:3:2-22538.

Hermann, D., Musshoff, O. and Agethen, K., 2014. I will never switch sides: an experimental approach to determine drivers for invest decisions of conventional and organic hog farmers. EAAE 2014. Congress "Agri-Food and Rural Innovations for Healthier Societies". Ljubljana, Slovenia.

Hermesch, S., Ludemann, C. and Amer, P. R., 2012. PigEV–a new tool to derive economic values for pigs. AGBU Pig Genetics Workshop – October 2012.

Heshmati, A., Kumbhakar, S.C. and Hjalmarsson, L., 1995. Efficiency of the Swedish pork industry: A farm level study using rotating panel data 1976-1988. European Journal of Operational Research, 80, 519-533.

Houben, E.H.P., Thelosen, J.G.M., Huirne, R.B.M., and Dijkhuizen A.A., 1990. Economic comparison of insemination and culling policies in commercial sow herds, assessed by stochastic simulation. Netherlands Journal of Agricultural Science, 38, 201-204.

Houska, L., Wolfoga, M., Nagy, I., Csornei, Z. and Komlósi, I., 2010. Economic values for traits of pigs in Hungary. Czech J. Anim. Sci., 55, 2010 (4), 139–148.

Huirme, R.B.M., 1990. Computerized management support for swine breeding farms. Ph.D. dissertation. Department of Farm Management, Wageningen Agricultural University, Wageningen, The Netherlands.

Huirme, R.B.M, Dijkhuizen, A.A., van Beek, P. and Hendriks, TH.H.B., 1993. Stochastic dynamic programming to support sow replacement decisions. European Journal of Operational Research, Volume 67, Issue 2, 161-171.

Jalvingh, A.W., Dijkhuizen, A.A., Huirme, R.B.M. and van Arendonk, J.A.M., 1992. Dynamic probabilistic modelling of reproduction and replacement management in sow herds. General aspects and model description. Agricultural Systems, 39, 133-152.

Jalvingh, A.W., 1992. The possible role of existing models in on-farm decision support in dairy cattle and swine production. Livestock Production Science, 31 (1992), 351-365.

Kamp, J.A.L.M., 1999. Knowledge based systems: from research to practical application. Pitfalls and critical success factors. Computers and Electronics in Agriculture 22, 243-250.

Kaplan, R.S., Norton, D.P. and Barrow, E.A. Jr., 2008. Developing the Strategy: Vision, Value Gaps, and Analysis. Palladrum. Article Reprint No. B0801A. BALANCED SCORECARD. COLLABORATIVE. HARVARD BUSINESS SCHOOL PUBLISHING.

Kralik, G., Toluši ć , Z., Margeta, V., Kralik ć L. and Gajčević, Z., 2006. Analysis of Pig Meat Production With Respect to Different Housing Systems of Pigs. 98 th EAAE Seminar 'Marketing Dynamics within the Global Trading System: New Perspectives', Chania, Crete, Greece.

Krieter, J., 2002. Evaluation of different pig production systems including economic, welfare and environmental aspects. Archiv fur Tierzucht, 2002, vol. 45, no 3, 223-236.

Kristensen, A.R., 1993. Markov decisions techniques applied to the animal replacement problem. Dr. Sc. Dissertation Dina KVL. Dep. of Animal Science and Animal Health. The Royal Veterinary and Agricultural University. Copenhagen. Denmark.

Kristensen, A.R. and Søllested, T.H., 2004. A sow replacement model using Bayesian updating in a three-level hierarchic Markov process: II. Optimization model. Livestock Production Science, 87, 25–36.

Kroes, Y. and Van Male, J.P., 1979. Reproductive lifetime of sows in relation to the economy of production. Livest. Prod. Sci. 6, 179-183.

Kure, H., 1997. Marketing Management support in slaughter pig production. Ph.D. dissertation. Departament of Animal Science and Animal Health, The Royal Veterinary and Agricultural University, Copenhagen.

Lammers, P.J., Honeyman, M.S., Kliebenstein, J.B. and Harmon, J.D., 2008. Impact of gestation housing system o weaned pig production cost. Applied Engineering in Agriculture, Vol. 24(2), 245-249.

Legay, J.M., 1997. L'experience et le modele: Un discours sur la methode. INRA Editions, Paris.

Lemke, U. and Valle Zárate, A., 2008. Dynamics and developmental trends of smallholder pig production systems in North Vietnam. Agricultural Systems, vol. 96, issue 1-3, 207-223.

Majewski, E., Hinners-Tobrägel, L., Straeszewski, S. and Was, A., 2002. Polish Agriculture under Different Policy Scenarios: Impacts on Production and Farm Income. Agrarwirtschaft 51, Heft 8.

Macbeth, G.M. and McPhee, C.P., 1986. An Economic Evaluation of Breeding Systems with Selection and Crossing of Large White and Landraee Pigs in a Closed Herd. Agricultural Systems, 20, 219-239.

Mbaso, M. and Kamwana, B., 2013. Comparative analysis of profitability among feeder-pig, pig-finishing, and farrow-to-finish production systems under the Smallholder Improvement Management System in Ntcheu District of Central Malawi. Livest Res Rural Develop 25.10.

Mbuthia, J.M., Rewe, T.O. and Kahi, A.K., 2015. Breeding objectives for pigs in Kenya. I: Bio-economic model development and application to smallholder production systems. Trop Anim Health Prod, 47, 299–309.

Meuwissen, M.P.M., Horst, S. H., Huirne, R. B.M and Dijkuizen, A. A., 1999. A model to estimate the financial consequences of classical swine fever outbreaks: principles and outcomes. Agricultural Systems. Volume 42, Issues 3–4, 249–270.

Nadal-Roig, E. and Plà, L.M., 2014. Multiperiod planning tool for multisite pig production systems. Journal Animal Science, 4154–4160.

Nadal-Roig, E. and Plà, L.M., 2015. Optimal Planning of Pig Transfers Along a Pig Supply Chain. Chapter Handbook of Operations Research in Agriculture and the Agri-Food Industry Volume 224 of the series International Series in Operations Research & Management Science, 1-18.

Niemi, J. K., 2006. A dynamic programming model for optimising feeding and slaughter decisions regarding fattening pigs. Agricultural and Food Science. Vol. 15: Suplement 1.

Odening, M., Mußhoff, O. and Balmann, A, 2005. Investment decisions in hog finishing: an application of the real options approach. Agricultural Economics. Volume 32, Issue 1, 47–60.

Ohlman, J.W. and Jones, P.C., 2008. An integer programming model for optimal pork marketing. Annals Operations Research, ISSN 1572-9338.

Perez, C., de Castro, R,. Simona, D. and Jiménez, G., 2010. Development of lean supply chains: A case study of the Catalan pork sector. Supply Chain Management, 11, 271-280.

Pettigrew, J.E., Cornelius, S.G., Eidman, V.R. and Moser, R.L., 1987. Integration of factors affecting sow efficiency: a modeling approach. Journal of Animal Science, 63, 1314-1321.

Plà, L.M., 2007. Review of mathematical models for sow herds management. Livestock Science, 106, 107-119.

Plà, L.M., Pomar, C. and Pomar, J.,2003. A Markov decision sow model representing the productive livespan of herd sows. Agricultural Systems, 76, 253-272.

Pomar, C., Harris, D.L., Savoie, P. and Minvielle, F., 1991. Computer simulation model of swine production systems: III. A dynamic herd simulation model including reproduction. Journal of Animal Science, 69, 2822-2836.

Reimer, J.J., 2006. Vertical integration in the pork industry. Amer. J. Agr. Econ. 88(1) (February), 234–248.

Rodríguez-Sánchez, S. V., Plà-Aragonés, LL. M. and Faulin, J., 2010. Spanish Pork supply chain context. Thesis.

Rodríguez-Sánchez, S. V., Plà-Aragonés, LL. M. and Albornoz, V. M., 2012. Modeling tactical planning decisions through a linear optimization model in sow farms. Livestock Science. Volume 143, Issues 2–3, 162–171.

Rodriguez-Zas, S.L., Davis, C.B., Ellinger, P.N., Schinitkey,G.D., Romine, N.M., Conner, J.F., Knox, R.V. and Sothey, B.R., 2006. Impact of biological and economic variables on optimal parity for replacement in swine breed-to-wean herds. J. Anim. Sci. 84, 2355-2565.

Rutten-Ramos, S. and Deen, J., 2009. An investigation of the success of production-based sow renoval and replacement in the context of herd performance. Journal of Animal Science, 1794-1800.

Spedding, C.R.W., 1988. An Introduction to Agricultural Systems. Elsevier, London.

Seddon, Y.M., Cain, P.J. and Guy, S.A., 2013. Development of a spreadsheet based financial model for pig producers considering high welfare farrowing systems . Livestock Science 157, 317–321.

Singh, D., 1986. Simulation of Swine Herd Population Dynamics. Agricultural Systems, 22, 157-183.

Søllested, T.A. and Kristensen, A.R., 2002. A Sow replacement model using Bayesian updating in a 3 level hierarchic Markov process http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.296.7155&rep=rep1&type=pdf (last access November 13th, 2015).

Stalder, K.J., Lacy, C., Cross, T.L. and Conatser, G.E., 2003. Financial impact of average parity of culled females in a breed-to-wean swine operation using replacement gilt net present value analysis. J. Swine Health Prod. 11, 69-74.

Tess, M.W., Bennet, G.L. and Dickerson, G.E., 1983. Simulation of genetic changes in life cycle efficiency of pork production. I. A bioeconomic model. Journal of Animal Science 56, 336-353.

Triekens, J., Petersen, B., Wognum, N. & Brinkmann, D., 2009. European por chains. Wagening Academic Publishers, 285pp.

Udovc, A., 1997. The decisions support system KMETIJA-A tool to help farmers at production-economic decision-making. First European Conference for Information Technology in Agriculture. The Royal Veterinary and Agricultural University Copenhagen, Denmark, 15–18 June 1997.

Wen-cong, L., Yong-xi, M.A. and Bergmann, H., 2014. Technological Options to Ameliorate Waste Treatment of Intensive Pig Production in China: An Analysis Based on Bio-Economic Model. Journal of Integrative Agricultura, 13(2), 443-454.

Yuan, H. , Xia, S. , Wang, Q. and Wu, K., 2008. A bioeconomic model by quantitative biology to estimate swine production. IFIP International Federation for Information Processing. Volume 258, 667-675.

Zonderland, J. J. and Enting, J., 2003. The Pig Farm Manager for modelling pig production systems. International Farm Management Congress. Research Institute for Animal Husbandry, Lelystad, Netherlands.

Chapter 3

Technical efficiency of sow farms: a parametric and non-parametric approach

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Abstract

Pig production is very important in Spain and increasing competition has led the pig industry to look for ways of improving the efficiency of the production process. This chapter presents the analysis of technical efficiency in sow farms vertically integrated into the same company comparing parametric and non-parametric approaches. Empirical data from 96 Spanish sow farms classified into two groups depending on the final product, that is, farms producing weaned piglets (FPP) or feeder pigs (FPFP) were available. The results for the stochastic frontier production function for feeder pigs and weaned piglets exhibit problems related to multicolinearity. Even though, the observed trends of technical efficiencies calculated from both approaches were consistent. The results revealed considerable efficiencies in this study being FPP more efficient that FPFP (0.99 vs 0.87 with the parametric approach, and 0.93 vs 0.91 with VRS-DEA model). Scale efficiency was also very high showing that 58% of FPP and 45% of FPFP are small farms in which efficiency gains would be expected by increasing the size. In addition, farm-specific factors affecting productive inefficiencies from CRS-DEA and VRS-DEA models were explored using a Tobit model. The output, number of sow, feed consumed and artificial insemination were the variables showing significant coefficients at the 5% level. Finally, the efficiency measures presented in this study are similar to other European studies and demonstrate the higher technical efficiency of the pig sector in Spain.

Keywords: technical efficiency; sow farms; scale efficiency; stochastic production frontier.

1.1 Introduction

The importance of pig production for the Spanish economy is reflected by recent agricultural statistics for Spain's swine industry. The sector contributes 15% of the Final Agricultural Product and accounts for 35% of the total economic value of the country's livestock production. Pork is the main meat consumed in Spain (60 kg/person/year); 55% of total meat consumption. Moreover, after Germany, Spain is the second largest pig producer in the European Union (EU).

Due to recent EU regulation of pig farms and continuous growth of the census, there has been increasing concern about the measurement and comparison of the technical efficiency of different Spanish sow farms. Vertical integration is more and more common in the sector, concentrating production in few hands. Private companies and cooperatives play the role of the so-called integrators (Rodriguez et al., 2014). This integration leads to base production on different farms owned by the same integrator. Hence, identify the best practices among farms to increase technical efficiency is crucial for either farmers or integrators. The future of swine producers integrated or not, will depend on their ability to enhance their economic performance by improving productive efficiency rather than increasing farm size. The current literature on livestock production contains several studies of the efficiency of dairy farms (Cloutier and Rowley, 1993; Reinhard et al., 1999; Jaforullah and Whiteman, 1999; Hansson and Öhlmer, 2008), sheep farms (Gaspar et al., 2008; Ripoll-Bosch et al., 2012; Theodoridis et al., 2012) and extensive livestock farming (Gaspar et el., 2009), but fewer for sow farms (Galanopoulos et al., 2006). Moreover, hardly any economic studies have been undertaken on Spanish swine farms, which is strange given the importance of the sector in Spain.

Pig farming in Spain could be divided in three different phases according to final product and different economic activities. The first one relates to farms producing piglets, the second one to producing feeder pigs and the third one to producing fattened pigs. Integrators own more than one sow farm and also several rearing and fattening farms. However it is common to host the second phase in a sow farm generating two types of sow farms: those producing piglets or producing feeder pigs. Less and less common are the farrowing-to-finish farms embracing all the phases. The foundation of the economic activity relies on good herd management practices in sow farms which are much more complicated compared to the management of the other pig farms (Rodriguez et al., 2014). In this context it is reasonable that companies owning several sow farms are wondering about the efficiency of their farms and detecting the ones more efficient to be taken as a reference. Hence, for the purposes of this study, we consider a sow farm to be a farm that houses sows and that produce as output either weaned piglets or feeder pigs. Inputs include reproductive sows, concentrates and labour, etc. Different farms tend to organise their operations in different ways, so consequently values for individual outputs will also tend to differ, even if they are integrated under the same company. There is therefore a special interest in comparing different sow farms and highlighting efficient practices, in order to identify a best-practice sow farm group. This group of farms could then be used as a point of reference for less efficient units and for benchmarking performance. As observed by Weersink et al. (1990), identifying possibilities for improving efficiency should help to enhance the profitability of farms and make the pig industry more competitive. The existence of an official record keeping system (the BD-porc®, 2013), which registers the main controllable variables on a Spanish farm, allows us to select the inputs and outputs registered by farm basis to calculate efficiency and perform subsequent improvements.

The simplest way of measuring technical efficiency; the pure relationship between input and output as such, is often inadequate due to the existence of multiple inputs and outputs relating to different resources, activities and environmental factors. A variety of techniques have been proposed to study the efficiency overcoming this inconvenient. For instance, the measurement of relative efficiency where there are multiple possibly incommensurate inputs and outputs was early addressed by Farrell (1957) and developed by others in the 1960s and early 1970s. The method is focusing on the construction of a hypothetical efficiency frontier of a firm to compute efficiency measures relatives to this reference firm. Most of the papers related to the measurement of productive efficiency have based their analysis either on parametric or non parametric methods. The choice of estimation method has been being an issue of debate, and some researchers prefer parametric approach (e.g. Berger, 1993) and other the non-parametric approach (Banker et al., 2004). Parametric frontier functions require the definition of a specific functional form for the function of production meanwhile DEA does not distinguish between technical efficiency and statistical noise effects avoiding the need to assume functional relationship between inputs and outputs. The aim of this chapter is to analyse the technical efficiency of Spanish sow farms comparing parametric and non-parametric approaches. In addition, several technical indexes used regularly for sow herd management will be explored as explanatory variables for efficiency scores. Therefore, the present chapter is structured as follows; in the next section an overview of both approaches is presented. Sow farm data used in this analysis are presented in Section 3. This is followed by some results and conclusions, in Sections 4 and 5 respectively. Finally, the chapter concludes with a brief outlook of the subject in Section 6.

2 Methodology

2.1 Parametric Approach

The parametric approach requires the definition of a specific functional form for the technology and for the inefficiency error term, using mathematical programming or econometric techniques. It can be subdivided into deterministic and stochastic models. Deterministic models envelope all the observations, identifying the distance between the observed production and the maximum functions, defined by the frontier and the available technology, as technical inefficiency. On the other hand, stochastic approaches allow distinguishing between technical efficiency and statistical noise.

Farrel (1957) suggested the use of functional forms in the estimation of production functions. Aigner and Chu (1968) were the first ones to estimate a parametric frontier, adjusting a Cobb-Douglass function and imposing the non-negativity of the error terms. The model was:

$$Y_i = \alpha + \sum_{j=1}^{r} \beta_j X_{j,i} + V_i - U_i \quad (1)$$

where i=1, ….N indicates the units and j=1,….,r indicates de inputs, Y_i is output of the i-th firm, $X_{j,i}$ are productive factors used by the i-th firm, β is a vector of parameters to be estimated and V_i-U_i is the composed error term where V_i represents randomness (or statistical noise) and U_i represents technical efficiency. V_i are assumed to be independently and identically distributed $N(0,\sigma_i^2)$ random errors, independent of U_i, and U_i are nonnegative random variables associated with technical inefficiency production, which are assumed to be independent and identically distributes and truncations (at zero) the normal distribution with mean, μ and variance $\sigma_u{}^2$. It allows the definition of the likelihood functions and it gets estimators for β and variance parameters, $\sigma^2=\sigma_v{}^2+\sigma_u{}^2$ and $\gamma=\sigma_u{}^2/\sigma^2$. Subtracting V_i from both sides of Eq. (1) yields

$$\tilde{Y}_i = Y_i - V_i = \alpha + \sum_{k=1}^{r} \beta_k X_{k,i} - U_i \quad (2)$$

where $\tilde{Y}_i$ is the observed output of the i-th firm adjusted for the stochastic noise captured. For a given level of output $\tilde{Y}_i$, the technically efficiency input vector for the i-th firm, X_i^t is derived by simultaneous solving Eq. (2) and the input ratios $X_1/X_i=K_i$ (i>1), where K_i *is* the ratio of observed inputs X_1 and X_i

The measures of technical efficiency relative to the production frontier are defined as:

$$EFF_i = E(Y_i^*|U_i, X_i)/ E(Y_i^*|U_i=0, X_i), \quad (3)$$

where Y_i^* is the production of the i-th firm, which will be equal to Y_i when the dependent variable is in original units and will be equal to exp(Y_i) when the dependent variable is in logs. EFF_i will take a value between zero and one. The efficiency measures can be shown to be defined as (Jondrow et al., 1982; Battese and Coelli, 1988):

Logged Dependent Variable	Efficiency (EFF$_i$)
Yes	$Exp\ (-U_i)$
No	$(x_i\beta - U_i)/x_i\beta$

2.2 Non-parametric approach

Non-parametric approach doesn't require the specification of any particular functional form to describe the efficient frontier. In these circumstances, suppose that we have observations of *n* farms, each one transforming inputs into *m* outputs, efficiency of a target farm *j* can be expressed as:

$$rE_j = \frac{a_1 y_{1j} + a_2 y_{2j} + \ldots + a_m y_{mj}}{u_1 x_{1j} + u_2 x_{2j} + \ldots + u_s x_{sj}} = \frac{A^T \cdot y_j}{U^T \cdot x_j} \tag{4}$$

where rE_j is the relative efficiency for farm *j*

a_i is the weight given to output *i*, i= 1,2,…,m

y_{ij} is the amount of output *i* from farm *j*

u_i is the weight of input *i* from farm *j*, i= 1,2,…,s

x_{ij} is the amount of input *i* from farm *j*

The initial assumption is that this measure of efficiency requires a common set of weights to be applied across all sow farms. This immediately raises the problem of how such an agreed common set of weights can be obtained. It could be possible that a farm might value inputs and outputs differently and therefore adopt different weights, and consequently each farm should be allowed to adopt a set of weights which shows it in the most favourable light in comparison to the other farms. In that case relative efficiency of farm *j* respect to the set of *n* farms can be obtained by solving the following model:

$$\begin{aligned} &\textit{maximise } rE_j = \frac{A^T \cdot y_j}{U^T \cdot x_j} \\ &\textit{subject to}: \ \frac{A^T \cdot y_k}{U^T \cdot x_k} \leq 1; k = 1,\ldots,n \end{aligned} \tag{5}$$

where *n* represents the total number of farms involved in the analysis and the weights, *a*'s and *u*'s components of the vectors *A* and *U*, are treated as the decision variables of the problem. They could be constrained to be greater than or equal to some small positive quantity in order to avoid any input or output being totally ignored in determining the efficiency. The solution produces the weights most favourable to farm *j* and also produces a measure of efficiency, rE_j. If rE_j = 1 then farm *j* is efficient relative to the others but if rE_j turns out to be less than 1 then some other farm is more efficient than farm

j, even when the weights are chosen to maximise efficiency of farm j. These farms constitute the peer group for farm j. A peer group is a group of efficient farms that act as a reference for an inefficient one. Thus, an inefficient farm can identify and eliminate their less efficient practices by comparing to its peer group.

The model presented is a fractional linear program with infinite solutions when there exist. To solve the model it is first necessary to convert it into an equivalent linear form as Charnes et al. (1978) proposed. They were the first to develop the DEA approach based on the concept of technical efficiency of Farrel (1957). Hence, DEA is a linear programming technique that converts multiple inputs and outputs into a scalar measure of efficiency and it is extensively used in Economics and Operations Research (Seiford, 1996). The transformation of Eq. 5 into a linear model provides (Charnes et al., 1978):

$$\begin{aligned} & maximise\ A^T \cdot y_j \\ & subject\ to: \ A^T \cdot y_j - U^T \cdot x_k \leq 0; k = 1,\ldots,n \\ & \qquad U^T \cdot x_k = 1 \\ & \qquad A, U \geq 0 \end{aligned} \tag{6}$$

About the linear transformation applied in Eq. 5 we can remark that in maximising a fraction or ratio it is the relative magnitude of the numerator and denominator that are of interest and not their individual values. It is thus possible to achieve the same effect by setting the denominator equal to a constant and maximising the numerator.

For linear programs in general the more constraints the more difficult a problem is to solve. Hence the dual DEA model involves fewer constraints and uses to be simpler than primal and it is usual to solve it rather the than the primal. Following mathematical formulation corresponds to the dual model of the linear version of Eq. 6. Let η_j be the output oriented efficiency associated to farm j. Let Y=(y_j) be an (m×n) matrix of outputs for n Spanish sow farms with y_j representing the (m×1) vector of outputs for the jth farm. Let X=(x_j) be an (s×n) matrix of inputs with x_j representing the (s×1) vector of inputs for the jth farm and an (n×1) vector of weights to be defined. The linear version of the model is as follows:

$$\begin{aligned} & \eta_j = max_{\eta,\mu} \begin{pmatrix} 1 & 0_n^T \end{pmatrix} \begin{pmatrix} \eta \\ \mu \end{pmatrix} \\ & subject\ \ to: \begin{pmatrix} 0_m & \text{-}X \\ -y_j & Y \end{pmatrix} \begin{pmatrix} \eta \\ \mu \end{pmatrix} \geq \begin{pmatrix} -x_j \\ 0_s \end{pmatrix} \\ & \qquad \eta, \mu \geq 0 \end{aligned} \tag{7}$$

which assumes the existence of constants returns to scale (CRS). This assumption of the original model may be relaxed following Banker et al. (1984) by adding any of the constraints $\Sigma\mu_i$=1 for variable returns to scale (VRS) or $\Sigma\mu_i \leq 1$ for non-decreasing returns to scale (NDRS) (Banker et al., 1984; Färe et al., 1985; Lovell, 1994). Apart from output-oriented relative technical efficiency measure defined as in Eq. 7, input oriented measures can be also obtained:

$$\theta_j = min_{\theta,\lambda} \begin{pmatrix} 1 & 0_n^T \end{pmatrix} \begin{pmatrix} \theta \\ \lambda \end{pmatrix}$$
$$subject\ \ to: \begin{pmatrix} 0_s & Y \\ x_j & -X \end{pmatrix} \begin{pmatrix} \theta \\ \lambda \end{pmatrix} \geq \begin{pmatrix} y_j \\ 0_m \end{pmatrix} \tag{8}$$
$$\theta, \lambda \geq 0$$

where θ_j represents the input oriented efficiency associated to farm j and Eq. 8 assumes the existence of constants returns to scale (CRS). This assumption of the original model may be relaxed like in Eq. 7 by adding any of the constraints $\Sigma\mu_i=1$ for variable returns to scale (VRS) or $\Sigma\mu_i\leq 1$ for non-increasing returns to scale (NIRS). Input-oriented measures of inefficiency measure the potential reduction in inputs holding outputs constant. Alternatively, output-oriented measures of inefficiency measure the potential increase of outputs, holding inputs constant. We understand inefficiency as the complementary to one of the efficiency. Efficiencies are usually expressed in percentage terms. In this work we will focus on input oriented measures, then the θ represents a proportional reduction in all inputs ($0\leq\theta\leq 1$) and θ_j is the minimum value of θ for farm j. Maximum value for is one, and represents the farm operating at best-practice (given the existing set of observations). We will consider θ_j^c, θ_j^v and θ_j^n solutions for DEA models assuming CRS, VRS and NIRS respectively.

There are different methods of testing a farm's return to scale nature (Banker et al., 1984; Färe et al., 1985; Seiford and Zhu, 1999). We will use the scale efficiency index method provided by Färe et al., (1985) because is robust and simple. We assume no inefficiency due to input congestion, i.e. farms are subject to strong input disposability. The scale efficiency index measure for farm j can be calculated as:

$$S_j=\theta_j^c / \theta_j^v \tag{9}$$

If the value of the ratio is equal to unity then farm j is scale-efficient. This means that the farm is operating at its optimum size and hence that the productivity of inputs cannot be improved by increasing or decreasing the size of the sow farm. The VRS model ensures that a farm is only compared to other farms of a similar size (Fraser and Cordina, 1999).

If not and $\theta_j^c = \theta_j^n$ then the results suggest that scale inefficiency is due to increasing returns to scale. This means that the farmer can improve the productivity of inputs by increasing the farm size. Or when $\theta_j^c < \theta_j^n$ then the results suggest that scale inefficiency is due to decreasing returns to scale. This means that the farm is bigger than its optimum size.

2.3 Explanatory variables

Following the two-step approach (Coelli, 1998) different explanatory variables were proposed to estimate inefficiency scores. First estimates of relative efficiencies using the inputs and outputs are calculated. Second the effect of different variables on efficiency is analysed. Apart all the inputs and output, other exogenous variables as piglet mortality, culling rate, litter size, piglets alive and farrowings per sow per year were considered. Since the inefficiency scores are censored, values between zero and one, a Tobit model is proposed:

$$\text{Ineff}^*_k = \alpha + \beta z_k + \varepsilon_k$$

$$\text{Ineff}_k = \begin{cases} \text{Ineff}^*_k \text{ if } \text{Ineff}^*_k > 0 \\ 0 \text{ otherwise} \end{cases}$$

Where Ineff^*_k represents the latent variable related to the inefficiency scores and is a dependent variable not censored. Ineff_k is the censored variable defined by the DEA efficiency scores; z is a vector of independent explanatory variables related to the k-farm, α is the constant term; β is the vector of parameters to be estimated and ε is the statistical noise, normally distributed with mean zero.

3 Sow farm data

An initial sample of 193 sow farms from the north-east of Spain was considered. It is the main pig producing area of Spain (around 2% of the national surface area concentrates 15% of total national production). The farms belonged to the same pig supply chain and data is recorded in the main swine data bank of Spain (BD-porc®), which is promoting a new extension program to encourage pig industry economists to complement economic analysis with efficiency studies. The farms were classified into two groups according to their final product: piglets or feeder pig. Homogeneity was considered from the perspective of both sow farms (belonging to the same company) and the common environment. This meant that observed differences in technical efficiency would be the result of managerial ability. A filtering process was performed, and several farms were rejected because of problems associated with previous health care problems (e.g. classical swine fever and Aujersky disease), different production systems, geographical situation, and recent initiation in the activity or outliers detected by statistical analysis. If a farm reported unreasonable values, or values more than two standard deviations from the mean, it was eliminated from the data set. Hadi's (1992, 1994) method for identifying and removing multiple outliers was also used. Hence, only 96 farms from the initial sample were finally considered. The reasons for rejecting the other 97 farms were: incomplete economic data (64), inconsistencies in data (9) and outliers (24). The farms used in the study included 45 producing piglets (average weight 5.8 kg per piglet sold) and 51 producing feeder pigs (average weight 18.7 kg per feeder pig sold) respectively. Data relating to these farms are shown in Table 1 and 2. The period analysed was 1st January to 31st December 2006

The choice of variables was constrained by the availability of data registered with the BD-porc® data-bank, economic data provided by the company and protocols suggested by Dyson et al. (2001) for avoiding pitfalls in the use of DEA. It was assumed that sow farms produced one output: weaned piglets or feeder pigs. The two outputs are different in age and weight. Weaned piglets are from three to four weeks-old with a weight of around 7 kg whilst feeder pigs are from four to six weeks older and weighting between 15 to 20 kg. Depending on the activity, seven or eight inputs were considered: labour working in the farm, both salaried and family workers, average number of breeding sows, feed consumed by sows, veterinary expenses, other expenses (water, fuel, electricity, repairs, etc.), feed consumed by piglets (FeedWP) and/or feeder pigs (FeedS) and number of inseminations (AI). It was difficult to measure labour because the registered data was not introduced in the same way for all farms. Labour was therefore expressed in terms of equivalent workers (1920 h/year). Tables 1 and 2 summarise statistics on inputs and outputs for each group of farms considered. Sow farms producing piglets (FPP) produced more units, i.e. piglets, than farms producing feeder pigs (FPFP). The size of the farm, in terms of its number of sows, was also bigger. This seems logical considering both the shorter productive cycle for FPP and the greater value per unit produced by the second as opposed to the first group. Data presented in Tables 1 and 2 make it possible to calculate several sow-related ratios. Some of these ratios are similar for both groups of farms, for instance kg of feed consumed per sow (1065 kg for FPP and 1080 kg for FPFP) and the number of inseminations per sow (7.51 for FPP and 7.52 for FPFP).

Table 1. Summary of variables for DMUs producing FPP.

Variables	Mean	Std	Median	Minimum	Maximum
Output (Kg) {O}	63,958.40	28,654.60	56,419.00	23,031.00	141,610.00
Labour (#) {I}	2.374	1.10	2.12	0.77	5.23
# Sows {I}	520.99	242.24	420.26	174.15	1,131.60
Feed (Kg){I}	554,680.86	242,983.20	492,420.02	161,965.00	1,189,774.95
Veterinary (€) {I}	397.44	221.66	308.60	127.12	981.12
Expenses (€) {I}	10,657.27	4,873.65	9,289.72	3,348.60	22,500.91
FeedWP (Kg) {I}	108.90	71.95	88.81	20.72	292.65
AI (#) {I}	3,911.91	1,755.48	3,318.00	1,609.00	8,344.00

However, other ratios calculated from Tables 1 and 2 revealed differences between the two groups and were more useful for characterising piglet and feeder pig production. For instance, the output produced for each type of farm (112kg vs 364 kg), feed consumed by suckling piglets (109kg vs 589kg) or the veterinary expenses per sow or per unit produced (0.76 € vs 1.67 €) were also greater for producers of feeder pigs than piglets. All of this reveals that the longer productive cycle and lifespan of feeder pigs imply, an increase in both feed consumption and veterinary expenses by young pigs respect to farms producing only piglets. In addition, the average size of farms (571 vs 301) was different, being farms producing piglets bigger than those producing feeder pigs.

Table 2. Summary of variables for DMUs producing feeder pigs.

Variables	Mean	Std	Median	Minimum	Maximum
Output (Kg) {O}	109,708.51	63,227.56	89,106.00	31,811.00	321,649.99
Labour (#) {I}	1.36	0.79	1.12	0.36	3.95
# Sows {I}	301.43	176.23	248.58	81.08	885.58
Feed (Kg){I}	325,004.79	190,910.79	264,182.01	79,560.00	923,600.97
Veterinary (€) {I}	501.70	274.98	444.93	141.93	1,433.09
Expenses (€) {I}	9,463.07	5,466.95	7,494.61	2,662.90	27,825.77
FeedS (Kg) {I}	5,830.30	3,575.19	4,575.04	1,352.14	18,497.17
FeedWP (Kg) {I}	588.71	345.19	493.22	0.00	1,627.14
AI (#) {I}	2,262.92	1,466.93	1,812.00	361.00	7,950.00

4 Empirical Results and Discussion

4.1 Parametric approach

The maximum-likelihood estimated of the parameters of the stochastic production frontier was obtained for feeder pigs and weaned piglets using the program, FRONTIER 4.1 (2013). The stochastic frontier production for the cross-section of feeder pigs and weaned piglets is specified as follows:

For weaned piglets:

$$\ln \text{Output}_i = \beta_0 + \beta_1 \ln \text{Labour}_i + \beta_2 \ln \text{Sows}_i + \beta_3 \ln \text{Feed}_i + \beta_4 \ln \text{Veterinary}_i + \beta_5 \ln \text{Expenses}_i + \\ + \beta_6 \ln \text{FeedWP}_i + \beta_7 \ln \text{AI}_i + V_i - U_i$$

For feeder pigs:

$$\ln \text{Output}_i = \beta_0 + \beta_1 \ln \text{Labour}_i + \beta_2 \ln \text{Sows}_i + \beta_3 \ln \text{Feed}_i + \beta_4 \ln \text{Veterinary}_i + \beta_5 \ln \text{Expenses}_i + \\ + \beta_6 \ln \text{FeedWP}_i + \beta_7 \ln \text{AI}_i + \beta_8 \ln \text{FeedS}_i + V_i - U_i$$

where *i* refers to the *i*-th DMU in the sample; and V_i and U_i are the random variables as defined in Section 2. The variance parameters were estimated in terms of $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / \sigma^2$.

A Cobb-Douglas production function with the forward-selection technique and the stepwise method using PROC REG of SAS was estimated for each group of farms (Table 3). The estimated regression coefficients for input variables were different depending on the activity analysed and not significant (at the 5% level) in any case. However, parameter γ was not significantly different from zero for FPP (i.e. the inefficiency effects are not significant in determining the level and variability of the output) and significant for FPFP (at the 5% level).

Table 3. Estimated Cobb-Douglas production frontiers.

	FPP		FPFP	
Estimates	Value	SE	Value	SE
β_0	0.53	1.00	4.46	2.27
β_1	-	-	-	-
β_2	0.13	1.00	0.58	0.36
β_3	-0.49	1.00	0.18	0.32
β_4	-	-	0.18	0.55
β_5	0.20	1.0	-	-
β_6	-	-	-	-
β_7	-0.10	1.0	-	-
β_8	-	-	-	-
σ	0.0064	1.0	0.0360	0.0100
γ	0.0500	1.0	0.9190**	0.0860
Log (likelihood)	50.189**		37.4630**	

** Significant at the 5% level

The parameters β_i represent the elasticity of output with respect to each input i. For instance, those with the greatest elasticity were number of sows (FPP) and feed consumption of sows (FPFP). These results are meaningful because both variables are important components in the production cost of piglets. However, the signs of the slope coefficients in FPP had different signs, positive and negative mixed. In particular, the sign of the slope coefficients of β_3 (Feed) was not consistent: negative for FPP and positive for FPFP. Finally, the Log (likelihood) was significant at the 5%level in both groups of farms and so there is a significant relationship between the dependent variable and the set of independent variables. These results revealed the existence of different production functions for each group of sow farms.

Table 4. Frequency distributions of technical efficiency estimates from the stochastic frontier method.

Efficiency Score	FPP	Efficiency Score	FPFP
Mean	0.98577	Mean	0.87198
Minimum	0.98196	Minimum	0.59692
Maximum	0.98898	Maximum	0.97450
Standard deviation	0.00146	Standard deviation	0.07967

Once the production function was estimated, the technical efficiency for each farm was calculated. Some statistics of the estimated technical efficiencies are presented in Table 4. The mean technical efficiency estimated was 0.98577 and 0.87198 for weaned piglets and feeder pigs respectively. The main implication of these results is that the set of farms analysed are very efficient, being on average FPP more efficient than FPFP. Surprisingly, the efficiency of FPP is very high, with a capability of less than a 2% of technical efficiency improvement and with a low standard deviation. The fact that FPFP are less efficient than FPP can be interpreted as production in FPP is more complicated, controlled and delicate than in FPFP. A reason for that is the longer production cycle deployed in FPFP introducing variability in the final output as revealed the higher coefficient of variability (0.45 vs 0.58) in FPFP. On the other hand, this situation may partially explain the bad estimates of the stochastic production frontier for FPP and suspecting of problems related to multicolinearity.

4.2 Non-parametric approach

As stated before, the solution to the DEA model (Eq. 8) provides a measure of the relative efficiency of each DMU and the weights leading to the efficiency. To solve the different DEA models the DEAP software was utilised (Coelli, 1996). The constant returns to scale (CRS), variable returns to scale (VRS), non increasing returns to scale (NIRS) and scale (Scale) input-oriented DEA frontiers were estimated for the same number of farms as for the stochastic frontier depending on the final product: total weight of weaned piglets or feeder pigs. This meant solving three linear mathematical programs for every farm. The scale efficiency for every farm was obtained by (Eq. 9). The summarised statistics for the four estimated measures for the two groups of farms are presented in Table 5.

Table 5. Statistics of DEA models.

	FPP			FPFP		
	Mean	Std	Minimum	Mean	Std	Minimum
CRS	0.89034	0.08702	0.71430	0.88681	0.10793	0.53550
VRS	0.93318	0.07437	0.74730	0.91066	0.10595	0.53700
NIRS	0.90087	0.08582	0.71430	0.89934	0.10832	0.53700
Scale	0.95464	0.05899	0.71430	0.97427	0.04103	0.76870

In both cases the average efficiency index is very high showing a strong market competition in agreement with the trend observed from the parametric approach similar to other European studies. For instance, the average efficiency under CRS and VRS is very similar to the figures reported by Lansink and Reinhard (2004) in the Netherlands, but slightly higher than those reported by Galanopoulus et al. (2006) in Greece or Sharma et al. (1999) in Hawaii. However, the stochastic frontier and DEA approach showed similar values, though with lower minimum values in the DEA approach which derived in different standard deviations. As the DEA approach is not stochastic, it interprets noise as inefficiency and so we can consider the different estimates consistent. This comparison agrees with the findings of Sharma et al. (1999) who obtained similar conclusions from both approaches. Furthermore, Banker et al. (2004) considered DEA-based estimator of efficient input better than stochastic-based ones even under heteroscedasticity. The mean efficiencies for the VRS, CRS, NIRS and Scale DEA frontiers range from 0.88681 to 0.97427. Thus, the DEA analyses reveal substantial productive efficiency in all the cases.

Summarising apart the number of relative efficient and inefficient farms (Table 6 and Table 7) we observe the mean technical inefficiency is quite high in both FPP (0.86 and 0.89) and FPFP (0.85 and 0.86) under CRS and VRS assumptions. The percentage of efficient DMUs producing feeder pigs under the CRS (25.49%) is greater than the percentage in producing weaned piglets (17.77%). In terms of the VRS model the percentage of efficient DMUs producing weaned piglets (40.00%) is greater than the percentage in feeder pigs (35.29%). For comparison reasons, we have also included in Table 6 and 7 the average inputs and output of efficient and inefficient farms under CRS and VRS. The comparison of efficient and inefficient farms within each group there is a no clear outcome. It seems reasonable the results of inefficient FPP under VRS and FPFP under CRS where with more inputs produce less output with respect to efficient farms. More difficult to explain the behaviour of the other inefficiencies like FPP under CRS where a reduction in several inputs leads to an increment in output, but maybe the noticeable increment of expenses (from 10,474 to 21,631) in this group of farms compromise the efficiency. On the other hand, inefficient FPFP under VRS exhibit less input in general (only Feedwp increases) and less output than corresponding efficient FPFP under VRS.

Table 6. Summary of relative efficiency (CRS and VRS) for FPP.

	CRS		VRS	
Variables	Efficients	Inefficients	Efficients	Inefficients
Mean	1.00	0.86	1.00	0.89
% Farms	17.77%	82,23%	40.00%	60.00%
Labour{I}	2.41	2.36	2.35	2.38
Sows{I}	535.64	517.82	520.20	521.52
Feed{I}	565,668.24	552,305.21	543,578.55	562,082.40
Veterinary{I}	347.79	408.17	370.65	415.30
Expenses{I}	10,473.83	21,631.17	10.366,96	10.850,80
Feedwp{I}	82,31	114,65	86.41	123.90
AI{I}	3,610.50	4,976.50	3,671.06	4,072.48
Output{O}	71,167.50	82,320.50	66,232.72	62,442.19

Table 7. Summary of relative efficiency (CRS and VRS) for FPFP.

	CRS		VRS	
Variables	Efficients	Inefficients	Efficients	Inefficients
Mean	1.00	0.85	1.00	0.86
% Farms	25.49%	74.51%	35.29%	64.71%
Labour{I}	1.27	1.40	1.51	1.29
Sows{I}	280.60	308.56	333.31	284.05
Feed{I}	309,109.92	330,442.50	359,505.94	306,185.97
Veterinary{I}	400.41	536.34	484.13	511.28
Expenses{I}	8,589.75	9,761.84	10,283.54	9,015.54
FeedS {I}	5,440.64	5,963.61	6,573.29	5,425.04
Feedwp{I}	459.99	632.75	568.22	599.89
AI{I}	2,005.92	2,350.84	2,409.50	2,182.97
Output{O}	114,261.15	108,151.03	129,769.83	98,765.97

Table 8 presents the scale efficiency scores complementing the mean scaled efficiency showed in Table 5 (0.95 for FPP and 0.97 for FPFP). Although previous mean values implied that the average size of farms is not far from the optimal size, most of the farms are characterised by increasing returns to scale (58% of FPP farms and 45% of FPFP). According to the efficiency analysis theory, these farms are small farms and efficiency gains would be expected by increasing the size and achieving cost savings, assuming no other constraining factor. Again, the variability in FPFP is higher than those FPP as shown in Table 8. Lansink and Reinhard (2004) reported similar scale efficiency for pig farms in the Netherlands while Galanopoulus et al. (2006) presented lower scores for Greek farms.

Table 8. Optimal, sub-optimal, and super-optimal distribution of DMUs producing weaned piglets and feeder pigs.

Sow farm	Scale efficiency	N	%	Mean output	Std output	CV
FPP	Sub-optimal	26	57.78%	46,141.73	12,954.97	0.28
	Supra-optimal	11	24.44%	100,827.55	22,998.87	0.23
	Optimal	8	17.78%	71,167.50	17,044.20	0.24
FPFP	Sub-optimal	23	45.09%	74,771.52	23,754.41	0.32
	Supra-optimal	14	27.45%	165,599.50	69,680.24	0.42
	Optimal	14	27.45%	111,214.00	57,999.18	0.52

To discuss further the possible link between efficiency and input variables depending on the production level of the DMU, and also to draw an approach to the relationship between efficiency and optimal dimension we have considered four groups of DMUs by production level (i.e. output). In Table 9 and 10 we summarise these results by group. Differences in efficiency by Output do not seem very important in any of both groups of DMUs. The results are similar to those reported by Sharma et al. (1999). Medium-size farms (532 sows in FPP and 306 sows in FPFP) were more scale efficient, but with small differences. Small FPP are the lest scale efficient showing a remarkable difference according to the rest of scores, so we can assert the size of a farm play a more important role in FPP than in FPFP regarding the scale efficiency. Most of the DMUs are characterised by increasing returns to scale. However, the results differ with respect to returns to scales properties with Sharma et al. (1997).

Table 9. Technical efficiency for FPP by Output.

	OUTPUT			
	< 44,000	44,000-56,400	56,401-78,700	>78,700
Number DMUs	11	11	12	11
Labour{I}	1.32	1.74	2.42	3.99
Sows{I}	285.10	386.68	531.95	879.23
Feed{I}	307,568.64	414,370.46	583,761.74	910,378.88
Veterinary {I}	258.86	262.24	404.07	663.97
Expenses{I}	6,008.26	7,743.22	11,143.88	17,689.37
FeedWP {I}	76.41	113.54	110.07	135.48
AI{I}	2,329.91	2,828.64	4,127.17	6,342.36
Scale (Mean)	0.89	0.98	0.99	0.96

Table 10. Technical efficiency for FPFP by Output.

	OUTPUT			
	< 67,349	67,349-89,106	89,107-138,473	>138,473
Number DMUs	14	12	12	13
Labour{I}	0.67	0.99	1.40	2.43
Sows{I}	148.26	217.33	305.98	539.83
Feed{I}	156,237.64	230,640.50	337,567.75	582,262.93
Veterinary{I}	275.33	400.16	598.68	749.68
Expenses{I}	4,767.53	6,721.14	9,565.00	16,956.75
Feedwp{I}	303.02	455.12	579.31	1,028.38
Feeds(I)	2,843.54	4,211.20	5,570.05	10,781.61
AI{I}	998.71	1,652.50	2,215.08	4,232.00
Scale (Mean)	0.97	0.99	0.99	0.96

As Galanopulus et al. (2006) recognise, the DEA analysis can neither fully explain the underlying differences in efficiencies in the use of a particular input, nor assess the constraints to changes in operational practices that would improve efficiency. In part this is why we considered in the next section additional explanatory variables to explain variations in efficiency scores and identifying places to make improvements in pig production systems.

4.3 Explanatory variables

To explain some variations the inefficiency scores were regressed on the DMU-level characteristics, using a Tobit model, since the inefficiencies vary from zero to unity. The objective is to identify the common features in the most efficient farms. Authors as Hansson and Öhlmér (2008) had used the same approach to investigate how operational managerial practices can contribute to improved dairy farm efficiency. Apart the input-output variables already considered additional variables selected by livestock experts from Bdporc databank were included in the analysis to explain variations in efficiency scores. These five exogenous variables are: piglet mortality, culling rate, litter size, piglets alive and farrowings per sow per year. Some other different explanatory variables related to Greek managerial practices had been considered by Galanopoulos et al. (2006) in a similar analysis. The inefficiency scores were regressed on these 14 variables (inputs+ output+ exogenous) and are presented in Table 11 and 12. For the results presented, the independent variable is the inefficiency score, so a positive (negative) sign of a coefficient reflects a negative (positive) effect on efficiency levels. Recall that the estimated coefficients in Tobit regression models do not have a direct interpretation as a true marginal effect but rather a two-scale effect: effect on the mean of the dependent variable and on the probability of the dependent variable being observed.

Table 11. Tobit model of FPP. Estimated parameters for CRS and VRS inefficiencies (14 variables).

	CRS			VRS	
Variables	Estimate	Std error	Variables	Estimate	Std error
Intercept	0.7675	0.2359	Intercept	-0.6335	0.3349
Output**	-0.0000	0.0000	Output**	-0.0000	0.0000
Labour	-0.0005	0.0004	Labour	-0.0009	0.0007
Sows**	0.0010	0.0005	Sows	0.0014	0.0007
Feed	0.0000	0.0000	Feed**	0.0000	0.0000
Veterinary	-0.0000	0.0001	Veterinary	-0.0001	0.0001
Expenses	0.0000	0.0000	Expenses	-0.0000	0.0000
FeedWP**	0.0002	0.0001	FeedWP**	0.0006	0.0001
AI**	0.0000	0.0000	AI**	0.0001	0.0000
FeedS	-0.0045	0.0093	FeedS	-0.0281	0.0145
Piglet mortality	0.0034	0.0032	Piglet mortality	-0.0043	0.0050
Culling rate	0.0006	0.0004	Culling rate	0.0008	0.0006
Litter size	-0.0113	0.0265	Litter size	0.0240	0.0400
Piglets alive	-0.0614	0.0332	Piglets alive	0.0036	0.0494
Farrowings pspy	0.0229	0.0552	Farrowings pspy	0.1495	0.0836

**Significant coefficients at the 5% level.

The Tobit results for FPP (Table 11) and FPFP (Table 12) indicate that no exogenous variable related to technical indexes considered in the analysis was significant explaining the inefficiencies of farms. Only the output, the size of the farm (Sows) the feed consumption of sows (Feed), suckling piglets (Feedwp) and the number of artificial inseminations (AI) are significant. As expected, Output has negative effects on inefficiency scores while Sows has positive effects. In a similar study, Galanopoulos et al. (2006) found that several managerial practices such as insemination method, origin of genotype and how the feed was prepared significantly influenced the technical efficiency of Greek pig farms. Although we didn't consider genotype because it was the same for all farms belonging to the same company and AI and Feed were considered as inputs, these variables showed similar significant influence on the efficiency of farms.

Table 12. Tobit model of FPFP. Estimated parameters for CRS and VRS inefficiencies (14 variables).

	CRS			VRS	
Variables	Estimate	Std error	Variables	Estimate	Std error
Intercept	0.6297	0.2661	Intercept	0.3812	0.3594
Output**	-0.0000	0.0000	Output**	-0.0000	0.0000
Labour	-0.0004	0.0013	Labour	0.0012	0.0017
Sows	0.0024	0.0015	Sows	-0.0002	0.0020
Feed	-0.0000	0.0000	Feed	-0.0000	0.0000
Veterinary	0.0001	0.0001	Veterinary	0.0002	0.0001
Expenses	-0.0000	0.0000	Expenses	-0.0000	0.0000
FeedWP	0.0001	0.0001	FeedWP	0.0001	0.0001
AI**	0.0000	0.0000	AI**	0.0001	0.0000
FeedS**	0.0000	0.0000	FeedS	0.0000	0.0000
Piglet mortality	0.0014	0.0032	Piglet mortality	-0.0020	0.0046
Culling rate	-0.0008	0.0007	Culling rate	-0.0011	0.0010
Litter size	0.0492	0.0372	Litter size	-0.0088	0.0524
Piglets alive	-0.0739	0.0426	Piglets alive	-0.0123	0.0590
Farrowings pspy	-0.1305	0.0875	Farrowings pspy	0.0056	0.1188

**Significant coefficients at the 5% level.

The results for FPFP (Table 12) only the output, the number of inseminations (AI) and the feed consumed by feeder pigs (FeedS) were significant. That is, less variables than for FPP. However, again, as expected, output had negative effects on inefficiency scores while AI and FeedS had positive effects under CRS. Under VRS only output and AI were significant. Overall, in terms of signs of the regression coefficients, these results are quite consistent for both activities (FPP and FPFP). However, it seems a little bit strange to observe some negative signs pointing out to interesting conclusions. For instance, under VRS the effect of piglet mortality is negative either in FPP or FPFP. From the analysis of these specific farms, it is not mortality itself who explain inefficiency, but a higher prolificity correlated to more efficient farms and hence more susceptible of suffering more casualties of piglets. Even though, the different sign shown by litter size and piglets alive in FPP and FPFP suggest again the importance of litter size in FPP to produce many piglets, but perhaps, larger litter sizes are not so suitable for FPFP. Less piglets, but weightier might be more interesting and profitable for FPFP. This argument can be reinforced observing the sign of the culling rate that also differs between FPP and FPFP. In FPP inefficiency is associated with higher culling rates while in FPFP is in the contrary. This agrees the general idea of managers about high culling rates in FPP with younger sows, more productive in number of piglets than older populations putting the emphasis more in the quantity than in the quality of piglets.

The fact that artificial insemination appeared as significant in all the analysis may suggest the importance of the reproductive performance in the technical efficiency of sow farms, either producing piglets or feeder pigs, regardless the number of sow or the feed consumption of concentrates in many cases. The importance of artificial insemination as explanatory variable was already detected by Galanopoulus et al. (2006).

5 Conclusions

Pig farming is a biological activity with many uncertainties, so in view of efficiency measurements the choice of stochastic frontier analysis allowing for a correction of stochastic events would seem obvious. However, the parametric specification of the production technology can be problematic not always provide suitable results and are more difficult to interpret as we have shown. For example, the results for the stochastic frontier production function for feeder pigs and weaned piglets exhibit problems related to multicolinearity. Even though, the observed trends of technical efficiencies calculated from the parametric approach were consistent with those calculated with the non-parametric method for the same set of DMUs.

The sow farms analysed were highly technically efficient, being FPP slightly more efficient than FPFP. With respect to scale efficiency, scores were also high being FPFP more scale efficient than FPP. However, the important percentage of farms operating at below their optimal scales suggests that the current trend towards larger farm sizes could have a beneficial impact upon the efficiency of sow farms (either they produce piglets or feeder pigs) in future. Considering that current levels of efficiency are already quite high, it is expected a lot of effort to achieve further improvements. Mean technical efficiency and the percentages of efficient DMUs are higher in this study compared with other published results. This fact can suggest a more homogeneous and competitive DMUs in the Spanish context dominated by vertically integrated companies. On the other hand, it has been seen how the increase of number of inseminations leads to a higher level of technical efficiency.

The strength of the DEA methodology lies in the fact that it focuses on individual farms (microeconomic agents) and can be used by advisers, specialist or extension service agents to promote and diffuse best practices in farm management. It may therefore facilitate local action to combat relative inefficiency and become an important feature of programmes aimed at raising overall performance standards in the pig farming sector.

The computational and interpretative simplicity of DEA face stochastic methods make it a practical tool for individual agents such as small companies. Furthermore, the structure of the Spanish pig sector, with production concentrated in a relatively small number of companies and cooperatives, may benefit from such efficiency studies. However, DEA analysis should be only considered a starting point for identifying places to make improvements in farm production rather than an ending point.

6 Outlook

Although it was not in the scope of the study, other applications of technical efficiency should be pointed out as important future trends in this kind of studies. Sustainable development is a matter of concern with increasing attention from policy-makers and academics. For instance, the concept of environmental efficiency has gaining importance recently, mainly in Europe, but also in other countries. Manure management issues and GHG emissions are concerns have also a rising interest (Piot-Lepetit, 2014).

Many times, the consideration of environmental aspects is related to the existence of undesirable inputs (Piot-Lepetit, 2014) and the way they can be dealt and interpreted by the methodology, either stochastic frontier or DEA models. Hence, Piot-Lepetit and Vermersch (1998) used DEA to measure the efficiency of French pig farms, and derived a shadow price of organic nitrogen. Similarly, Lansink and Reinhard (2004) investigate the possibility of improving the environmental performance of Dutch pig farms reducing ammonia emissions while Asmild and Hougaard (2006) employed the same DEA methodology to evaluate the environmental improvement potential of Danish pig farms. Environmental efficiency was also considered by Yang (2009) in pig farming in Taiwan. Other proposals beyond pig farming are also published concerning the eco-efficiency of farms (Picazo-Tadeo et al., 2014). Eco-efficiency benefits of public expenditure in agri-environmental programs, although the cost-benefit balance is disputable. Finally, Yang (2009) and Picazo-Tadeo et al. (2014) emphasised also the benefits of training farmers to promote the integration between farming and environment and hence, achieving a more efficient and sustainable production.

7 References

Aigner, D. and Chu , S.F., 1968. On estimating the Industry Production Function. American Economic Review, 58, 826-839.

Asmild, M. and Hougaard, J., 2006. Economic and environmental efficiency of Danish pig farms. Agricultural Economics,35, 171–181.

Banker, R.D., Charnes, A. and Cooper, W.W., 1984. Some models for estimating technical and scale inefficiencies in DEA. Management Science, 30, 1078-1092.

Banker, R.D., Chang, H. and Cooper, W.W., 2004. A simulation study of DEA and parametric frontier models in the presence of heteroscedasticity. European Journal of Operational Research, 153, 624-640.

Battese, G.E. and Coelli, T.J., 1988. Prediction of firm-level technical efficiences with a generalized frontier production function and panel data, Journal of Econometrics, 38, 387-399.

BD-porc®, 2013. http://www.irta.es/bdporc/

Berger, A.N., 1993. Distribution-free estimates of efficiency in the U.S banking industry and tests of the standard distributional assumptions. Journal of productivity analysis, 4, 261-292.

Charnes, A., Cooper, W.W. and Rhodes, E., 1978. Measuring the efficiency of decision making units. Eur. J. Oper. Res 2, 429-444.

Cloutier, L.M. and Rowley, R., 1993. Relative technical efficiency: data envelopment analysis and Quebec's dairy farms. Canadian Journal of Agricultural Economics, 41, 169-176.

Coelli, T., 1996. Recent developments in frontier modelling and efficiency measurement A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program. CEPA Wprking Paper 96/08. Centre for Efficiency and Productivity Analysis. Departament of Econometrics, University of New England. Australia.

Coelli, T.J., 1998. A mullti-stage methodology for the solution of oriented DEA models. Operations Research Letters, 23, 143-149.

Dyson, R.G., Allen, R., Camacho, A.S., Podinovski, V.V., Sarrico, C.S. and Shale, E.A., 2001. Pitfalls and protocols in DEA" European Journal of Operational Research, 132, 245-259.

Färe, R., Grosskopf, A. and Cooper, W.W., 1985 The measurement of efficiency of production. Kluwer Nijhoff, Boston.

Farrell, M.J., 1957. The measurement of productive efficiency. J.R. Statis. Soc., Series A, 120, 253-281.

Fraser, I. and Cordina, D., 1999. An application of data envelopment analysis to irrigated dairy farms in Northern Victoria, Australia. Agricultural Systems, 59, 267-282.

FRONTIER 4.1. A computer Program for Stochastic Frontier Production and Cost Function Estimation. http://www.uq.edu.au/economics/cepa/frontier.php (last access December 20th, 2013).

Galanopoulos, K., Aggelopoulos, S., Kamenidou, I. and Mattas, K., 2006. Assessing the effects of managerial and production practices on the efficiency of commercial pig farming, Agricultural Systems, 88, 125-141.

Gaspar, P., Escribano, M., Mesías, F.J., Rodriguez de Ledesma, A. and Pulido, F., 2008. Sheep farms in the Spanish rangelands (dehesas): Typologies according to livestock management and economic indicators. Small Ruminant Research, 74, 52-63.

Gaspar, P., Mesías, F.J., Escribano, M. and Pulido, F., 2009. Assessing the technical efficiency of extensive livestock farming systems in Extremadura, Spain. Livestock Science, 121, 7-14.

Hadi, A.S., 1992. Identifying multiple outliers in multivariate data. Journal of the royal statistical society, Series B, 54,761-777.

Hadi, A.S., 1994. A modification of method for the detection of outliers in multivariate samples. Journal of the royal statistical society, Series B, 56, 393-396.

Hansson, H. and Öhlmér, B., 2008. The effect of operational managerial practices on economic, technical and allocative efficiency at Swedish dairy farms, Livestock Science, 118, 34-43.

Jaforullah, M. and Whiteman, J., 1999. Scale efficiency in the New Zeland dairy industry: a non-parametric approach. The Australian Journal of Agricultural and Resource Economics, 43, 523-541.

Lansink, A. O. and Reinhard, S., 2004. Investigating technical efficiency and potential technological change in Dutch pig farming, Agricultural Systems, 79, 353-367.

Lovell, C.A.K., 1994 "Linear programming approaches to the measurement and analysis of productive efficiency" TOP, 2, 175-223.

Piot-Lepetit, I. (2014). Technological externalities and environmental policy. How to simulate manure management regulation within a DEA framework. Annals of Operations Research, 214, 31–48.

Piot-Lepetit, I. and Vermersch, D., 1998. Pricing organic nitrogen under the weak disposability assumption: an application to the French pig sector. Journal of Agricultural Economics, 49, 85–99.

Picazo-Tadeo, A.J., Gómez-Limón, J.A. and Reig-Martínez, E., 2011. Assessing farming eco-efficiency: A Data Envelopment Analysis approach, Journal of Environmental Management, 92, 1154-1164.

Reinhard, S., Lovell, C.A.K. and Thijssen, G., 1999. Econometric estimation of technical and environmental efficiency: an application to Dutch dairy farms. American Journal of Agricultural Economics, 81, 44-60.

Ripoll-Bosch, R., Díez-Unquera, B., Ruiz, R., Villalba, D., Molina, E., Joy, M., Olaizola, A. and Bernués, A, 2012. An integrated sustainability assessment of mediterranean sheep farms with different degrees of intensification, Agricultural Systems, 105, 46-56.

Rodriguez, S.; Plà, L.M. and Faulin, J., 2014. Piglet production inside the Pork Supply Chain Management. a linear optimization model in sow farms. Annals of Operations Research, 219, 5-23.

Seiford, L., 1996. Data envelopment analysis: the evolution and state of the art. The Journal of Productivity Analysis, 7, 99-137.

Seiford, L. and Zhu, J., 1999. An investigation of return to scale in data envelopment analysis. Omega, 27, 1-11.

Sharma, K.R., Leung, P. and Zaleski, H.M., 1997. Productive efficiency of the swine industry in Hawaii: stochastic frontier vs. data envelopment analysis. Journal of Productivity Analysis, 8, 447–459.

Sharma, K.R., Leung, P. and Zalesky, H.M., 1999. Technical allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and nonparametric approaches. Agricultural Economics, 20, 23-35.

Theodoridis, A., Ragkos, A., Roustemis, D., Galanopoulos, K., Abas, Z. and Sinapis, E., 2012. Assessing technical efficiency of Chios sheep farms with data envelopment analysis, Small Ruminant Research, 107, 85-91.

Weersink, A., Turvey, C.G. and Godah, A., 1990. Decomposition measures of technical efficiency for Ontario dairy farms. Canadian Journal of Agricultural Economics, 38, 439-456.

Yang, C.-C., 2009. Productive efficiency, environmental efficiency and their determinants in farrow-to-finish pig farming in Taiwan, Livestock Science, 126, 195-205.

Chapter 4

AnaPorkDSS: A decision support system to evaluate pig production economics

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Abstract

A decision support system to evaluate pig production economics (AnaPorkDSS) based on a spreadsheet model has been developed to estimate net present value and costs associated with the pig production activity under Spanish conditions. This article describes the model structure, input data requirements, and summarizes basic reports generated by the model. The model is capable of estimating net present value for a farrowing-to-finish farm producing pigs that are sold to the slaughterhouse. Incomes from sales are estimated for both fattened pigs and culled sows and boars. The AnaPorkDSS is written as a multipage spreadsheet model and is operated on a PC in a windows environment. Different macros are included in the model which assures the consistency of input parameters and the management of menus. The analysis of the starting up of the activity is used to illustrate the usefulness of the AnaPorkDSS.

*Keywords: d*ecision support system; pig production; net present value estimation; pig production.

1 Introduction

During past decades the Spanish census of pigs has been increased little by little whilst in other European countries has stabilized and even decreased. The importance of pig production for the Spanish economy is reflected by recent agricultural statistics for Spain's swine industry. In 2003, the sector contributed 10.4% of the Final Agricultural Product[1] and accounted for 30% of the total economic value of the country's livestock production[2]. Pork is the main meat consumed in Spain (66.1 kg/person/year); 55% of total meat consumption. Moreover, after Germany, Spain is the second largest pig producer in the European Union.

Traditional pig production in Spain was based on small familiar sow farrowing - to finish farms, but this is undergoing a rapid change. For instance, vertical integration of production and processing companies, contract production of piglets and fattening pigs, and associations of growers purchasing inputs and selling pigs are a few examples of that. Thus, pig production in Spain tends to be divided in three different stages according to the final product of each one and activities involved. The first relates to farms producing piglets, the second those producing feeder pigs and the third those producing fattened pigs. This specialisation gives additional efficiency gains as Rowland et al. (1998) pointed out and it is becoming widely extended within the Spanish pig industry. In this context, existing or future farrowing - to finish farms have to decide whether adopting new technology or entering into production contracts or cooperatives is or not convenient, i.e., profitable for their own interest. A final decision should be based on sound economic analyses.

On the other hand, the existence of an official record keeping system (the BD-porc®, 2000), which registers the main controllable variables on a farm, is available to detect main inputs and best outcomes registered by farm basis in Spain. Other public data sources on produce prices and concentrates costs are included in the model. Furthermore, reliable scenarios based on past data are build and used in an extended economic analysis. This information is important for a decision maker or swine specialist involved in the setting up of a new farrowing –to-finish farm.

A decision support system to evaluate farrowing –to-finish production economics is presented in this paper. The methodological framework chosen to assess economic farm efficiency was by spreadsheet simulation. Therefore the development of a simulation model allowing to measure and determine economic analyses of farrowing –to-finish farms is presented. Spreadsheets were the computer tool selected to develop the simulation model given the environment where the DSS is intended to be applied and expected background of potential users. The work also includes a discussion about the availability of information required for solving the model and examines a few practical considerations for applying these

[1] http://www.mapya.es/app/SCP/indicadores/indicadores.aspx?lng=es

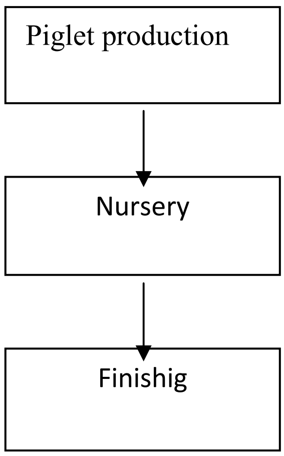
[2] http://www.mapya.es/ministerio/pags/hechoscifras/espanol/pdf/10.pdf

results. The description of classical operation in sow farms is presented in Section 2. This is followed by the formulation and implementation of the models and their different parts and an illustrative example of use, in Sections 3 and 4 respectively. Conclusions are derived in Section 5.

2 Description of different farrowing –to-finish farm systems

Nowadays, individual pig farms are split into different systems depending on the input and output. Elementary division of pig production is in three stages where the first one is related to farms producing piglets, the second one producing feeder pigs and the third one producing fattened pigs (see Figure 1). Farms from these stages can be observed separately or combined with other farms belonging the same, upper or lower stages.

Figure 1. Representation of a three-site pig production system.



The piglet production system results in a specialization of the swine production industry characterized by a herd of sows in a continuous process of reproduction. The commercial product are the piglets, which after weaning are sold or transferred to rearing-fattening farms. This specialisation gives additional efficiency gains as Rowland et al. (1998) pointed out and it is widely extended within the modern Spanish swine industry.

An example of this specialisation is observed in confinement facilities of sow farms which consist of a service facility, a gestation facility and a farrowing facility with multiple farrowing rooms. All these facilities may be in one or in several buildings. The service facility houses breeding sows, gilts (young sows) and boars. Different management strategies in reproduction can be implemented, for instance, group weaning of all litters from a farrowing room, i.e. a batch, is practised to synchronise breeding and farrowing. During the reproductive cycle sows are culled for different reasons and replaced by new gilts. Replacement strategies may prescribe culled sows can remain on the farm until they are sent to the slaughterhouse or replaced immediately (usually after some farm specific delay). Replacement gilts and sows are generally kept in the service facility to be inseminated. They are moved from service to gestation facility when pregnancy is confirmed, if not, they remain to be reinseminated. Gilts and sows in the gestation facility are moved into the farrowing room approximately one week before parturition. To synchronise the breeding and farrowing of a group of sows, all litters from a farrowing room are weaned simultaneously and sent to the nursery or sold. After weaning the sows are sent back to the service facility. The farrowing room is cleaned, sterilised and closed for a drying period. After the drying period, the room is ready to receive the next batch of sows.

The operation of a sow farm is the more complex activity in pig production and the flow of pigs through rearing and fattening stages depends on that. Furthermore, technical and economic impact on facilities is different depending on the way production is organized. Although there are many computerized tools to capture data, record and process data in information at farm level, few systems are developed giving insight into the economic analysis of the activity. When starting up the activity or introducing management changes, farmers need information about the expected profit of each alternative. Thus, the analysis and comparison of different strategies in the long term is of great value for strategic decision-making.

3 Model structure and format

The AnaPorkDSS is written as a multipage spreadsheet model in MSExcel for Windows (© Microsoft). The model is contained in one file and is distributed over ten spreadsheet pages labelled according its content. The model structure is divided in four main parts or sections as described below: Input data, Results over five years, Economical results and Production cost estimation. This structure is controlled by macros just to make easier the use and structuring the access to all spreadsheet avoiding internal complexity.

The commercial add-in Crystal Ball[3] was used in the simulation study, basically in the sensitivity analysis of several parameters in different.

3.1 Input data required by the model

Simple menus are used (see Assistant of Users in Figure 1) to guide users in the introduction of input data. When input data is lacking the model cannot work properly because a zero value is assumed by default. The main menu is organized as a table of contents giving access to all sheets in the model. The main menu of input data includes four submenus corresponding to different pages of the spreadsheet that are:

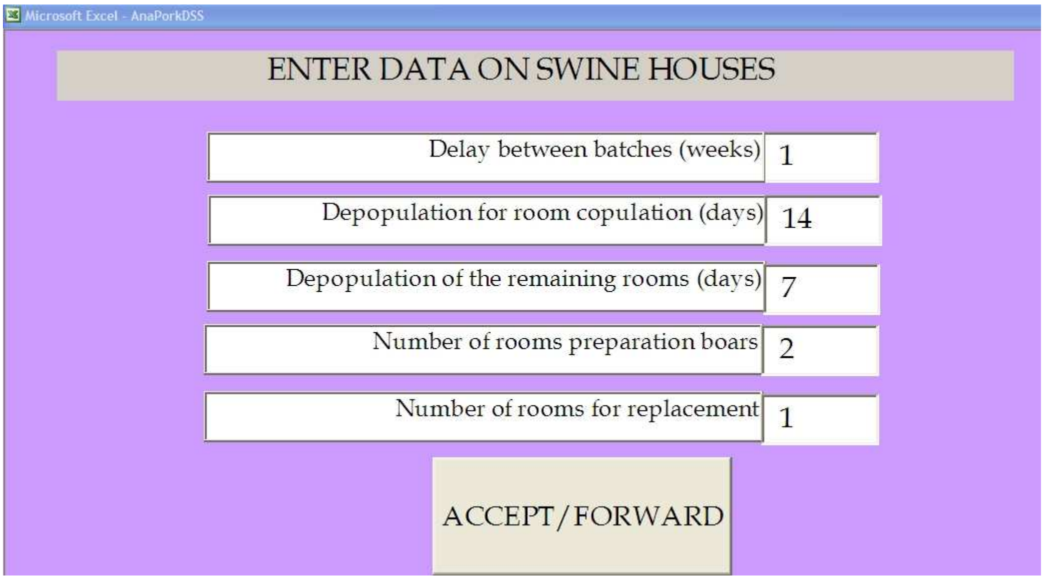
[3] http://www.decioneering.com/

- Page “Introduction Technical Information (I)”
- Page “Introduction Technical Information (II)”
- Page “Introduction Economics Information”
- Page “User Level”

3.1.1 Introduction Technical Information (I)

Information entered in this section represents the basic input data describing housing facilities needed to host the whole activity process (Figure 2). It is assumed batch management of sows in cycles of one or more weeks introduced as parameter. Room needs for sows in the service, gestation and lactation sections as well as number of batches are derived. Drying period in days per facility and number of boar crates have to be specified.

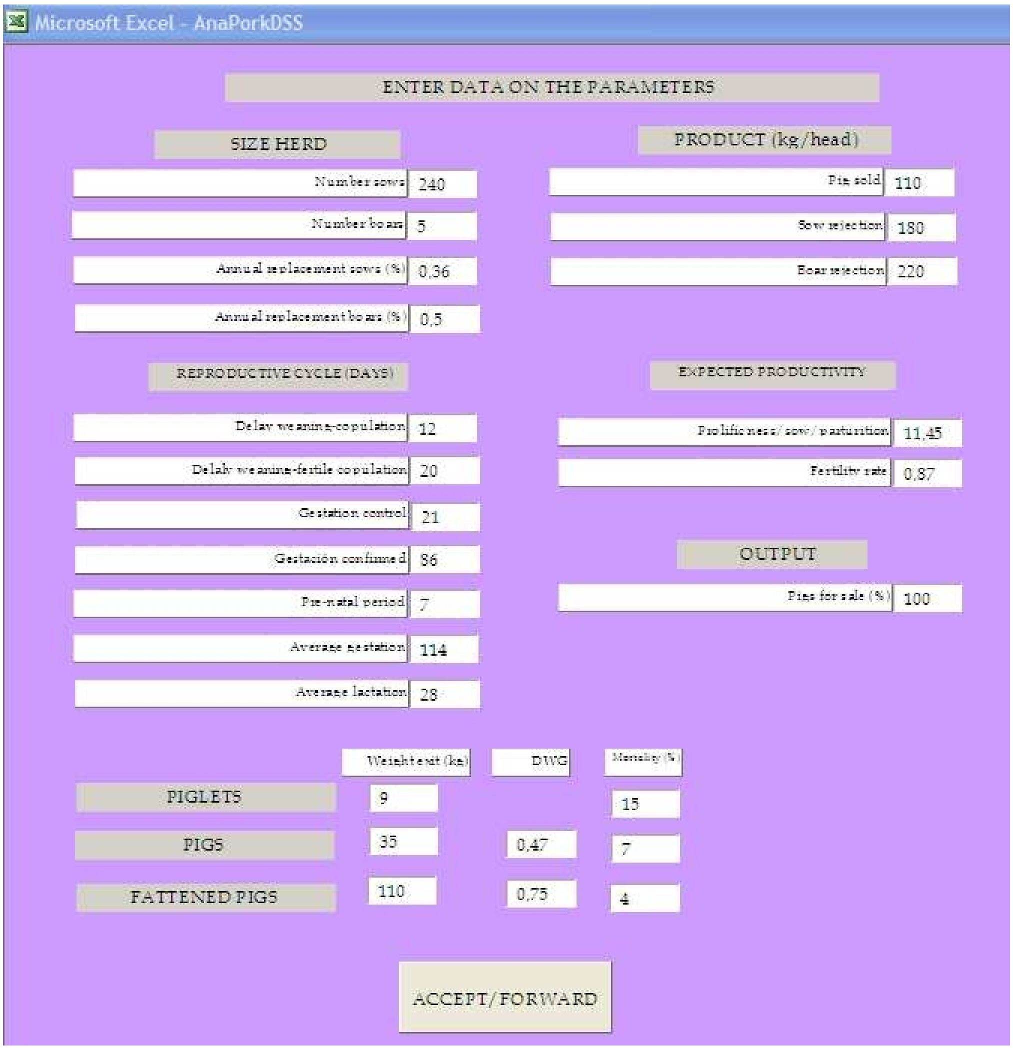
Figure 2. Page: Introduction Technical Information (I).



3.1.2 Introduction of Technical Information (II)

Data to be entered here includes basically five general sections (see Figure 3). The first one devoted to the herd size, number of sows and boars and also annual replacement rate. The second one is related to different intervals conforming the reproductive cycle of sows. The third one is used for parameters controlling the growth of piglets and potential pig meat production of the farm. Weights at the end of each growing stage, the daily weight gain and mortality have to be introduced here. The fourth section concerns weights of animals sold to the slaughterhouse: fattened pigs and sows and boars culled. In the last section, several indexes affecting productivity can be fixed: litter size, fertility and percent of piglets fattened (commercial products are piglets or fattened pigs in a proportion given by this rate).

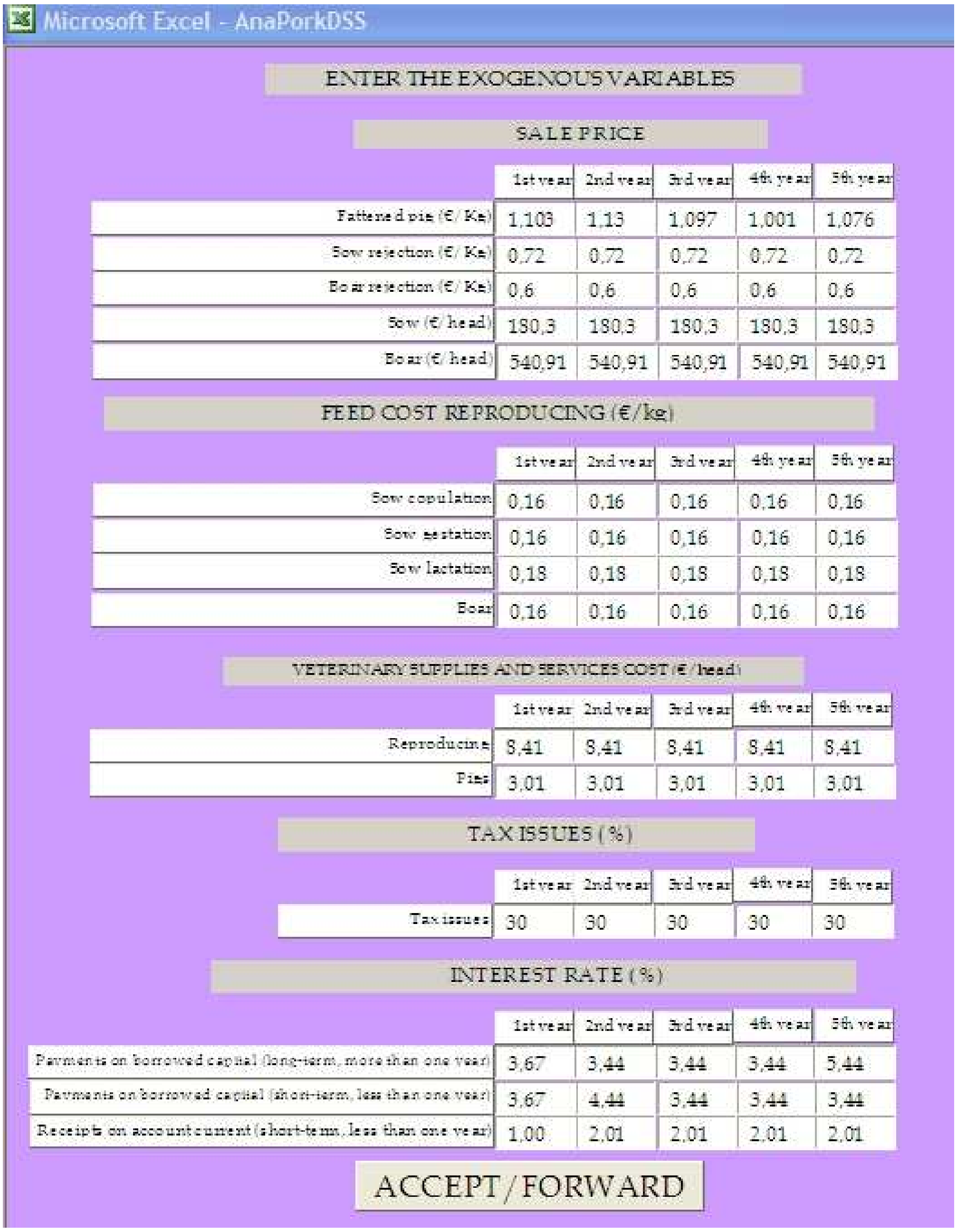
Figure 3. Page: Introduction Technical Information (II).



3.1.3 Introduction of Economics Information

This page includes economics information required for economics calculation related to the farming activity. Parameters are organised in five tables (Figure 4) all of them with five columns corresponding to each of the five years the model simulates the pig production. These tables contain respectively sold prices for different elements contributing to incomes, concentrate prices to calculate feed cost, estimation of veterinary expenses per sow and piglets, taxes rates under Spanish Finances Ministry and official loan rates.

Figure 4. Page: Introduction of Economics Information.



Microsoft Excel - AnaPorkDSS

ENTER THE EXOGENOUS VARIABLES

SALE PRICE

	1st year	2nd year	3rd year	4th year	5th year
Fattened pig (€/Kg)	1,103	1,13	1,097	1,001	1,076
Sow rejection (€/Kg)	0,72	0,72	0,72	0,72	0,72
Boar rejection (€/Kg)	0,6	0,6	0,6	0,6	0,6
Sow (€/head)	180,3	180,3	180,3	180,3	180,3
Boar (€/head)	540,91	540,91	540,91	540,91	540,91

FEED COST REPRODUCING (€/kg)

	1st year	2nd year	3rd year	4th year	5th year
Sow copulation	0,16	0,16	0,16	0,16	0,16
Sow gestation	0,16	0,16	0,16	0,16	0,16
Sow lactation	0,18	0,18	0,18	0,18	0,18
Boar	0,16	0,16	0,16	0,16	0,16

VETERINARY SUPPLIES AND SERVICES COST (€/head)

	1st year	2nd year	3rd year	4th year	5th year
Reproducing	8,41	8,41	8,41	8,41	8,41
Pigs	3,01	3,01	3,01	3,01	3,01

TAX ISSUES (%)

	1st year	2nd year	3rd year	4th year	5th year
Tax issues	30	30	30	30	30

INTEREST RATE (%)

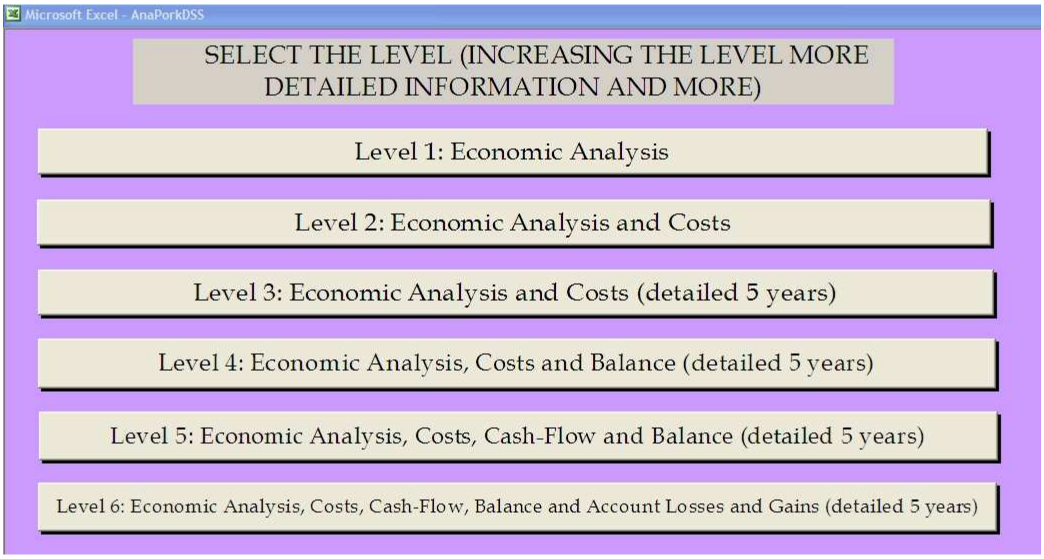
	1st year	2nd year	3rd year	4th year	5th year
Payments on borrowed capital (long-term, more than one year)	3,67	3,44	3,44	3,44	5,44
Payments on borrowed capital (short-term, less than one year)	3,67	4,44	3,44	3,44	3,44
Receipts on account current (short-term, less than one year)	1,00	2,01	2,01	2,01	2,01

ACCEPT / FORWARD

3.1.4 Outcomes under different levels of access

This page filters the access to different outcomes of the model (Figure 5). This implementation intends to make easier the inspection of different outcomes. On the other hand, users can select outcomes according their corresponding background or personal interests. Therefore, results can be accessed by groups represented by levels in the menu going from one up to six, from the simplest to the more complex results. Results available at each level are presented in several spreadsheets and discussed below in next section.

Figure 5. Different Levels of access to outcomes.



3.2 Economic results and information

Once all parameters are set and after selecting the level of access, several results are available. All results are available selecting the sixth level shown in Figure 5. These are calculated assuming five years of operation in a three-site farm producing, rearing and fattening piglets. Outcomes for each year are stored in corresponding pages and they represent intermediate results from which other economic results and rates are obtained. Derived results are linked and organised in different pages, ten in total:

- Page "Economic Analysis"
- Page "Cost analysis of Pig production"
- Pages "Estimation of operational results during five years" (five pages)
- Page "Accounting reports"
- Page "Gain and losses"
- Page "Cash Flow: Estimation of Financial resources"

3.2.1 Economic Analysis

The AnaPorkDSS allow the user to perform an economic analysis. The economic criterion considered for performing the investment analysis is the Net Present Value criterion (NPV). NPV is defined as a sum of present values of future cash flows during part of the lifespan of the project exploitation (1).

$$NPV = \sum_{k=0}^{n} \frac{CF_K}{(1+i)^k} \qquad (1)$$

where:

CF_k it is the net cash flow for the k^{th} year of the investment project

i the discount rate

n time horizon of the investment project

The use of AnaPorkDSS is based on a time horizon of five years, the firsts of the project lifespan which are used to calculate the NPV.

Additional criteria common in economic analysis are calculated as for example the leverage point and Internal return rate among other indexes are calculated.

3.2.2 Pig production cost analysis

Individual pig producers have few capacity to modify the marked trend concerning expected incomes, thus the control of production cost offer them a major source of improvement for their own economical results. For such purpose was built this page useful to display and analyse different sources of cost in pig production.

3.2.3 Estimation of operational results during five years

The model represents the operation of a farm during five years from the beginning of the activity. One page is devoted for each year and they are linked conveniently in the way that results of a year affect the following ones. These pages include the estimation of incomes and expenses from input parameters. When considering the initial settlement of the activity, the first two years of production are affected by a progressive starting up till the plain capacity operation.

3.2.4 Accounting reports

The outcomes of the activity for the five years are presented here organized depending on the Spanish accounting system taking into account the different chapters and concepts involved.

3.2.5 Gain and losses

This section includes the summary of gain and losses expected from the first five years of the activity.

3.2.6 Cash Flow: Estimation of Financial resources

This section includes the financial budget expected from the first five years of the activity. The sheet allows the user to consider different financial sources and combinations of own or external financial resources.

Figure 6. Page: Cash Flow.

Microsoft Excel - AnaPorkDSS

	1st year	2nd year	3rd year	4th year	5th year
Initial cash balance	213.688,81	6.136,89	6.970,76	6.684,04	6.394,28
Total receipts	573.869,27	602.887,12	585.601,92	535.535,98	574.687,95
Sales fattened pigs	140.763,43	508.110,38	493.271,76	450.104,86	483.829,00
Sales sows rejection	8.727,87	11.197,44	11.197,44	11.197,44	11.197,44
Sales boars rejection	396,00	396,00	330,00	330,00	330,00
Indirect taxes sales: fattened pigs, sows and boars rejection	23.981,97	83.152,61	80.767,87	73.861,17	79.257,03
Borrowed capital	400.000,00	0,00	0,00	0,00	0,00
Receipts on account current	0,00	30,68	34,85	42,51	74,48
Total payments	941.743,71	479.691,61	480.020,24	482.806,89	470.273,77
Budget buildings	277.385,55	0,00	0,00	0,00	0,00
Indirect taxes: buildings	44.381,69	0,00	0,00	0,00	0,00
Initial expenses: notary, proceedings…	3.700,00	0,00	0,00	0,00	0,00
Indirect taxes: initial expenses	112,00	0,00	0,00	0,00	0,00
Buy assets	245.525,21	0,00	0,00	0,00	0,00
Indirect taxes: buy assets	62,51	0,00	0,00	0,00	0,00
Buy boars	4.327,28	1.622,73	1.352,28	1.352,28	1.352,28
Indirect taxes: buy boars	302,91	113,59	94,66	94,66	94,66
Buy sows	45.870,69	25.121,47	15.577,92	15.577,92	15.577,92
Indirect taxes: buy sows	3.210,95	1.758,50	1.090,45	1.090,45	1.090,45
Reproducing feed	31.971,22	40.769,69	40.769,69	40.769,69	40.769,69
Indirect taxes: reproducing feed	2.237,99	2.853,88	2.853,88	2.853,88	2.853,88
Piglets, feeder pigs and pigs feed	170.442,86	272.390,54	272.390,54	272.390,54	272.390,54
Indirect taxes: piglets, feeder pigs and pigs feed	11.931,00	19.067,34	19.067,34	19.067,34	19.067,34
Vaccines	7.447,36	18.232,03	18.232,03	18.232,03	18.232,03
Indirect taxes: vaccines	688,06	1.276,24	1.276,24	1.276,24	1.276,24
Veterinary services and medical supplies	9.495,99	9.495,99	9.495,99	9.495,99	9.495,99
Indirect taxes: veterinary services and medical supplies	1.519,36	1.519,36	1.519,36	1.519,36	1.519,36
Insurance	3.906,58	3.906,58	3.906,58	3.906,58	3.906,58
Direct taxes	0,00	0,00	13.420,91	17.955,42	5.422,30
Labor expense: salary	23.559,76	23.559,76	23.559,76	23.559,76	23.559,76
Labor expense: payroll taxes and benefits	3.365,60	3.365,60	3.365,60	3.365,60	3.365,60
Other costs employee: courses…	3.365,67	3.365,67	3.365,67	3.365,67	3.365,67
Payments on borrowed capital (short-term and long-term)	35.151,24	39.490,39	36.899,10	35.151,24	35.151,24
Repairs: buildings and equipment	5.769,72	5.769,72	5.769,72	5.769,72	5.769,72
Indirect taxes: repairs	923,16	923,16	923,16	923,16	923,16
Utilities: electricity, gas, phone charges…	4.387,39	4.387,39	4.387,39	4.387,39	4.387,39
Indirect taxes: utilities	701,98	701,98	701,98	701,98	701,98
Liquidation Indirect taxes: receipt (+) and pay (-)	-42.089,62	54.938,56	53.240,80	46.334,10	51.729,96
Excess receipts (+) or excess payments (-)	-325.784,82	68.256,95	52.340,87	6.394,99	52.684,22
Average remnant treasury required	6.136,89	6.970,76	6.684,04	6.394,28	6.159,33
Borrowed capital required (-) or excess resources (+)	-118.232,90	67.423,08	52.627,59	6.684,74	52.919,17
Remmand treasury	6.136,89	6.970,76	6.684,04	6.394,28	6.159,33
Accumulate: borrowed capital required (-) or excess resources (+)	-118.232,90	-50.809,83	1.817,76	8.502,51	61.421,68

4 A case study

4.1 Basic parameters

The AnaPorkDSS is applied to analyse the response variables that are affecting the future operation of a farrow-to-finish farm (technical and economic). Depending on the control of the farmer over the variables included in the model these are classified in controllable – decision variables-, and uncontrollable.

Most farms can be characterized a small business firms that have to act as price takers. An individual farmer has few possibilities of influencing his environment, making it more important to anticipate changes in the environment of the farm correctly and in time. This makes information about external conditions important for strategic planning.

Distinct aspects of the relevant farm environment are related with uncontrollable variables:

1. The economic environment:
    a. Sale price of the pigs
    b. Feed cost
2. Monetary environment:
    a. Cost of capital
    b. Discount rate
3. Legislative environment:
    a. Taxes

There are the variables that we can be controlled inside of the operation:

1. Economic variables:
    a. Level of indebtedness
2. Technical variables:
    a. Prolificity
    b. Mortality
    c. Number of sows

In Table 1 all the analysed variables are presented. They are classified in economic and technical parameters. These variables are selected because they represent major factors affecting environment and economic performance of the farm. Under decision maker point of view inputs are either controllable (e.g. number of sows) or uncontrollable (e.g. taxes). As output variable was selected the NPV.

Biological parameters used in the analysis of sows boars and piglets come from the BD-porc data bank which is an official databank supported by the Spanish Ministry of Agriculture. This data source was considered suitable for the scope of the study. These data reflected the pig operation under Spanish conditions that is different from other countries as it is remarked by several authors (e.g. Chavez and Babot, 2001).

Table 1. Variables analysed.

Variable	Input/Output	Controllable/ Non controllable	Economic/Technical Parameter	Source
Sale price of the pigs (€/kg)	Input	Non controllable	Economic	DAR[4]
Taxes (%)	Input	Non controllable	Economic	Assumed
Level of indebtedness (%)	Input	Controllable	Economic	Assumed
Cost of capital (%)	Input	Non controllable	Economic	Bank of Spain
Feed cost (€/kg): Piglets (0-9 kg)	Input	Non controllable	Economic	Eurostat and DAR
Feed cost (€/kg): Feeder pigs (9-35 kg)	Input	Non controllable	Economic	Eurostat and DAR
Feed cost (€/kg): Pigs (35-110 kg)	Input	Non controllable	Economic	Eurostat and DAR
Feed cost (€/kg): Reproducing: Sows	Input	Non controllable	Economic	Eurostat and DAR
Discount rate (%)	Input	Non controllable	Economic	Bank of Spain
NPV	Output	Non Controllable	Economic	---------
Prolific ness/sow/parturition[5]	Input	Controllable	Technical	BD-porc data bank
% Mortality Piglets	Input	Controllable	Technical	BD-porc data bank
% Mortality Feeder pigs	Input	Controllable	Technical	BD-porc data bank
% Mortality Pigs	Input	Controllable	Technical	BD-porc data bank
Number of sows	Input	Controllable	Technical	Assumed

[4] The Catalan Department of Agriculture

[5] It is the expected productivity.

The Sale price of pigs is the average price extracted from annual series for piglets and feeder pigs from the auction market of Mercolleida and available at the Catalan Department of Agriculture (Generalitat of Catalonia: accessed http://www20.gencat.cat/portal/site/DAR). In the model, only direct taxes (Taxes) are considered. This means that taxes are derived from the benefits generated by the economic activity.

The Level of indebtedness[6] is the degree of indebtedness of the farm and stays constant during the period of analysis. It depends on the own resources of the farmer.

The variable Cost of capital shown in Table 1, is the cost of repayment of other people's resources that uses the farm (as much of the indebtedness to length as short term). The evolution of the average price from annual series of Madrid Interbanking Offered Rate (Mibor: accessed http://www.bde.es) + 0.5% is used to fix its value[7].

The average price from annual series of the feed cost (http://epp.eurostat.ec.europa.eu and http://www20.gencat.cat/docs/DAR/Documents accessed the 5/04/2007) is classified by type of animal as it can be seen in the previous table.

Within the economic domain, it is well known the difficulty and the importance of the determination of Discount rate to be applied in an investment. In fact, the necessity to determine a reliable discount rate by the analyst of the investment constitutes one of the weaknesses of NPV. The Mibor by 3 months (average price from annual series) was selected because it is an indicator commonly used in many financial operations (Discount rate= Mibor + 0,5%).

As stated, the output is summarised through the NPV of the cash flow over the first five years.

In Table 2, inputs for the basic situation are presented. Available data run from year 1995 to year 2005[8]. The values in the basic situation are values standard (not extreme values of the series of data or assumed). It is considered as basic a series of five consecutive years for the Sale price, Feed cost, Cost of

[6] We have to consider that: Long term debt =amount/liabilities.

[7] The period (1995-2005) in Spain is characterized by the indebtedness in the majority of the cases to a variable type of interest. The preferential reference is the Mibor or Euribor (Euro Interbank Offered Rate) increased in a percentage. The percentage varies depending on the client, year in individual or organization. To simplify we have generalized it to a 0.5%. In addition, we have chosen by the Mibor to 3 months, being one more a more dynamic reference, and very used. As the Euribor did not exist during all the period of analysis, we have used the Mibor that yes has existed all the period. In addition, the difference between the value of the Euribor and the Mibor is despicable with the object of calculation.

[8] The series of data ranges from years 1995 to 2005. We have made annual averages for the different calculations.

capital and Discount rate. When the analysis considers the Taxes and the Level of indebtedness, the values are taken constant in the basic situation during the all five years of the analysis. The taxes changes are not frequent and the level of indebtedness is a strategic decision. The technical parameters are constant because they change slowly. In addition they determine the structure of the sow farm, and if we change them sharply it would be another sow farm.

Table 2. Values of the variables in the basic situation.

Variable	Input values: basic situation				
Economic parameters	1st year	2nd year	3rd year	4th year	5th year
Sale price of the pigs (€/kg)	1.09	1.21	1.25	0.89	0.83
Taxes (%)	30.00	30.00	30.00	30.00	30.00
Level of indebtedness (%)	55.00	55.00	55.00	55.00	55.00
Cost of capital (%)	4.50	3.68	5.28	4.58	3.99
Feed cost (€/kg): Piglets	0.35	0.34	0.31	0.33	0.33
Feed cost (€/kg): Feeder pigs	0.21	0.20	0.19	0.20	0.20
Feed cost (€/kg): Pigs	0.21	0.20	0.19	0.20	0.20
Feed cost reproducing (€/kg): Sows	0.21	0.20	0.19	0.20	0.20
Discount rate (%)	4.50	3.68	5.28	4.58	3.99
Technical parameters					
Prolific ness/sow/parturition	10.40	10.40	10.40	10.40	10.40
% Mortality Piglets	0.15	0.15	0.15	0.15	0.15
% Mortality Feeder pigs	0.07	0.07	0.07	0.07	0.07
% Mortality Pigs	0.04	0.04	0.04	0.04	0.04
Number of sows	240.00	240.00	240.00	240.00	240.00

4.2 Scenario Analysis

In Table 3 the two scenarios generated are presented. The scenarios generated are the better and the worse.

Table 3. Values of the variables in the better and worse scenario.

Variable	**Better**					**Worse**				
Economic parameters	1st year	2nd year	3rd year	4th year	5th year	1st year	2nd year	3rd year	4th year	5th year
Sale price of the pigs (€/kg)	1.31	1.02	0.96	1.04	1.07	1.21	1.25	0.89	0.83	1.07
Taxes (%)	20.00	20.00	20.00	20.00	20.00	40.00	40.00	40.00	40.00	40.00
Level of indebtedness (%)	30.00	30.00	30.00	30.00	30.00	70.00	70.00	70.00	70.00	70.00
Cost of capital (%)	4.58	3.99	2.84	2.78	2.83	10.50	7.86	5.70	4.50	3.68
Feed cost (€/kg): Piglets	0.31	0.33	0.33	0.30	0.33	0.38	0.37	0.35	0.34	0.31
Feed cost (€/kg): Feeder pigs	0.19	0.20	0.20	0.18	0.20	0.23	0.22	0.21	0.20	0.19
Feed cost (€/kg): Pigs	0.19	0.20	0.20	0.18	0.20	0.23	0.22	0.21	0.20	0.19
Feed cost reproducing (€/kg): Sows	0.18	0.19	0.19	0.17	0.19	0.22	0.21	0.20	0.19	0.18
Discount rate (%)	4.58	3.99	2.84	2.78	2.83	10.50	7.86	5.70	4.50	3.68
Technical parameters										
Prolific ness/sow/parturition	10.85	10.85	10.85	10.85	10.85	10.00	10.00	10.00	10.00	10.00
% Mortality Piglets	0.05	0.05	0.05	0.05	0.05	0.25	0.25	0.25	0.25	0.25
% Mortality Feeder pigs	0.06	0.06	0.06	0.06	0.06	0.08	0.08	0.08	0.08	0.08
% Mortality Pigs	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.05	0.05
Number of sows	265.00	265.00	265.00	265.00	265.00	215.00	215.00	215.00	215.00	215.00

The better scenario have been generated with the values of all most favourable variables and the worse scenario was generated with the values of all the most unfavourable variables.

In order to generate the better and worse scenarios, five consecutive years with low or high values from the series of data have been selected to build the corresponding series of values by scenario (Sale price, Feed cost, Cost of capital and Discount rate).

In the Taxes, Level of indebtedness and technical variables the better and worse values are constant during the five years. The better and the worse values are good or bad values reasonable that can take the variables on the basis of the series of date or the experience. In this study a better value in the Level of indebtedness is a low value (30%) and a worse value is a high value (70%). As observed in Table 3, a better value in the Number of sows is a high value (265) and a low value is worse (215).

As observed in Table 4, a positive NPV is obtained for any scenario. Then, the activity is always viable. In addition, it is observed the great variability of the NPV based on scenarios. So depending on the parameters used varies greatly NPV, regardless the viability of the operation.

Table 4. NPV in the worst scenario (values of all the most unfavourable variables), basic (values considered like basic) and in the best (values of all the most favourable variables).

Worst scenario	Basic scenario	Best scenario
15,410.00 €	237,607.22 €	484,852.09 €

4.3 Sensitivity Analysis

A sensitivity analysis was carried out to analyse the impact of various input values on the net present value (NPV) and production of the farm under study. Only one variable is modified at a time, while for the other variables the basic, better or worse values are used. Results of the sensitivity analysis are presented in Table 5.

In Table 5 it can be seen that the NPV is much more sensitive to changes in the different variables in the worse situation. Likewise there is a greater sensitivity of the NPV compared with variations of the variables in the basic situation that in the best situation.

As shown in Table 5 the variables that have a high impact in NPV are:

1. Sale price of the pigs: given the main source of income depends on this variable.
2. Feed cost (Pigs): given the main production cost is related with animal feeding.
3. Litter size per sow: when prolificity increases the productivity increases as well, generating more sales and income.

4. Mortality rate of Piglets: it affects reducing litter size, then it reduces productivity, production, and incomes. The rest of technical variables have a very small impact in the production.
5. Number of sows: when herd size varies the production does the same in the same sense, e.g. generating more sales and income when increasing.

These variables as shown in Table 5 have an impact much more than proportional. For example, an increment of 1% of Sale price of the pigs supposes an increase of 5% of the NPV in the basic situation. Therefore, they are variable to control, because small fluctuations generate great variations in the NPV. The NPV is not elastic to variations of the other variables.

Table 5. Results of the sensitivity analysis in the NPV and the production of variations of 1% in the variables in the better, basic, and worse situation.

Variables	Better situation		Basic situation		Worse situation	
Economic parameters	NPV (€)	Production (number pigs)	NPV (€)	Production (number pigs)	NPV (€)	Production (number pigs)
▲1% Sale price of the pigs (€/kg)	**▲3.8%**	**----**	**▲5.0%**	**----**	**▲35.4%**	**----**
▲1% Taxes (%)	▼0.1%	----	▲0.0%	----	▲6.7%	----
▲1% Level of indebtedness (%)	▼0.1%	----	▼0.2%	----	▲4.8%	----
▲1% Cost of capital (%)	▼0.1%	----	▼0.4%	----	▼6.5%	----
▲1% Feed cost (€/kg): Piglets	▼0.0%	----	▼0.1%	----	▼0.5%	----
▲1% Feed cost (€/kg): Feeder pigs	▼0.4%	----	▼0.6%	----	▼4.5%	----
▲1% Feed cost (€/kg): Pigs	**▼1.5%**	**----**	**▼2.0%**	**----**	**▼15.2%**	**----**
▲1% Feed cost reproducing (€/kg): Sows	▼0.1%	----	▼0.2%	----	▼1.5%	----
Technical parameters						
▲1% Prolific ness/sow/parturition	**▲1.8%**	**▲1.0%**	**▲2.3%**	**▲1.0%**	**▲14.4%**	**▲1.0%**
▲1% % Mortality Piglets	**▼1.9%**	**▼1.0%**	**▼0.5%**	**▼0.2%**	**▼16.1%**	**▼1.0%**
▲1% % Mortality Feeder pigs	▼0.1%	▼0.1%	▼0.2%	▼0.1%	▼1.8%	▼0.1%
▲1% % Mortality Pigs	▼0.1%	▼0.0%	▼0.1%	▼0.0%	▼1.0%	▼0.1%
▲1% Number of sows	**▲1.2%**	**▲1.0%**	**▲1.6%**	**▲1.0%**	**▲7.9%**	**▲1.0%**

Table 6 contents values of the different parameters that cause a NPV=0. The Sale price of the pigs has a value that question the economic viability of the operation (0.77-0.86-1.00 €/kg) that can fall into the range of values that have been taken as basic for that variable (0.83-1.09 €/kg).

Feed cost (Feeder pigs and Pigs) may affect the viability of the operation because the value that question the economic viability of the operation (0.26 €/kg for Feeder pigs and 0.22 €/kg for Pigs in the worse situation) is not in the range of values considered as basic (0.19-0.21 €/kg for Feeder pigs and pigs), but it is near in the worse situation. A scenario where the combination of drought and the utilization of cereals for the production of bio fuels, provokes an important increment in feed cost (increases near the 100%). Some producers have pointed this possibility this year (2008), and in this case, they arrive at the levels that conditioned the viability of the sow farm. This fact would introduce to new exogenous variable in the model that should be an object of study because our series of data finalizes year 2005.

The rest of values of variables that may affect the viability of the operation are very unlikely, and consequently they are theoretical, but not feasible values in normal conditions. This would only be possible if diseases leading an increase of mortality rates of the animals (including the sows) in a very important form.

Table 6. Value of the parameters that cause a NPV = 0 (in the better, basic and worse situation), basic values and possibility that occur.

Variables	Value that it causes NPV=0				
Economic parameters	**Better situation**	**Basic situation**	**Worse situation**	**Value Basic**	**Possible/Impossible**
Sale price of the pigs (€/kg)	**0.77**	**0.86**	**1.00**	**(0.83-1.09)**	**POSSIBLE**
Taxes (%)	--	--	--	0.30	IMPOSSIBLE
Level of indebtedness (%)	--	--	0.85	0.55	IMPOSSIBLE
Cost of capital (%)	37.00	18.00	8.00	(3.5-5.5)	IMPOSSIBLE
Feed cost (€/kg): Piglets	10.10	6.50	1.10	(0.31-0.35)	IMPOSSIBLE
Feed cost (€/kg): Feeder pigs	**0.69**	**0.53**	**0.26**	**(0.19-0.21)**	**POSSIBLE**
Feed cost (€/kg): Pigs	**0.33**	**0.30**	**0.22**	**(0.19-0.21)**	**POSSIBLE**
Feed cost reproducing (€/kg): Sows	2.10	1.30	0.33	(0.19-0.21)	POSSIBLE
Technical parameters					
Prolific ness/sow/parturition	4.45	6.10	9.31	10.40	IMPOSSIBLE
% Mortality Piglets	0.57	0.47	0.29	0.15	IMPOSSIBLE
% Mortality Feeder pigs	0.48	0.38	0.13	0.07	IMPOSSIBLE
% Mortality Pigs	0.48	0.35	0.10	0.04	IMPOSSIBLE
Number of sows	33.00	92.00	188.00	240.00	IMPOSSIBLE

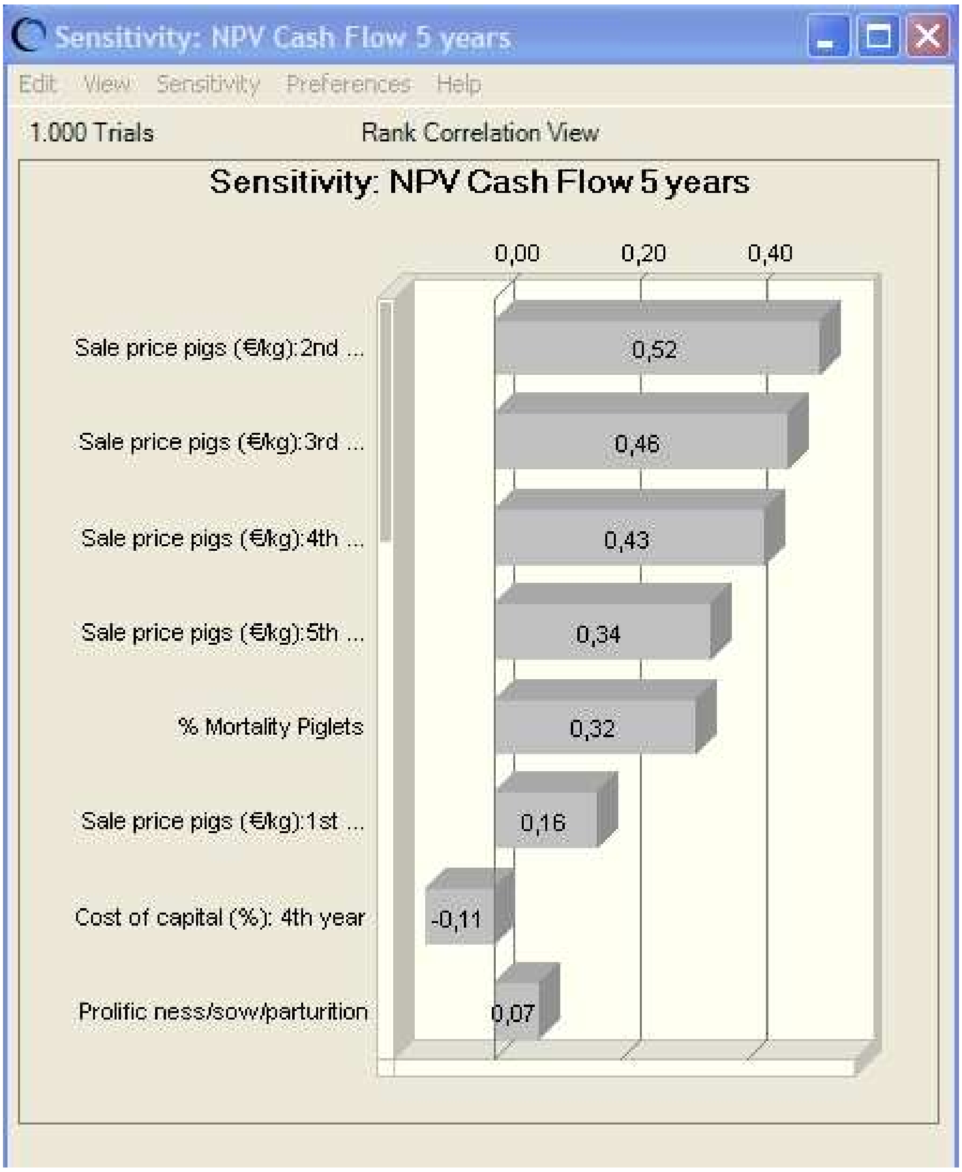
4.4 Stochastic Simulation

In order to make the analysis with Cristall Ball; all distribution of variables are considered as normal (normal distribution). The expectation is the value considered in the basic situation (determined in section 4.1). The standard deviation, the minimum and maximum, is the value of the standard deviation, minimum and maximum of the series of data. In the case of the Taxes, Level of indebtedness and Number of sows we have not a series of data. Then we have selected of average the basic value, an standard deviation of 10% and the minimum and maximum are the values that we have determined in Table 3 as better or worse (e.g. in the Number of sows the minimum is the worst, but in the Taxes the minimum is the better).

The variables more positively (influences positive) and negatively correlated (influences negative) with the NPV are shown in Figure 7. It emphasizes that the result is consistent with the variables are more influencing to the NPV determined in section 4.3 (Sale price pigs, % Mortality Piglets and Prolific ness/sow/parturition) . It is only possible to emphasize that in this analysis of with an elevated negative correlation appears Cost of capital but in the sensitivity analysis it did not appear.

The consistency of results is logical, since in section 4.3 the variables selected with a more sensible NPV, were highly correlated with the NPV. At heart, there are two approaches different from the same idea.

Figure 7. Analysis with Cristall Ball: more correlated variables with the NPV.



Observing the percentiles since there is more of a 90% of possibilities that NPV is positive, and by as much the operation it is viable.

Table 7. Value of NPV with an analysis with Cristall Ball.

Minimum	**Mean**	**Maximum**
-131,037.55€	222,212.89€	564,247.03€

Table 7 shows the NPV average and maximum similar to NPV in the basic and best scenario that it is obtained in the previous section (see Table 4) analysis with Cristall Ball can be performed. On the other hand, the NPV minimum (comparable to the NPV in the worst scenario of the previous section) is quite lower. This negative value of the minimum NPV did not happen in the case of the sensitivity analysis. This is because when defining the variables in this simulation extreme values like the lowest and highest of the data series have been used. There are extreme values (more extreme than the low and high value of the Table 3, because in Table 3 annual averages are used) that generate scenarios more extreme than in section 4.2. For example, in the variable of Sale price of the pigs we have a minimum value of the historical series of 0.54 €/kg that has been used of minimum value of the variable, but when generating the pessimistic scenario we used values of five years consecutive that in no case (as it is possible to be seen in Table 3) are so low. Therefore, the analysis with Cristall Ball operates with more extreme values (than they are not possible to be given habitually consecutively in the years), generating more variability.

Finally, in this analysis with Cristall Ball, the results are calculated using the values of the basic, worse and better situation (the three scenarios generated) as well as the expectation. Other parameters (the distribution, the standard deviation, the minimum and the maximum) are kept since it has been described before in this section. The results show that the mean of the NPV of the three scenarios are statistically different, confirming the validity and the impact of the scenario. For the same level of confidence, the variability of the NPV in the better situation is higher than in the basic and worse situation. This high variability is generated because in this scenario the farm has a big total production (great prolificity, high number of sows and low mortality) and therefore the variations in the sales prices affect more to the NPV, and generates more variability. In consequence, it is necessary to emphasize the strong impact of the scenario to perform the economic analysis of the sow farm.

5 Conclusions

Modern pig production is a multiphase operation: piglet production, rearing pigs and fattening pigs. Different facilities can be involved and final product for each phase may vary from firm to firm according to internal organization. Practical tools for analyzing different alternatives are needed. Different outputs have to be obtained for different purposes when starting the activity. All aspects of planned activity have to be analysed. These are financial analysis, cost production, technical rates, economic analysis, accounting analysis, etc. Spreadsheet models are usually deterministic what is an inconvenient, but the use of simulation add-ins can improve the sort of analyses that can be performed. The use of this software is advantageous since it is available for any user.

This model will help us to the decision making on the creation of a new operation, the decision of a new investment or the extension of the operation. The model will obtain the NPV of that decision, but since it has been explained previously, it will show one detailed to economic and financial information based on our level (see Section 3) and necessities to us.

The AnaPorkDSS was written in MS Excel for Windows. The model was designed as a DSS tool to be used in analyzing complex pig production systems. Although it was initially developed to analyse pig farms systems found in Spain and using national accounting system, the model can be easily adapted to handle situations in other production regions where pig production is important.

The model as used in the previous sections to analyse a particular case is useful. The analysis of this particular case, based on relevant variables, and starting off of a basic situation, has become from the analysis of sensitivity and the scenarios.

The results of this analysis have determined as the variables (controllable variables and uncontrollable variables) affect to the viability of our operation, analysed through the NPV. We have been able determined quantitatively as they affect the Prolificity, the Number of sows, and the %Mortality Piglets to the NPV, within the controllable variables. These variables are determining, and therefore object to pursuit. Also we have quantified as three non controllable variables as they are Sale price and Feed cost Pigs can put in danger the viability of the operation, with the aggravating one of which we cannot control them (we are price accepting). Finally, we have determined the consistency of the operation in viability terms, with the peculiarity of the great variability of the NPV.

6 References

Chavez, E.R. and Babot, D., 2001. Evolución de la producción porcina en España en la última década (1990-99) y análisis comparativo dentro de Europa. Anaporc XXI (216), 52-69.

Rowland, W.W., Langemeier, M.R., Schurle, B.W. and Featherstone, A.M., 1998. A nonparametric efficiency analysis for a sample of Kansas swine operations. Journal of Agricultural and Applied Economics, 30, 189-199.

Chapter 5

Strategic and economic planning on pig farms

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Abstract

This paper presents the utility of a strategic planning tool that allows the user to assess and analyse the economic performance of a farrow-to-finish pig farm. The study is focused on providing financial insight to pig farmers regarding integration contracts. The aim is to support the decision making concerning the investment on the creation of a new family farm and assessing whether integration contracts are or not convenient to the farmer.

Vertically integration is rather common within the pig sector, but depending on the country. So that, pig farmers have to assess integration contracts and compare them with other commercial agreements mainly with abattoirs. The proposed strategic planning tool evaluates alternatives by calculating the Net Present Value (NPV) of a farrow-to-finish pig farm over a 10-year time horizon under different financial scenarios. A realistic case study of a typical farrow-to-finish farm in the region of Catalonia (Spain) was considered. Results show than when the sale price is less than 1.08 €/kg of live-weight the project becomes unprofitable in all the scenarios. Farmers under integration contracts appreciate the stability in revenues leaving aside the downside of variations in the sale price. The results suggest that it is advisable for farmers to enter into integration contracts. Finally, in all financial alternatives the investment for a farmer with an integration contract was consistent while for an individual producer the project would be only feasible with self-financing.

Keywords: economic analysis; net present value; pig farm; production planning; strategic decision-making.

1 Introduction

The importance of pig production for the Spanish economy is reflected by recent agricultural statistics for the Spanish swine industry. In 2012, it represented the 14.1% of the Final Agricultural Production (MAGRAMA, 2013). In Spain pig production is concentrated in specific regions like Catalonia and Aragon with the largest pig inventories (APPAVE, 2011; Babot et al., 2012). The number of small farms is higher than large farms, and dominated by small family farms, a 46% of farms had fewer than 120 sows in 2013 (El sector de la carne de cerdo en cifras, 2014). However, most of the pig production units are controlled by vertically integrated companies or cooperatives (Perez et al., 2009; Soldevila et al, 2009). Sow farms under integration contracts covers an 81% of farms in Aragon (APPAVE, 2011) and a 77% in Catalonia (Babot et al., 2012).

Herd management considers three planning horizons: operational, tactical and strategic (Shapiro, 2001). Operational decisions are those that are made on a day-to-day basis (e.g. the number of inseminations) and they have a very short term impact. Tactical decisions that have an effect in the medium term (e.g. culling rules for sows). Finally, strategic decisions involve long-term decisions (more than one year) and usually consider structural aspects. Such long-term decisions are often non-reversible and involve a significant cost like assessing the design of a new farm. Modern herd management needs appropriate Decision Support System (DSS) to improve or maintain their competitiveness. Hence, the objective of this paper is to illustrate the use of AnaPorkDSS (Ezcurra-Ciaurriz and Pla-Aragonès, 2011) to validate hypothesis involving strategic and economic planning on pig farms. The hypothesis is to check whether it is beneficial to the farmer the signature of integration contracts. In addition an analysis of the required bank financing is also performed.

2 Material and methods

The spreadsheet model AnaPorkDSS (Ezcurra-Ciaurriz and Pla-Aragonès, 2011) is used to make all the calculations presented in this study. The input data needed by AnaPorkDSS representing a common Spanish family farm is taken from the official Spanish Databank (Bdporc®, 2013). Sale prices are taken from the main pig auction market Mercolleida (Generalitat of Catalonia, 2013) and other minor parameters are borrowed from EUROSTAT (EUROSTAT, 2013). The appendix provides the values of the main inputs of the case study. AnaPorkDSS is used to perform an empirical analysis under three different financial alternatives assessing the interest of being an independent or integrated producer. The remuneration with the contract of integration was assumed depending on production. In the model, direct taxes and indirect taxes are also considered. The variable cost of capital is the cost of repayment of the loans (as much of the indebtedness to length as short term). Feed cost (see the Appendix) is calculated by type of animal (Eurostat, 2013 and GENCAT, 2010).

2.1 Problem description

Very few models have systematically addressed the economic analysis under the strategic planning point of view, and no model is focused on the study of a new farm and support to decide whether entering into production contracts is or not convenient for a family farm. AnaPorkDSS can operate as a deterministic or stochastic model and so it makes easier the economic analysis of several alternatives. The NPV and the Internal Rate of Return (IRR) are employed to compare production alternatives and support strategic decisions. Notice that NPV and IRR are two standard criteria to appraise long-term projects and capital budgeting, widely used throughout economics, finance, and accounting. Furthermore, AnaPorkDSS allows the inclusion of variables as the cost of capital, loans, discount rate and initial investment.

Recall the NPV is defined as a sum of present values of future cash flows during the lifespan of the project.

$$NPV(i) = \sum_{k=0}^{n} \frac{CF_K}{(1+i)^k} \quad (1)$$

where:

CF_k it is the net cash flow for the kth year of the investment project

i the discount rate

n time horizon of the investment project

The discount rate by default is of 5%. A time horizon of ten years is considered to calculate the NPV and IRR. IRR is defined from NPV as the value of discount rate that makes the NPV equal to zero:

$$\text{NPV (IRR)} = 0 \quad (2)$$

The simulation model considers settlement expenses, related to preliminary studies or administrative permissions apart to those operational. Usually, the farm is filled progressively with gilts entered in bands till the full capacity of operation (Martel et al., 2008). The prolificity of sows is affected by the parity number (see in Figure 1). Furthermore, the sow herd structure over time changes and it affects productivity of farm.

Figure 1. Prolificity in the parity (Fernandez et al., unpublished data).

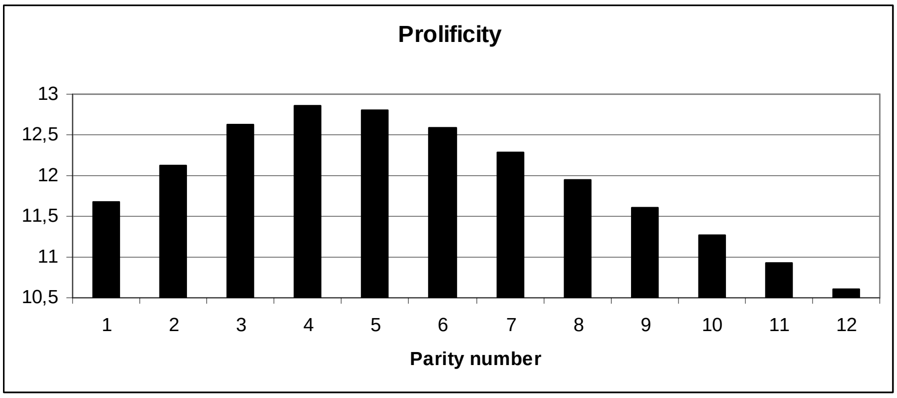


Figure 2 represents the scheme of the decision chain leading to create a pig farm, and see whether entering or not into an integration contract. Firstly, the analysis assumes that farmer signs a standard integration contract (Integration Contracts YES). In the second steep, three financial scenarios are analysed: "No loan" (develop a sow farm without debt), "Loan 5"(return period debt of five years) and "Loan 10" (return debt within 10 years). First the model is applied to the scenario “No loan”. The main model input parameters (Input data) are introduced, considering the initial costs of the activity (t = 0). The development of the activity for ten years (1≤t≤10) is simulated. The model generates different results (Results over ten years, Economic results and Production cost estimation). From these results, the model calculates the NPV and IRR. Secondly, in the second stage, the model is applied to the scenario “Loan 5” and finally to the scenario “Loan 10”.

From these results, it is performed a sensitivity analyses that finds out how sensitive the NPV and IRR is to any change in an input. Find the base case output (NPV o IRR) at the base case value of the input for which we intend to measure the sensitivity (such as Prolifity). We keep all other inputs in the model constant. The inputs for which we intend to measure the sensitivity are the Prolificity, the Sale price of the pigs and the Discount rate.

The analysis turns to iterate the process, whereas the sow farm was created without entering into an integration contract (Integration Contracts NO). With these results the value of NPV are: NPVi. NPVi is the value of the six alternatives:

(i) NPV_1: Integration contracts “YES” and “No loan”,

(ii) NPV_2: Integration contracts “YES” and “Loan 5”,

(iii) NPV_3: Integration contracts “YES” and “Loan 10”,

(iv) NPV_4: No integration contracts “NO” and “No loan”,

(v) NPV_5: No integration contracts “NO” and “Loan 5”

(vi) NPV_6: No integration contracts “NO” and “Loan 10”.

The following steep compare NPVi. The model determines: i) No creation pig farm: All NPVi is negative, the family sow farm is not viable, ii) Integration contracts are convenient: The NPVi for integration contracts exceeds NPVi for not integration contracts and iii) Integration contracts are not convenient: NPVi is less for integration contracts than NPVi without integration contracts.

Figure 2. Scheme of analysis decision to create a pig farm, and decide whether entering or not into integration contracts.

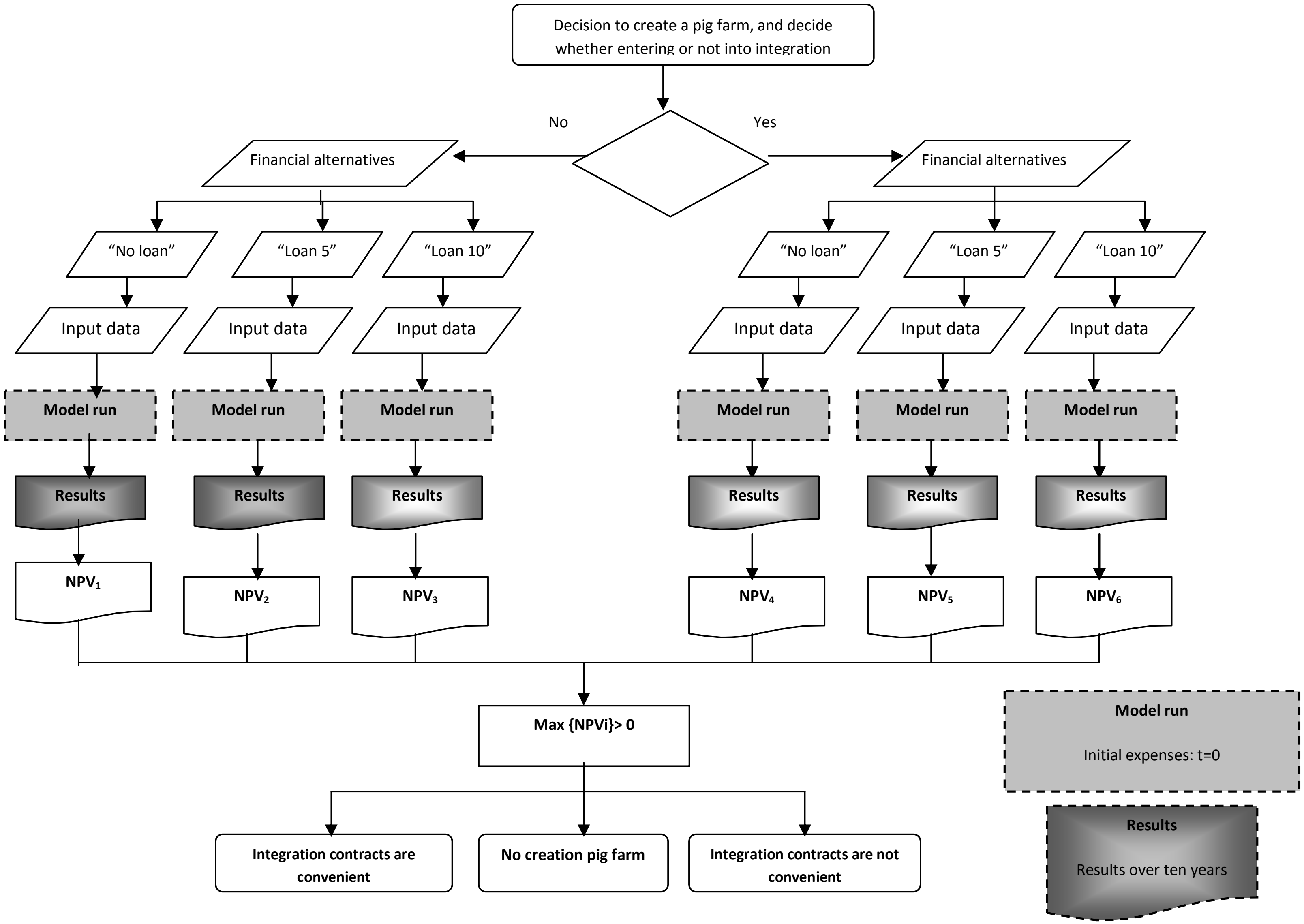
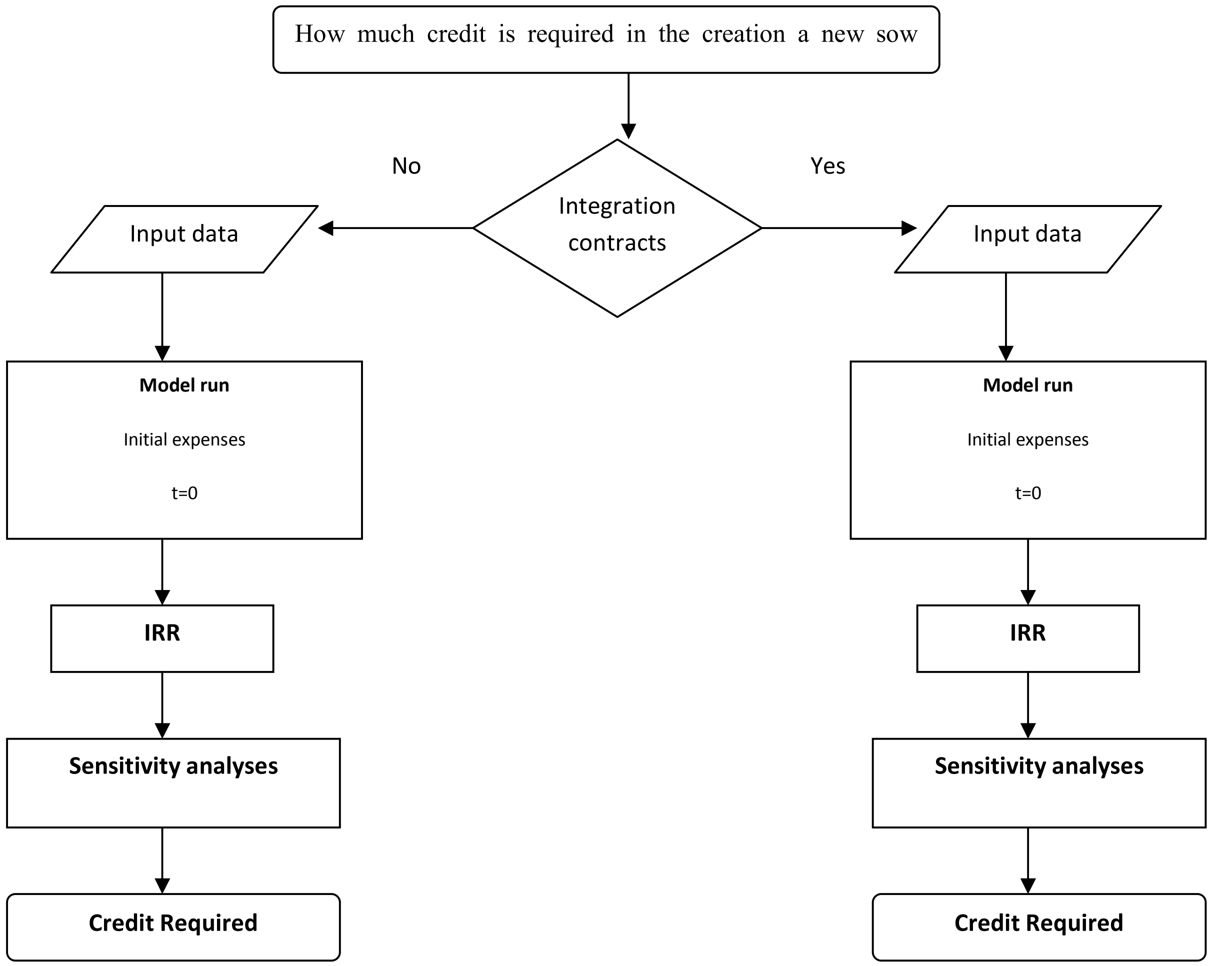


Figure 3 shows the analysis to determine the credit required, or the complementary self-financing, in the creation of a new sow farm. In the first steep, the analysis assumes that a farmer signs an integration contract (Integration Contracts YES). Main input parameters (Input data) are introduced, considering the initial costs of the activity at t = 0. Afterwards, the development of the activity for ten years (1≤t≤10) is simulated. The model calculates the IRR. In a second steep, a sensitivity analysis is performed to determine how sensitive the IRR is to any change in the own capital invested by the farmer. Finally determines the proper financial sources for the sow farm under integration contract. Subsequently, a similar analysis is performed to the farm without integration contracts (Integration Contracts NO).

Figure 3. Scheme of analysis: How much credit is required in the creation a new sow farm?



Within the economic domain, it is well known the difficulty and the importance of the determination of the discount rate to be applied to assess an investment. In fact, a reliable discount rate constitutes one of the weaknesses of the NPV. The discount rate reflects the opportunity cost of capital, defined as the expected return forgone by bypassing other potential investment activities for a given capital. The average Annual

Equivalent Rate (AER) from 2007-2012 in Spain was the 4% (BDE, 2013). So, we assumed a discount rate, i, of 5% based on the 4% of AER plus a spread of 1%.

2.2 Integration under different financial alternatives

Within an environment of crisis, there are strong restrictions by financial institutions to approve investment projects. In this context, it is considered very interesting to analyse the response of the project to different levels of financial availability.

To show the influence of different financial policies, an analysis on three financial alternatives is defined; namely:

(i) "No loan": no access to external financing.
(ii)"Loan 5": availability to external financing with a 5-year repayment term.
(iii) "Loan 10": availability to external financing with a 10-year repayment term.

2.3 Fitting own capital needs

To determine the necessary own capital, an analysis is performed (see Figure 3). To illustrate how variation on specific items impact on the credit required, an analyses of three parameters on the three financing alternatives is performed; namely:

(i) Prolificity (born alive/sow/farrowing): To see how the NPV are affected by this parameter, this parameter was changed after two models of prolificacy differ depending on the sow herd structure.
(ii) Sale price of the pigs (€/kg): To see how the solution by the model are affected by the sale price of the pigs, a feasible range from 0.80 € to 1.35 € was considered.
(iii) Discount rate: To illustrate the risk aversion factor influence into the decisions taken by the model, a sensitivity analysis on the discount rate was performed. This parameter was changed from 0% to 24% in 2% increments.

3 Results and discussion

3.1 Integration under different financial alternatives

Table 1 presents the NPV and IRR in the three financial alternatives considered. As shown Table 1 the investment project becomes unprofitable since NPV, as individual producer, is negative (so the IRR is greater than the discount rate). Therefore, the investment is only consistent for and individual producer if done with self-financing, with a 3% discount rate. The investment with a producer contract is profitable in the "No loan" and "Loan 5 years" financial alternatives.

The best alternative is the non-financing alternative, because there is no financial cost on capital. As expected, NVP is strongly dependent on the cost of capital. The second best alternative is "Loan 10 years", given that annuities to pay off the loan are divided over 10 years, longer than in the alternative "Loan 5 years". The scenario "Loan 5 years" generated a large treasury stress with a high financial cost.

In the three financial alternatives considered the NPV is greater for a producer with integration contract.

Table 1. NPV and IRR in the three financial alternatives.

	Individual producer		Integration contract	
	NPV (€)	IRR	NPV (€)	IRR
No Loan	-130,655.95	3%	84,641,85	6%
Loan 5 years	-608,785.73	--%	17,819,80	5%
Loan 10 years	-444,517.66	--%	-21,485,69	5%

Figure 4 shows the evolution of the gain per pig produced/sold for the three alternatives considered together the sales price of the pigs and the feed cost.

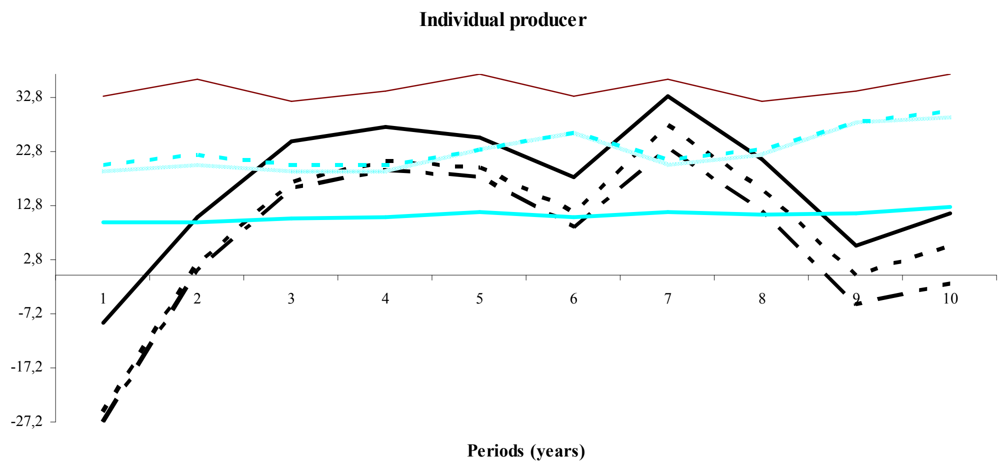
In the three alternatives considered the first period the gain per pig is negative because the first year of production are affected by the initial investment and start up. This period fixed cost and variable cost are higher than the income per pig sold. As expected, the best alternative is the non-financing alternative (not cost of capital), the second best alternative is "Loan 10 years", and the last alternative "Loan 5 years".

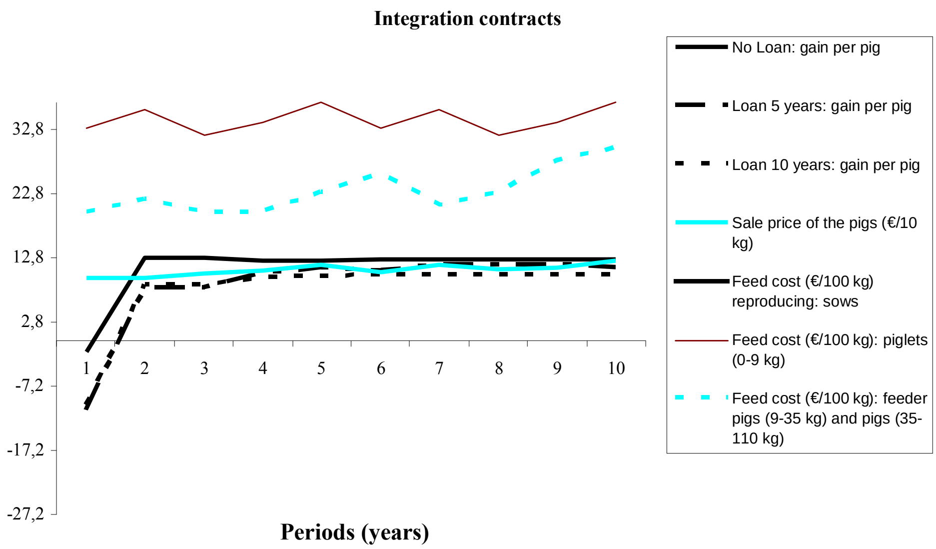
Figure 4 shows that gain per pig is strongly dependent on the feed cost for an individual producer. The gain per pig is affected by this parameter and decreases as the feed cost increases because the feed cost is the most important variable cost. The six and the nine year increase the feed cost and the gain per pig decreases.

By contrast, the seven year the gain per pig is the high because the feed cost decreases. Similar results were found with the TACT model (Alsop et al., 1994). In the "No Loan" alternative the gain per pig is positive (except the first year), but in the alternatives with external financing the gain per pig is negative (cost is higher than incomes) in any periods.

As expected, gain per pig is not dependent on the feed cost or on the sale price of the pigs for a producer with integration contract. The gain per pig is stable all the time. This is one reason for the farmer to accept this kind of contracts since they decrease the risk.

Figure 4. Comparasion among the three financing alternatives considered: gain per pig, sale price of the pigs and feed cost.





3.2 Fitting own capital needs

3.2.1 Prolificity

Ezcurra-Ciaurriz and Plà-Aragonès (2011) and Jalvingh et al. (1992) determine that changes in litter size have a large effect on income. Different prolificity curves calculated from commercial farms using the model proposed by Toft and Jorgensen (2002) were calculated. As show Figure 5, two models were generated (Model 1 and Model 2) based in these prolificity curves. They were used to estimate the economic impact of this variable. We estimate the technical and economic indices that define the productive performance of sows.

Figure 5. Prolificity sensitivity analysis in the two sow herd structures considered.

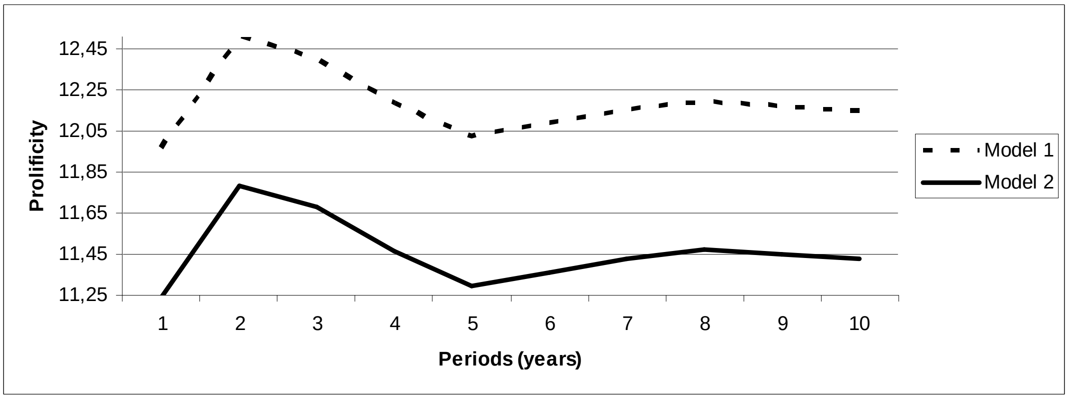


Figure 6 shows the production of pigs (and sales) associated with the Model 1 and Model 2. The differences in the production of number of pigs between two models are significant.

Figure 6. Production in the two population pyramid of sows considered.

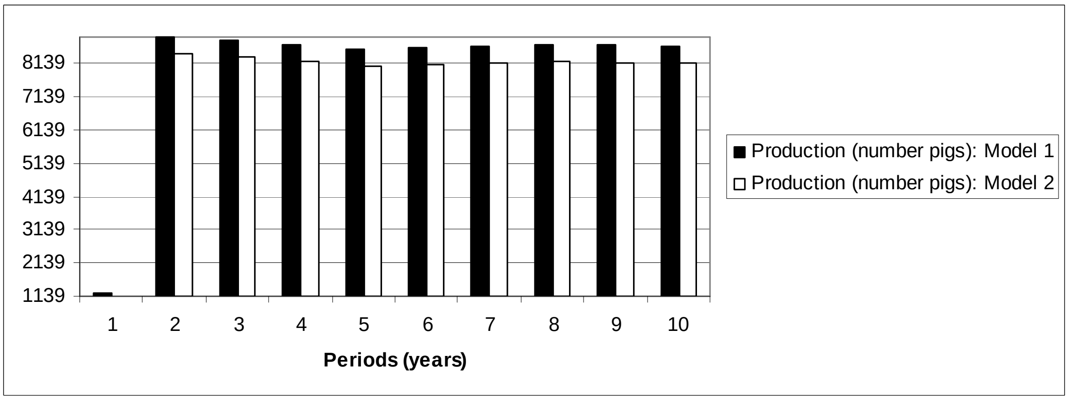


Table 2 shows that NPV is strongly dependent on the model of prolificacy because the variation in relation with basic situation is high. The NPV indicates that the determination of the sow herd structure determines the viability in the setting up of a new farrowing –to– finish farm. The variation in NPV is positive for Model 1 because the prolificity (and production) is higher than the basic situation. For the Model 2 the variation in NPV is negative respect the basic situation for a farmer with integration contract. In this case the prolificity and production are lower than the basic situation. Thus the incomes are lower however the fixed costs (cost of capital debt or amortization of buildings and equipment) are invariables, and then the variation in NPV is negative.

Table 2. Variation NPV in relation with basic situation showed in Table 1 (Loan 10 years) in the two population pyramid of sows considered.

	NPV (€)	
	Individual producer	Integration contract
Model 1	▲40.17 %	▲9.04 %
Model 2	▲8.04 %	▼530.00 %

3.2.2 Sale price of the pigs

Sale price is another important parameter in the economic analysis of the activity. Figure 7 shows that the NPV increases with the sale prices of the pigs. As expected it can be observed that the alternative "No Loan" (no cost of capital) is the best alternative when feasible.

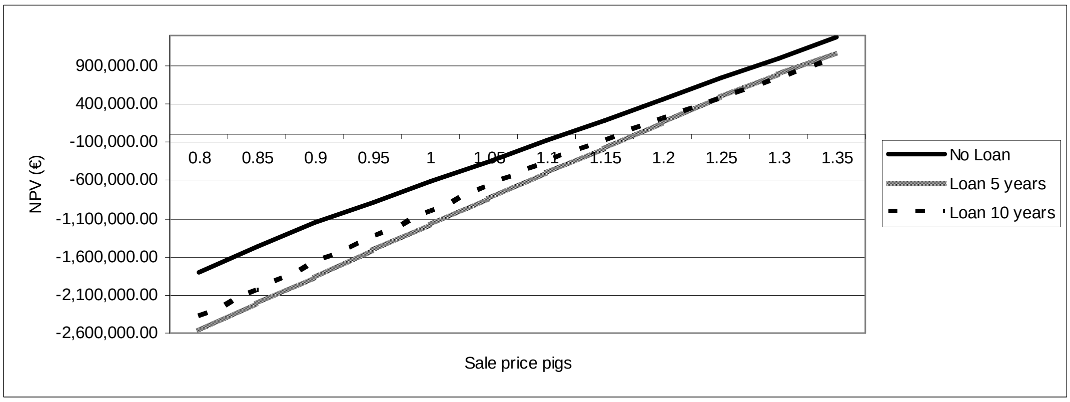
When the sale prices of the pigs is larger than 1.08 €/kg the project is profitable. In the others alternatives ("Loan 5" and "Loan 10") the project become acceptable when the sale prices of the pigs is larger than 1.15 €/kg. The difference between 1.08 and 1.15 is the cost of the external financing.

The economic result was very sensitive to changes in the value of fattened pigs sold. Changes in piglet price have a large effect on gross margin per sow per year (Jalvingh et al., 1992), and therefore NPV is very sensitive to changes in pigs price.

However, this is a factor over which an individual producer has little control (Alsop et al., 1994). When the sale prices is lesser than 1.08 €/kg for all scenarios the project becomes unprofitable.

The result is not sensitive to changes in the sale price of the pigs for a producer with integration contract.

Figure 7. Sale prices of the pigs: sensitivity analysis in the three financing alternatives considered for an individual producer.



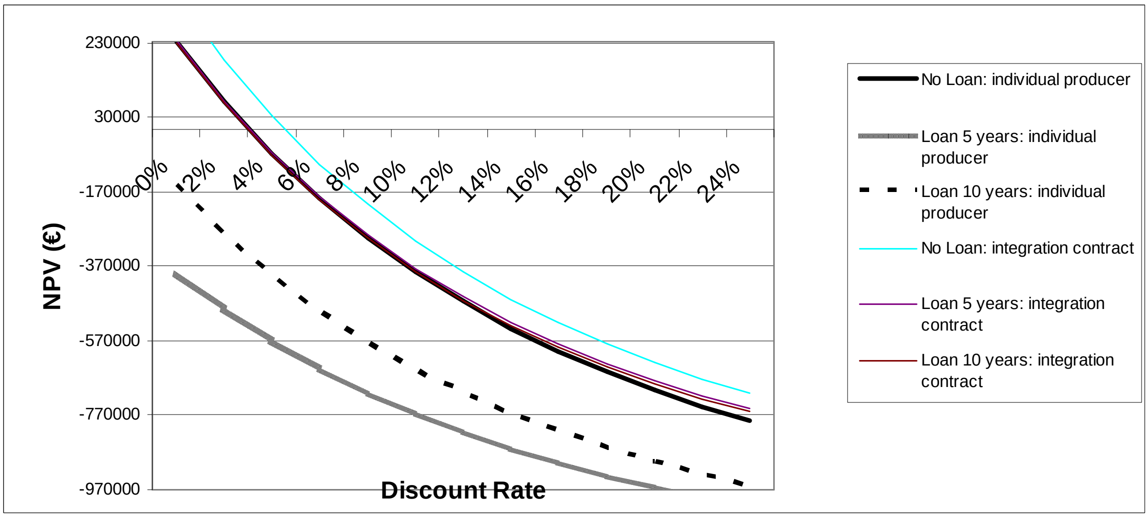
3.2.3 Discount rate

As expected, NPV is strongly dependent on the chosen discount rate. Figure 8 shows the influence of the discount rate on the NPV. This result is consistent with Rodriguez-Zas et al. (2006). This is due to the fact that the opportunity cost of the investments increases with the discount rate. The money used to invest is tied up for a long time, and therefore cannot be used for other purposes, whereupon it is less convenient to assign monetary resources to the project as the risk perception increases.

In the integration contract NPV is better than the NPV in the individual producer in the three alternatives (see Figure 8). For the individual producer and the integration contract the best alternative is the "No Loan" (non cost of capital).

If the risk aversion is low (low discount rate), the differences among the best alternative and the others is large. The difference among the best alternative and the others decreases as the discount rate increases.

Figure 8. Discount rate sensitivity analysis in the three financing alternatives considered.

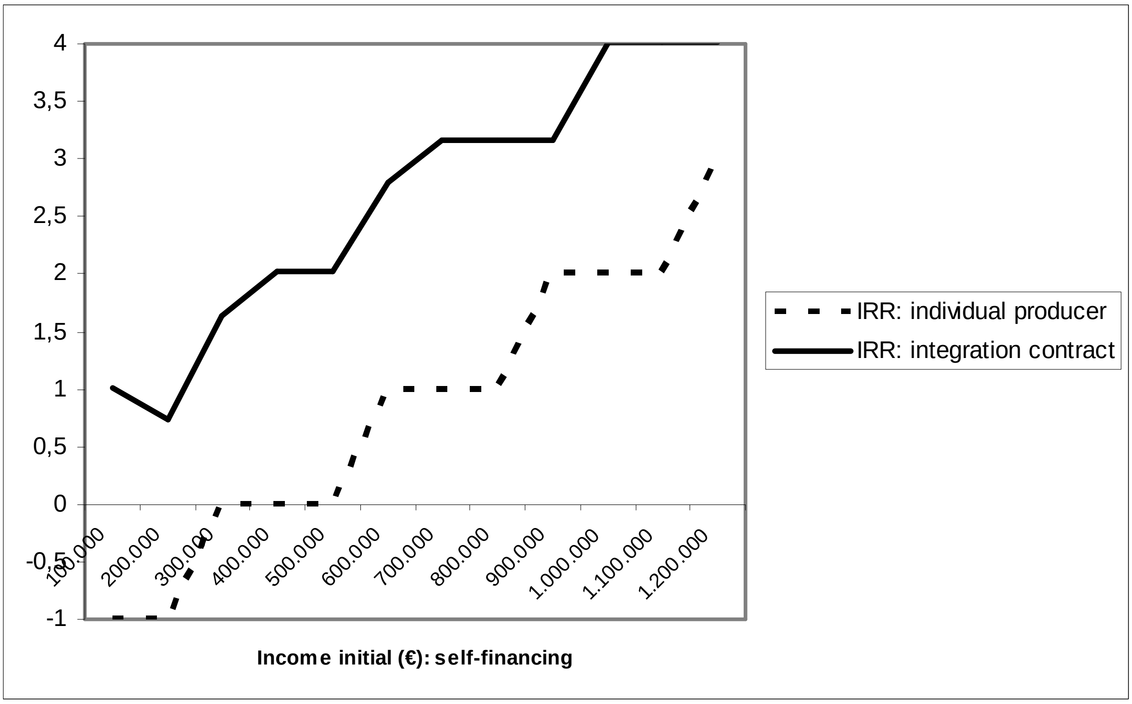


3.2.4 Required self-financing

This analysis is very useful when a farmer wants to apply for a loan from a bank. Based on this information, the bank determines own resources requires to have the farmer to give him funding. In an environment of low liquidity in the financial sector, this analysis can be very useful for both the pig farmer and banks analysts.

Figure 9 shows the influence of the self-financing on the IRR. Starting from the basic situation (see Appendice), with an income initial required of 1,263,905.12 €, is observed that in any event gets an IRR sufficient to cover the financial costs of borrowing (the cost of capital is 5.00 %). As a result, the financial institution not granted in this case credit to pig farmer.

Figure 9. IRR evolution on the basis of the income initial (self-financing).



4. Conclusion

The objective of this paper was to support the decision making concerning the economic viability of a new family farm. The analysis is based on the determination of the own capital required and assessing whether entering into integration contracts is or not convenient. Then, in all alternatives NPV with an integration contract is higher than NPV as individual producer. The results show that it is convenient enter into production contracts. The results of the analysis have determined how several variables affect to the viability of our operation, analysed through the NPV. Regarding analyses the investment is only consistent if done with self-financing, with a 3% discount rate for an individual producer. In all financial alternatives is consistent the investment for a farmer with an integration contract. As expected, the best alternative is the non-financing alternative (not cost of capital) for an individual farmer and for a farmer with an integration contract; the second best alternative is “Loan 10 years”, and the last alternative “Loan 5 years”. Second, the analysis presented that NPV is strongly dependent on the model of prolificity. NPV in a population pyramid of sows considered is -265,945.06 € for an individual producer (-19,543.87 € for integration contract), while with another pyramid of sows considered is -408,797.19 € (-135,360.17 € for integration contract). These values indicate that the determination of the sow herd structure determines the viability in the setting up of a new farrowing –to– finish farm.

Starting from the basic with an income initial required of 1,263,905.12 €, is observed that in any event gets an IRR sufficient to cover the financial costs of borrowing for an individual producer. As a result, the financial institution not granted in this case credit to pig farmer. For the pig farmer, in an integration contract, the financial institution granted credit in all scenarios.

Finally, yearly the sale prices is lesser than 1.08 €/kg for all alternatives the project becomes unprofitable for the individual farmer. This variable is very important, and the problem is that is a non-controllable variable. Farmer within an integration contract does not see is affected by variations in the sales prices.

5. Aknowledgements

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6. References

Alsop, J.E., Rafues, J.B., Keith, I.R., Koopman, W., Jalvingh, A.W. and Dohoo, I.R., 1994. Implementation of a computer simulation swine tactical decision, support model in Prince Edward Island. Can. Ve. J., 35, 153-157.

APPAVE. 2011. Informe del sector porcino en Aragón. Ejercicio 2010. Retrieved from http://bases.cortesaragon.es/bases/ndocumenVIII.nsf/69b541b37a1f7fb0c12576d20031f70e/4a08148d2bcf1e50c1257b730031d304/$FILE/Informe%202010%20sector%20Porcino%20Aragon_1.pdf. (last access December 4th, 2014).

Babot, D., Soldevila, C., Cortés, A., Álvarez, J., García, E., Larrosa, K., Noguera, L., Contreras, D. and Blanco, G., 2012. Informe del sector porcino. Ejercicio 2011. Grupo Gestión Porcina (Departamento de Producción Animal, Universidad de Lleida). Retrieved from http://agricultura.gencat.cat/web/.content/de_departament/de02_estadistiques_observatoris/08_observatoris_sectorials/04_observatori_porci/informes_anuals/fitxers_estatics/op_inf_anual_2011_cast.pdf. (last access December 7th, 2014).

BDporc®, 2013. Sistema electrónico de acceso al Banco de Datos de Referencia del Porcino Español. Retrieved from http://www.bdporc.irta.es/index.jsp. (last access November 18th, 2013).

BDE, Banco de España. 2013. Retrieved from http://www.bde.es/clientebanca/tipo/entidades.htm. (last access November 18th, 2013).

El sector de la carne de cerdo en cifras. Principales indicadores económicos en 2013, 2014.Subdirección General de Productos Ganaderos. Retrieved from .http://www.eurocarne.com/daal?a1=informes&a2=indicadores_porcino_2014.pdf (last acess, January 7th, 2015).

Eurostat, 2013. Retrieved from http://epp.eurostat.ec.europa.eu. (last access May 31th, 2013.)

Ezcurra-Ciaurriz, X. and Plà-Aragonès, L.M., 2011. AnaporkKDSS: a decision support system to evaluate pig production economics. Proyecto Social: Revista de Relaciones Laborales. 14, 23-44.

Fernandez, Y., Bono, C., Babot, D., Pla, L.M., 2015. (in press) Impact of prolificity in sow replacement policies [Impacto de la prolificidad en las políticas de remplazo en explotaciones porcinas]. ITEA.

GENCAT, 2010. Generalitat de Catalunya. Retrieved from http://www20.gencat.cat/docs/DAR/Documents. (lass access June 4th, 2010).

Generalitat of Catalonia. 2013. Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi Natural. Retrieved from http://www20.gencat.cat/docs/DAR/DE_Departament/DE02_Estadistiques_observatoris/20_Observatori_Agroalimentari_de_Preus/03_Preus/01_Preus_en_origen/01_Preus_en_llotges_i_mercats/Fitxers_estatics_NOU/PLlotja_Ramaders/Catalunya/PO_Cat_Ramaders_2013.pdf. (last access June 4th, 2013).

Generalitat de Catalunya, 2013. Departament Agricultura i Ramaderia, Observatori Porcí. Retrieved from http://www.dssporci.udl.cat/es/economico.jsp. (last access June 26th, 2013).

Jalvingh, A.W., Dijkhuizen, A.A., Huirme, R.B.M. and van Arenkonk, J.A.M., 1992. Dynamic probabilistic modelling of reproduction and replacement management in sow herds. General aspects and model description. Agricultural Systems, 39, 133-152.

MAGRAMA. MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE. 2013. Retrieved from http://www.magrama.gob.es/es/prensa/13.10.24%20Arias%20Ca%C3%B1ete%20Congreso%20ANAPORC_tcm7-303777_noticia.pdf. (last access October 25th, 2013).

Martel, G., Dedieu, B. and Dourmand, J.Y., 2008. Simulation of sow herd dynamics with emphasis on performance and distribution of periodic task events. Journal of Agricultural Science, 146, 365-380.

Perez, C., De Castro, R. and Font i Furniols, M., 2009. The pork industry: a supply chain perspective. Br. Food J., 111, 257-274.

Rodriguez-Zas, S.L., Davis, C.B. , Ellinger, P.N. , Schimitkey, G.D., Romine, N.M. , Conner, J.F. , Knox, R.V. and Sothey, B.R., 2006. Impact of biological and economic variables on optimal parity for replacement in swine breed-to-wean herds. J. Anim. Sci., 84, 2355-2565.

Rodríguez, S. V., Faulin, J. and Plà, L. M, 2014. New opportunities of operations research to improve pork supply chain efficiency. Ann. Oper. Res., 219, 5-23.

Shapiro, J.F., 2001. Modeling the Supply Chain. Duxbury Applied Series-Thompson Learning., pp. 37.

Soldevila, V., Viladomiu, L. and Francés, G., 2009. Catalonian pork value chain's resilience: ready for environmental challenge? Retrieved from http://ageconsearch.umn.edu/bitstream/58134/2/Soldevila.pdf. (last access January 7th, 2015).

Toft, N. and Jørgensen, E., 2002. Estimation of farm specific parameters in a longitudinal model for litter size with variance components and random dropout. Livestock Production Science, Vol. 77, No. 2-3, PII S0301-6226(02)00061-1,175-185.

Appendices

Basic situation

Static variables: value assumed	Value
Sows lifetime (months)	33.38
% Annual replacement sows	0.36
Pig weight (kg)	110.00
Pigs for sale (%)	100.00
Remuneration farmer: integration contract (€/pig)	27.00
Veterinary services and medical supplies: reproducing sows (€/kg)	8.40
Veterinary services and medical supplies: piglets (€/kg)	3.10
Direct tax rate (%)	20.00
Indirect tax rate (%[***])	10.00 or 21.00
Cost of capital (%) long term	5.00
Cost of capital (%) short term	6.00
Loan: years repayment	10
Interest (%) on savings	1.00
Discount rate (%)	5.00
Income initial level	1,263,905.12
Debt (%)	50.00
Sow places	480
Buildings: lifetime (years)	10-20[†††]
Equipment or vehicles: lifetime (years)	10-18
Number employers full time	3

[***] Depending on the product: 10 or 21 %.

[†††] Range from 10 to 20 years.

Static variables: source BD-porc data bank	Value
Mortality piglets (%)	15.00
Mortality feeder pigs (%)	7.00
Mortality pigs (%)	4.00

		Value (for every year)									
Non static variables	**Source**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10 th**
Prolific ness/sow/parturition[‡‡‡]	Assumed	12.32	12.51	12.30	12.11	12.0	12.13	12.18	12.19	12.16	12.14
Sale price of the pigs (€/kg)	DAR[§§§]	0.96	0.96	1.04	1.07	1.16	1.05	1.16	1.11	1.13	1.24
Feed cost (€/kg) reproducing: sows	Eurostat and DAR	0.19	0.20	0.19	0.19	0.23	0.26	0.20	0.22	0.28	0.29
Feed cost (€/kg): piglets (0-9 kg)	Eurostat and DAR	0.33	0.36	0.32	0.34	0.37	0.33	0.36	0.32	0.34	0.37
Feed cost (€/kg): feeder pigs (9-35 kg)	Eurostat and DAR	0.20	0.22	0.20	0.20	0.23	0.26	0.21	0.23	0.28	0.30
Feed cost (€/kg): pigs (35-110 kg)	Eurostat and DAR	0.20	0.22	0.20	0.20	0.23	0.26	0.21	0.23	0.28	0.30

‡‡‡ It is the expected productivity.
§§§ The Catalan Department of Agriculture.

Acronyms

AnaPorkDSS: AnaPork Decision Support System. Strategic tool selected to optimize and perform an economic analysis in a farrow-to-finish pig farm.

BDE: Banco de España. National central bank and supervisor of the Spanish banking system.

Bdporc®: Base Datos Porcina. Electronic system which provides internet access and a set of AIDS to decision-making in the pig production.

DSS: Decision Support System.

Eurostat: European Statistical System. Directorate-General of the European Commission located in Luxembourg. Its main responsibilities are to provide statistical information to the institutions of the European Union (EU).

GENCAT: Generalitat de Catalunya. Regional Government of Catalonia.

IRR: Internal Rate of Return. The value of discount rate that makes the NPV equal to zero.

MAGRAMA: Ministerio de Agricultura, Alimentación y Medio Ambiente. Spanish Ministry of Agriculture.

NPV: Net Present Value. Accounting an assessment of the long-term profitability of a project made by adding together all the revenue it can be expected to achieve over its whole life and deducting all the costs involved, discounting both future costs and revenue at an appropriate rate.

Chapter 6
Conclusions

The objective of this Ph.D. thesis was to contribute to improve the production efficiency of the swine production, focused in sow farms. This has been achieved from two secondary objectives i) Analysis of technical and economic efficiency assessing the most important variables affecting efficiency and ii) proposing a model embedded into a DSS for the strategic planning. Figure 1 summarise briefly the conclusions of this research.

Figure 1. Conclusions of this research and chapters in which are based.

CONCLUSIONS
CHAPTER 2 **STRATEGIC PLANNING** 1. There is a lack of strategic models as DSS instrument.
CHAPTER 3 **SOW FARMS EFFICIENCY** 1. The computational and interpretative simplicity of DEA face stochastic methods makes DEA a more practical tool for benchmarking and analysis efficiency. 2. Regarding the analysis of efficiency in sow farms: a. sow farms analysed were generally revealed to be highly technically efficient b. efficiencies and the percentages of efficient DMUs are higher in this study compared with other published results from other countries c. the number of inseminations was found significant to explain efficiency scores in sow farms.
CHAPTER 4 **DECISION SUPPORT FOR STRATEGIC PLANNING: PROPOSED MODEL** 1. The proposed model help farmers to evaluate strategic decisions and asses the creation of a new farm.
CHAPTER 5 **DECISION SUPPORT FOR STRATEGIC PLANNING: APPLICATE PARTICULAR CASES** 1. Applicate the model to particular cases: a. analyse a particular case through the NPV: we have determined the consistency of the operation in viability terms, with the peculiarity of the great variability of the NPV b. production contracts are convenient for farmers c. sow farm, in an integration contract, is economically profitable enough to ask the financing banks and the capacity to return the loan. 2. Further research using this model: a. investigation of the success of production-based sow removal and replacement in the context of herd performance, b. economic analysis of the greenhouse gas emissions

The number of strategic models used in practice within the swine industry is still very limited (Chapter 2). One reason is that they fail to capture the actual needs of the farmers and to understand their decision-making in practice (Lindblom et al., 2014). In addition current management information systems in livestock farming are not well yet suited to support all important steps of the decision-making process. We propose the adoption of strategic models capable to calculating the technical and economic consequences of various decisions and management strategies over time for the farm. These models have to be sow farm-specific and available for use in practice. The farmer is not a computer expert or economist and therefore the model must be easy to use.

The intended adoption of strategic models to better plan farmer activities might represent substantial savings and increased efficiencies. In Chapter, 2 fifty-four economic models for the sow farms published from 1979 to 2015 were reviewed. Regarding modelling techniques and mathematical methods, simulation is the most dominant technique. Therefore, simulation models are preferred, making it also possible to gain insight into the consequences of sub-optimum decisions (Jalvingh et al., 1992).

Among the papers revised, most of them were focused in tactical and/or operational decisions. As the second component of production cost is the replacement of sows, most of tactical model considered sow herd dynamics.

Only the 13% of the models revised are developed in spreadsheet. In addition, the study reveals a lack of models developed in commercial software (i.e. spreadsheet). We propose the development and use in practice the models implemented in commercial software. An embedded model in commercial software is useful for simplicity and accessibility for the farmer.

As show Chapter 2, the hypothesis proposed in this thesis (Specific DSS for strategic decisions, suitable and accessible for farm or multisite closed cycle, has not been developed yet) is accepted.

We concluded that different economic measures have been used in literature to assess the economics of the pig production. Although the common results available of the papers were return (twelve models), profit (twelve works) and cost (eleven works).

Chapter 3 shows how for the estimation of economic and technical efficiency of pig farms of different sizes and with different outputs (feeder pigs or weaned piglets) can be estimated using parametric and nonparametric methods. Nonparametric methods (Data Envelopment Analysis or DEA) are more practical and intuitive than parametric methods. DEA is well suited to deal with this problem, as it is capable of handling multiple inputs and multiple outputs, measured in different units (Asmild et al., 2001). The computational and interpretative simplicity of DEA face stochastic methods make it a practical tool for agents such and individual farmer.

The sow farms analysed were generally revealed to be highly technically efficient (higher than 87% in all cases). The farms producing weaned piglets are more efficient that the farms producing feeder pigs (99% vs 87% with the parametric approach, and 93% vs 91% with VRS-DEA model). Considering that current levels of efficiency are quite high, it would be challenging and require a lot of effort to achieve further improvements. The pig farmers can benefit from imitating the production practices of the underlying benchmarks indicating the improvement potentials.

Scale efficiency was also very high showing that 58% of FPP and 45% of FPFP are small farms in which efficiency gains would be expected by increasing the size. In addition, farm-specific factors affecting productive inefficiencies from CRS-DEA and VRS-DEA models were explored using a Tobit model. Among the inputs, the size of the farm, feed consumed and number of inseminations were the most determinants of efficiency.

The above results validate that parametric and non-parametric approach is useful and equivalent to evaluate efficiency of a sample of pig farms (hypothesis propounded in this thesis).

Efficiency measures presented in this study are similar to other European studies. Efficiencies and the percentages of efficient DMUs are higher in Spain compared with other published results in other countries. In Spain, it has been observed a concentration of pig producers in the last years with a decrease in the total number of farms and an increase in the number of pigs per farm (Agostini et al., 2013; Ramsey et al., 2013). This fact can suggest a more homogeneous and competitive DMUs in the Spanish context dominated by vertically integrated companies.

AnaPorkDSS can answer the core of the identified problems of most DSSs. AnaPorkDSS is a DSS developed for small family farms: easy to use (Chapter 4 and 5). Although it was initially developed to analyse pig farms systems existing in Spain and using corresponding national accounting system, the model can be easily adapted to handle situations in other production regions where pig production is important. Model information was requested from Malawi for use in farms of this country.

The model is used to analyse a case study (Chapter 5). This analysis has determined how the variables (controllable variables and uncontrollable variables) affect to the viability of our operation, analysed through the NPV. We have been able to determine quantitatively how they affect the Prolificity, the Number of sows, and the %Mortality Piglets to the NPV, within the controllable variables. These variables are key variables, and therefore object to pursuit. Also we have quantified how three non-controllable variables like Sale price and Feed cost of Pigs can put in danger the viability of the operation, with the aggravating one of which we cannot control them (we are price accepting). Finally, we have determined the consistency of the operation in viability terms, with the peculiarity of the great variability of the NPV.

Chapter 5 shows that it is convenient enter into production contracts. An individual sow farm, in an integration contract, is economically profitable enough to ask the financing banks and the capacity to return the loan.

A simplified version (free access on http://www.dssporci.udl.cat/economico.jsp) of the AnaPorkDSS is used by the Government of Catalonia (Generalitat of Catalonia) and the University of Lleida (UdL) in the Economic Observatory of the pig sector in Catalonia (Generalitat de Catalunya, 2013). It is working on a version online more complete that serves as DSS for more advanced users.

Further research using this model is possible to an investigation of the success of production-based sow removal and replacement in the context of herd performance, an economic analysis of the greenhouse gas emissions.

References

Agostini, P.S., Gasa, J. Manzanilla, E.G., Da Silva, C.A. and de Blas, C., 2013. Descriptive study of production factors affecting performance traits in growing-finishing pigs in Spain. Spanish Journal of Agricultural Research 11(2), 371-381

Asmild, M. and Hougaard, J.L., 2001. Economic and Environmental Efficiency of Danish pig farms http://www.unioviedo.es/7ewepa/pdf/enveff.pdf (last access December 18th, 2014).

Jalvingh, A.W., 1992. The possible role of existing models in on-farm decision support in dairy cattle and swine production. Livestock Production Science, 31, 351-365.

Lindblom, J., Lundström, C. and Ljung, M., 2014. Next Generation Decision Support Systems for Farmers: Sustainable Agriculture through Sustainable IT. http://ifsa.boku.ac.at/cms/fileadmin/Proceeding2014/WS_1_1_Lindblom.pdf (last access 18th, 2014).

Ramsey, D., Soldevila-Lafon, V., Viladomiu, L., 2013. Enviromental regulations in the hog farming sector: A comparasion of Catalonia, Spain and Manitoba, Canada. Land Use Policy, 32, 239-249.

Publications

Articles in Scientific Journals

Ezcurra-Ciaurriz, X. and Plà-Aragonés, L.M., 2011. AnaporkKDSS: a decision support system to evaluate pig production economics. Proyecto Social: Revista de Relaciones Laborales, 14, 23-44.

Ezcurra-Ciaurriz, X. and Plà-Aragonés, L.M., 2014. Handbook of Operations Research in Agriculture and the Agri-Food Industry Volume 224 of the series International Series in Operations Research & Management Science, 307-327.

Contributions in Conferences

Ezcurra, X., Moltó, M., Plà, Ll.M., 2003. Technical efficiency sow farms: a comparasion of methods. Eight European workshop on efficiency and productivity analysis. Oviedo, Spain, September, 24-27.

Ezcurra X., Plà Ll.M., 2005. Análisis técnico-económico de explotaciones porcinas basado en simulaciones con hojas de cálculo.XXXVII JORNADAS DE ESTUDIO, XII SOBRE PRODUCCIÓN ANIMAL . Zaragoza, Spain, May, 11-12.

Babot, D., Soldevila, C., Abella, S., García, E, Ezcurra, X., Plà, L.M., 2010. Gestión Técnica y Económica de Explotaciones Porcinas: España y Catalunya en el contexto de Europa. X Congreso de la Asociación Latinoamericana de Veterinarios especialistas en Cerdos (ALVEC). Mendoza, Argentina, August, 8-11.