Farm-economic analysis of reducing antimicrobial use whilst adopting good management strategies on farrow-to-finish pig farms

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1. Introduction

Pig farming employs high amounts of antimicrobials (Dunlop et al., 1998; Callens et al., 2012; European Medicines Agency, 2013; MARAN, 2014; Rushton et al., 2014). A significant fraction of those are also administered in human medicine (Laxminarayan et al., 2013). Their extensive use in pig husbandry, as suggested by relevant studies, is linked to the selection and spread of resistant bacteria, which may be transferred interspecies through direct or indirect contact (Schwarz et al., 2001; Aarestrup, 2005; Chantziaras et al., 2014).

According to the most recent ESVAC report (European Medicines Agency, 2014), in 2012 Belgium was ranked 6th, out of 25 countries in the EU, in terms of the volume of sales of antimicrobials for food producing animals, the majority in pig production (Filippitzi et al., 2014). Unfortunately, more recent reports of antimicrobial surveillance in Belgium have shown that after a declining trend of the antimicrobial usage in food production animals, the consumption of such agents has increased by 1.3% in 2014 with respect to 2013 (BelVet-SAC, 2011, 2012, 2013, 2014). This is despite the efforts of the Center of Expertise on Antimicrobial Consumption and Resistance in Animals (AMCRA), whose guidelines are encouraged to be used by Belgian veterinarians to aid their judicious prescription of antimicrobial agents. These guidelines state, amongst others, that antibiotics cannot be used as substitutes for good hygiene, housing and appropriate feed. However, standard prophylactic antimicrobial treatments are often considered by farmers as an easier, cheaper and less labor-intensive way to prevent bad health conditions and to avoid repercussions on the productivity and, indirectly, on the farm-financial situation, compared to therapeutic treatments (Callens et al., 2012), or investments in infrastructure or disinfection on the farm (Filippitzi et al., 2014).

The relation between the use of antimicrobials and higher productivity is described in literature since the early 50's. However, it was already acknowledged that the farming conditions were inversely related to the productivity response to antimicrobials (Coates et al., 1951; Hill et al., 1953). Recent studies post 2000 demonstrate that the effect of antibiotics on productivity were lower than those from the early trials. Current production conditions in Europe, and most of the developed countries, have substantially improved in the last decades, consequently it is questionable whether the effect of antimicrobials on productivity will remain high (Rushton et al., 2015).

The adoption of general herd management strategies (e.g. biosecurity practices or specific vaccinations) can be noted as a more sustainable alternative to prophylactic antimicrobials (Postma et al., 2015). Moreover, higher levels of biosecurity are associated with improved average daily weight gain, feed conversion ratio and a decreased consumption of antibiotics (Laanen et al., 2013). As such, financial concerns seem to become a dominant factor for considering the adoption of biosecurity strategies (Visschers et al., 2015). On the one hand, veterinarians feel the need to give information about the economic impact of advised interventions (Gunn et al., 2008) while on the other hand, farmers have shown an inverse relationship between the willingness to adopt biosecurity practices and their estimated costs (Fraser et al., 2010). Farmers have shown interest in knowing the costs of biosecurity measures, as well as its benefits entailed (Laanen et al., 2014), but the lack of such insight still represents a limit, while such detailed information could foster awareness. To date, few studies have evaluated the economics of biosecurity compared to antibiotics. Two studies estimated the direct costs associated to the use of preventive strategies (Siekkinen et al., 2012; Miller and Dorn, 1990). Two cross-sectional studies, which also accounted for the indirect economic impact due to changes in technical parameters, found that farrow-to-finish pig farms who exhibited a higher biosecurity and health status were correlated with improved technical parameters and a higher economic margin (Corrégé et al., 2011; 2012) than the farms with lowest biosecurity status. The methodological weakness of these studies are the lack of a control group and their cross sectional nature, which may have caused an overestimation of the effect. This could be controlled with a longitudinal study.

This study aims to use a quasi-experimental longitudinal approach for assessing economic impacts of antimicrobial substitution for good management practices, in particular biosecurity strategies.

2. Materials and Methods

The overall approach was a quasi-experimental design (Harris et al., 2006), in which treated farms were matched, using propensity scores (Dehejia and Wahba, 2002) with control farms. The latter were selected from the Flemish Farm Accountancy Data Network (FADN), an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy. The treated farms received tailored advice regarding biosecurity, general management, vaccination and antimicrobial use. Technical parameters of pig production were recorded before and after the advice was supplied and implemented. To account for the technological progress of pig production and to reduce selection bias, propensity score matching (PSM) was used, which results in a difference in differences (DID), i.e. the treatment effect that is attributable to the improvement in biosecurity, general management practices, vaccination and the change in antimicrobials usage. This DID served as input data in a farm production-economic input-output model whereby differences in enterprise profit are calculated. Direct economic effects of improved biosecurity, increased vaccination and reduced antimicrobial use were determined using a cost accounting analysis based on interviews with farmers and various databases for prices and purchase costs, and also fed into the farm production-economic model. To account for the heterogeneity in the pig farming population, the economic input-output model was simulated for 11 virtual but representative farms, which were constructed out of the full FADN-sample of farrow-to-finish pig farms in Flanders for the years 2010, 2011 and 2012.

2.1. Treated farms' data collection

Out of 65 farms participating in the 'reduction of antimicrobials project', 50 were farrow-to-finish pig farms which were retained for the economic evaluation study. The treated farms were visited on 3 occasions between September 2010 and May 2014. On average 8 months elapsed between the 1st and 2nd visit and between the 2nd and 3rd visit. During the 1st visit, data on specific aspects of health management like the used vaccination scheme, characteristics of anthelmintic therapy, or performed diagnostic tests were collected. Furthermore, antimicrobial usage and biosecurity status were obtained. The biosecurity status of the farms was assessed using Biocheck.UGent. This is a risk-based weighted scoring system expressed from 0 to 100 for an objective evaluation of the biosecurity status of a pig herd, taking into account both internal and external biosecurity (Laanen et al., 2010, 2013). Data on the antimicrobial use was translated into a treatment incidence with the help of the ABcheck.Ugent calculation system (Timmerman et al., 2006; Postma et al., 2014). Data on technical performance was obtained through face-to-face surveys with the farmers, implying two technical parameters from the farrowing stage, litter size (LS) and farrowing index (FI) and two technical parameters from the finishing stage, average daily weight gain (ADWG) and mortality of the finishers (MF).

Based on the 1st visit information, a tailored advice plan was developed and disseminated to the farmers on the 2nd visit. This plan consisted of measures to improve internal and external biosecurity, general management, vaccination schemes and to reduce the use of antimicrobials. A follow-up of compliance to the given advice was conducted during 3rd visit. During this last visit, similar data as in the first visit were collected.

2.2. Propensity score matching of the control farms

Pig husbandry is a production system with rapid technological changes (Vrints and Deuninck, 2014) and therefore we cannot guarantee that the interventions implemented are the only reason behind the change in the technical parameters. More, our quasi-experimental approach may suffer from selection bias because treated farms were not randomly selected from the whole population of farrow-to-finish pig farms. To circumvent this problem, a methodology was introduced, PSM with DID estimation, which is, to the authors knowledge, novel in the field of animal health economics. Put simply, this technique searches for control farms in a database with an as equal as possible probability to be in the treatment group and matches each treated farm with such a control farm. The outcome of the PSM is the DID which accounts for the difference between the after-before difference in the treated group versus the control group.

Data on 117 farrow-to-finish pig farms were obtained from the Flemish FADN dataset for 2011 and 2012. Those served to extract a control group with similar baseline characteristics to the treated group after computing a propensity score, whereby the conditional probability of being treated conditional on observed baseline covariates was calculated (Rosenbaum and Rubin, 1983; Austin, 2011).

The analysis was conducted in the R (R development Core Team 2013) package matching (http://CRAN.R-project.org/package=Matching) in which a one-to-one nearest neighbor matching without replacing was used.

2.3. Direct net costs of the interventions

The direct net costs of the tailored advice were assessed using a cost accounting analysis. Prices on commodities (e.g. boots, gloves, disinfectant products, etc.) were gathered from an online web shop often used by Belgian farmers (http://www.agrologic.be). Veterinary costs, including the analysis of samples, were obtained from Animal Health Care Flanders. The time spent performing certain proposed intervention tasks (such as changing boots between departments) was gathered from previous literature, consultation with experts, assumptions and common sense. Some purchased commodities were durable inputs, this means they can be used over a period of years on the farm, and incurred fixed costs (e.g. boots, boards, brooms). Therefore, depreciation was accounted for with a straight line method (Rushton, 2009a).

Vaccination prices were obtained through a questionnaire sent to 2 veterinarians active in pig veterinary medicine.

Information on the antibiotic products used on the farms was obtained by asking the farmer for their prophylactic and curative treatments. Further, the invoices of the herd veterinarian, and/or the invoices from the feed mills on purchase of antibiotic products over the year preceding the visit was used. The prices (in €/g or €/ml) of the used antibiotic were multiplied by the amount of g or ml of antimicrobial used by the animals treated to calculate the costs of the antibiotics in the 1st and the 3rd visit.

2.4. Input-output production economic model

Besides the direct costs, the interventions may also have indirect economic consequences due to changes in technical performance. We accounted for these indirect effects with a production-economic input-output model operationalized in Excel (Van Meensel et al., 2010), of which gross margin is the main outcome. Gross margin is defined as the farm revenues from the output minus the variable costs attributable to it (Rushton, 2009b) and it is described in Eq. (1).

$$\text{Gross margin (GM)} = \text{Revenues} - \text{Variable costs} \qquad (1)$$

We needed to add several adaptations to this previously developed simulation model. First, since the adoption of some strategies incurred fixed costs due to the purchase of durable inputs which incurred depreciation and extra labor, as an opportunity costs, gross margin was an inadequate economic indicator for our goal. Therefore, the enterprise profit (Rushton, 2009b) which is defined as the gross margin minus the fixed costs, was a more suitable indicator (Eq. (2)).

$$\text{Enterprise profit} = \text{GM} - \text{Total Fixed Costs} \qquad (2)$$

Data on the total fixed costs incurred by the 11 representative farms was not available. However, it was assumed that the total fixed costs, excluding the fixed costs associated to the implemented interventions, were equal before and after the intervention which allowed us to estimate the difference in enterprise profit after versus before the interventions (Eq. (5)).

$$\Delta\text{Enterprise profit}_{\text{after}-\text{before}} = \text{GM}_{\text{after}} - \text{Fixed Costs Intervention} - \text{GM}_{\text{before}} \qquad (3)$$

In addition, the initial deterministic simulation model was also customized into a Monte-Carlo-based stochastic model with @Risk 6.0 (Palisade Corporation, California) which allowed to insert two types of stochasticity. The first type reflects price volatility of the input and output prices: feed for sows (€/kg), feed for piglet (€/kg), and finishers (€/kg), finishing pigs (€/kg) and sold piglets (€/piglet). Data on the volatility of the feed prices was extracted from the Belgian national statistics (statistics Belgium) likewise historical prices of finishing pigs and piglets were obtained from a Belgian feed company for the years 2010, 2011, and 2012.

The second type of stochasticity accounted for was uncertainty regarding the treatment effect on the technical parameters and regarding the direct net costs of the treatment.

Simulations were used to estimate the effect on the enterprise profit in 11 representative Flemish farrow-to-finish pig farms due to the change on the technical parameters and on the direct costs. The simulation started from the situation of the farm before the intervention and compared it to the simulated situation after the intervention was implemented. The final model was run with 1,000 iterations for each of the 11 representative Flemish farrow-to-finish pig farms. The mean, standard deviation and 95% confidence interval of the $\Delta\text{Enterprise profit}_{\text{after}-\text{before}}$ were estimated in €/average present finisher pig/year, €/finisher pig/year and €/sow/year.

3. Results

3.1. Descriptive statistics

A total of 48 of the 50 treated farms remained during the whole study period. Treated farms had on average more sows (301) than control farms (175).

3.1.1.Technical parameters

At baseline level, treated farms showed a slightly higher FI, LS and MF than control farms. After the second visit treated farms showed an improved LS, ADWG and MF.

3.2. Propensity score analysis

The MF was significantly lower on treated farms than on control farms (mean -1.13%, SE: 0.02).

3.3. Direct net costs of the interventions

The median of the total direct net costs on the treated farms was reduced by -€2.68 /sow/year between visits 2 and 3. This was mainly caused by a reduction in antimicrobial usage, especially on the prophylactic treatments administered to the piglets, leading to a reduction in costs, median -€7.68/sow/year, which showed a large variation between farms. Increased biosecurity and more vaccinations resulted in respectively €4.76/sow/year (median €3.96/sow/year) and €5.94/sow/year (median €0.00/sow/year) higher costs which had a smaller variation compared to the reduced costs on antimicrobials.

3.4. Enterprise profit

Without taking volatility of prices into account, farms presented on average +€107.47/sow/year higher difference of enterprise profit after the antimicrobial use was reduced than before. On the other hand, when the price volatility was accounted for, the difference of the enterprise profit after versus before the antimicrobial use lower than when volatility was not modelled, but it was still positive with +€2.45/finisher pig/year or +€39.21/sow/year.

4. Discussion

In this study the reduction of antimicrobial use, accompanied by improved biosecurity, optimized vaccination and general husbandry practices yielded a reduction in net direct costs between the 3rd and the 1st visit, which was mostly due to a reduction on the usage of prophylactic treatment for the piglets (Postma and Dewulf, 2013). This implies that prophylactic treatments entail high costs. In our study, the use of antimicrobials was replaced by the implementation of management strategies, namely biosecurity and new vaccinations. Their additional costs were lower than the eliminated costs associated with a reduction of antimicrobial use. Similar results were found by a recent randomized clinical trial which demonstrated that the efficacy of administering antimicrobial metaphylaxis in finishing pigs was limited to those with lowest starting weight, and even then the costs of the antimicrobials will surpass the benefits entailed due to improved productivity levels (Ramirez et al., 2015). Our results suggest that, in spite of the farmers' general perception (Callens et al., 2012), antimicrobials are not necessarily cheaper than investing in adjusting the management strategies of the farm. The results of this paper can be used by veterinarians to motivate pig farmers to reduce their current use of antimicrobial treatments and to shift to use more sustainable practices like biosecurity strategies or vaccinations.

The average Flemish farrow-to-finish pig farm exhibited better parameters in 2011 (ADWG=659.90 g/day, MF=3.30%, FI=2.20 farrowing/sow/year, LS=12.20 living piglets/sow/year) and 2012 (ADGW=652.80 g/day, MF=2.90%, FI= 2.30 farrowing/sow/year, LS=12.40 living piglets/sow/year) (Vrints and Deuninck, 2014) than our control farms, but worse than the treated farms. This may have been caused by selection bias, in which participants, who are the forerunners in the reduction of antimicrobial usage, may have had higher production technical parameters and may have been more prone to participate in such a project. We accounted for it by computing a propensity score and the DID, which is intended to eliminate some of the selection bias, to estimate the attributable effect of the implemented interventions on the technical parameters. The results are in line with results of previous studies in which pig farms with higher biosecurity status were associated with better technical parameters (Corrégé et al., 2011; Laanen et al., 2013). To the authors' knowledge, the present study is one of the few in the field of animal health economics that conducted propensity score analysis. Whereas this statistical technique is extensively used in agricultural economics (e.g., Mendola, 2007), and is described for the use in veterinary epidemiology by Dohoo et al., (2009), we could only find one article concerned with economics of animal health in which this methodology is performed to match a control group to a treated group (Key and Mcbride, 2014). In observational studies such as the present study, in which to conduct an experiment with random allocation of treatment is cumbersome, propensity score analysis demonstrated to be especially advantageous (LaLonde, 1986; Mendola et al., 2007).

With respect to the net income of pig farms, at the time of the preparation of this manuscript, price evolutions were, particularly adverse with high prices for the feed and low prices for the finishers. The situation has been more or less like this from 2007 till now (Anonymous, 2015). our results showed that enterprise profit was positive for both the model which accounted for volatility, which is more realistic, and for the model which did not account for volatility, which suggests that results are robust: even with volatile prices, on average for the 11 representative farms, the enterprise profit was +€2.45/finisher pig/year. Two cross-sectional studies in farrow-to-finish pig farms conducted in France found that farms which had the highest biosecurity status compared with those with the lowest were associated with an economic margin of €180/sow/year (Corrégé et al., 2011) and €200/sow/year (Corrégé et al., 2012). If our results are translated into the same units there was a difference of enterprise profit between the treated and control farms of €39.21/sow/year which is smaller than the effect observed by their studies. This may respond to the cross-sectional design of the studies and the lack of control farms, which may have led to an overestimation of the economic margin. Moreover, volatility of the inputs and output prices was not accounted for in their study which may explain why the net benefit is higher than the resulted from our model with price volatility (€39.21/sow/year) and more similar to the results from our model without volatility (€107.47/sow/year).

In our study, we demonstrated that reduced antimicrobial use is possible without hampering the enterprise profit, more, high probability exists that, depending on the prices of feed and meat, the net profit is higher for farms which reduced antimicrobial use. Because positive profitability impacts of management changes in an adverse market environment is even more important, the results of this study can be crucial to aid veterinarians and other stakeholders to incentive pig farmers to reduce their current use of antimicrobials.

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