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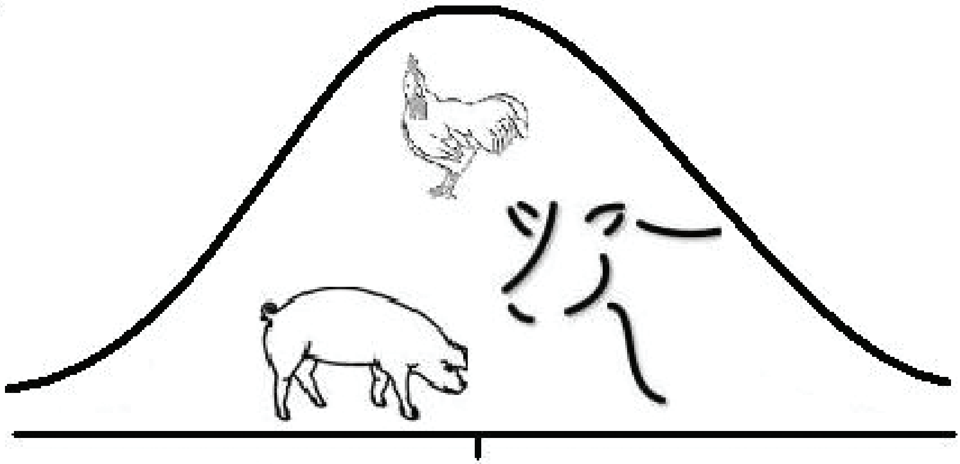

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Discovering real options in the optimal control of foot-and-mouth disease

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Introduction

As one of the most contagious animal diseases, epidemics of foot-and-mouth disease (FMD) pose recurrent threat to farm animal health and trade in livestock production of exporting countries (Tomassen et al., 2002). The last experience of FMD in the UK and the Netherlands rendered enormous financial loss in the economy as well as emotional uneasiness in the public (Woolhouse and Donaldson, 2001; Bouma et al., 2003).

Due to the common interest of FMD-free status, the EU has stipulated a minimal set of control measures, while leaving the option open for the member states to decide on taking additional control measures like pre-emptive culling or emergency vaccination (European Union, 2003). These additional measures, often of pre-emptive nature, are costly and controversial since their benefits are difficult, if possible, to ascertain. Among the lessons learned from last epidemics, the key issue is improving the quality of decision-making on these measures, particularly pre-outbreak and in the early stage of the epidemic (Anderson, 2002).

Risk and uncertainty are defining features of FMD epidemics (Keeling et al., 2001). The introduction and spread of FMD is a random process subject to biological and social variations. The uncertain situation is further compounded by the intervention of control measures and the responses of consumers, producers and trade partners in foreign countries. As a result, decisions have to be made under uncertainty. As an FMD epidemic develops over time, the management of FMD epidemic covers many periods as well. Consequently, a series of decisions have to be made corresponding to the specific phases of the epidemic. The consequences of control methods or strategies have been extensively modelled, simulated and evaluated (see for example, Berentsen et al., 1992; Jalvingh et al., 1998; Tomassen et al., 2002). However, an optimisation framework to support the dynamic and multi-stage decision making is still missing.

In the mean time, the development of real options theory offers new concepts and insights to the old problem of FMD control. The real options approach finds its root in financial option literature. In derivative markets, an *option* acquired at some cost gives the right but not the obligation for the holder to buy or sell an asset (*exercise the option*) at certain price before certain time (*maturity*). Holding an *option* instead of holding the asset prevents the holder from downside risk in future but enables them to capitalise in future favourable situation. In their path-breaking book “investment under uncertainty”, Dixit and Pindyck (1994) illustrate how this option concept could change investment decision rules in real investment projects (instead of stocks, hence the name “real options”). The real options approach addresses the option-like nature of many real investment opportunities which allows for the postponement and revision of decisions. The value of option comes from the flexibility it creates for the investor in choosing the timing and scale of the investment. In strategic planning, this gain from being able to wait or adjust plans according to new situation is called the value of flexibility, as further elucidated by Trigeorgis (1996). Being more flexible and realistic, real options approach has had successful applications in areas like natural resource management, R&D project evaluation (for example, Alvarez and Stenbacka, 2001) and shows great potential in evaluation and optimisation of multi-stage projects with uncertainty.

Given the insights from real options theory on sequential decision-making under uncertainty, the goal of this project is two-fold:

- To provide decision support for FMD control from real options point of view
- To explore a new area of application for real options theory, especially the possibility of generalizing it to the management of similar crisis events.

Road to Discovery

To “discover real options” in FMD control, the project relies on qualitative inputs from real options theory and computational support from Markov Decision Processes as well as FMD simulation models. The road map is as following:

- Starting: Theoretical analysis of the decision problem in FMD control
- Step 1: Defining and Indicating Value of Flexibility (With simple MDP model)
- Step 2: Modelling learning and multi-level decision process in FMD control with a Multi-level Hierarchic Markov Programming (MLHMP)
- Step 3: Fitting to reality: Parameter estimation from data or simulation outputs
- Finishing: Real Options Analysis

Results So Far

At the starting point, a systematic decision analysis is carried out on the decision problem of FMD control (Ge et al., 2006). To provide a frame of reference, we have adopted a ProACT framework which, besides addressing conventional elements like objective, alternative, consequences, trade-offs, particularly stresses the importance of uncertainty and linked decisions (Hammond et al., 1999). It is concluded that a flexible decision support is needed in which decision flexibility is taken into account.

In the next step, we try to answer the question whether flexibility, or the option to wait to decide on additional control measures, has value in the control of FMD epidemics. To this end, we have relied on decision models based on Markov Decision Processes to define and indicate the value of flexibility (Ge et al., 2005). Results show that flexibility can greatly influence the optimal control actions to taken and the control costs. Even though MDPs, combined with dynamic programming as a solution technique, had been successfully applied to optimise decisions for animal health management on farm level (e.g. Mourits, 2000), it is the first time that MDP is applied to animal health management on a national level.

The sequential approach and the stochastic nature of dynamic programming in the form of Markov decision processes make the method well suited for the quantitative support of decision-making in FMD control. Taking into account the fact that at a later stage, it is possible to observe the outcome from previous stages and get more information, expectations about the development of the epidemic might change. As a result, some previous assumptions might have to be modified, which might invalidate the previously simulated results. Specifically, the observation of the outcome from previous intervention will enable a Bayesian updating of the probability distribution about future. To fully describe the decision process and the learning process, the state space of MDP can easily explode and run into the famous *curse of dimensionality*. To circumvent this notorious dimensionality problem, various degrees of aggregation or decomposition are necessary. In herd management, a successful technique is coined Multi-level hierarchic Markov Decision Processes (MLHMP)(Kristensen and Jørgensen, 2000). In our Step.2, we applied this technique to model the various level of decisions in FMD control and the learning process (Ge et al., 2006).

Figure 1 shows the corresponding structure, in which the founder level of the MLHMP is a cycle of an FMD epidemic.

The outputs of such optimisation models indicate the optimal timing of the control measures as well as their performance with regard to the chosen objective. Again, it is shown that waiting is the optimal action when the level of uncertainty is relatively high and learning effect is significant.

Step.3 is a natural follow-up of previous steps. To estimate the parameters needed for real-life application, both real data and simulation outputs can be used. At this moment, research is going on to exploit the possibility of using Markov Chain Monte Carlo (MCMC).

As a finishing step, we will try to connect the previous findings with the theory of real options and analytically derive insights for the choice of timing for some control actions. The available control actions resemble investment projects that have future rewards in the form of avoided loss in the economy and society. Whether and when to take on these actions depend on the comparison of their option value and their immediate return. The option value of a project (action) depends on its exercise price-(the up front costs associated with the implementation of the measure) and the value of the underlying asset (the value of the loss avoided by the prevention or control measures). By calculating these option values, it can be determined whether the option is *in the money* or *out of the money*. If an option is deep in the money, it should be exercised, i.e. the control measures should be taken; if an option is *out of the money*, the action should be postponed so long as the option is not expired.

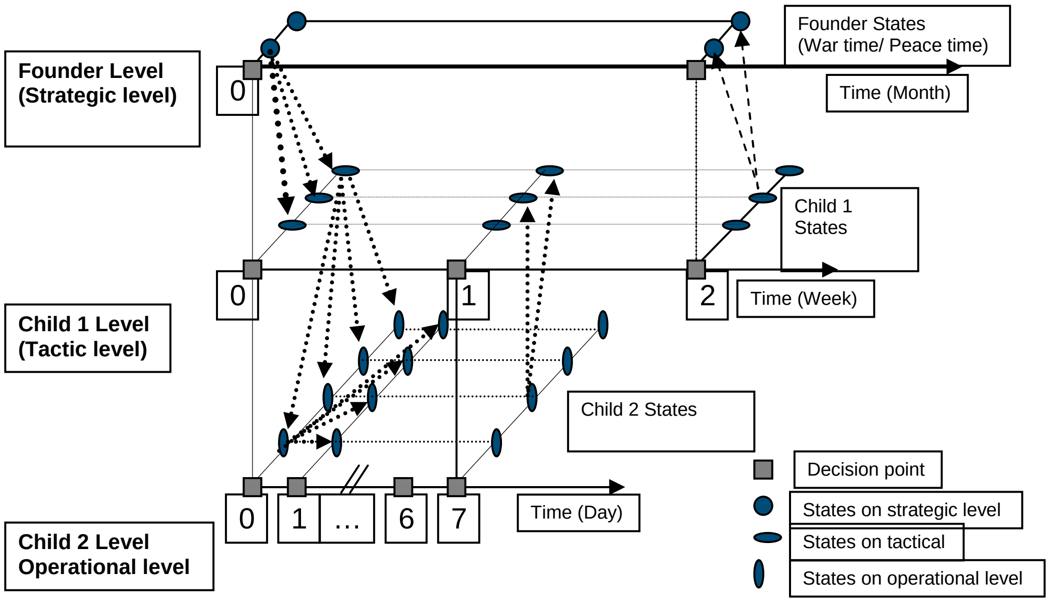

Figure 1. An overview of the decision space and state space in the MLHMP model.

Conclusion and Discussions

This project challenges traditional evaluation methods of FMD control measures. Three salient innovative aspects of this project are:

- The recognition of decision flexibility and strategic options in FMD control
- A novel application of real options approach from corporate investment decisions to the control of contagious animal disease at national level
- An integrated treatment of risk and uncertainty in an optimisation framework

Using MDP as a decision model, the value of flexibility under various circumstances can be assessed by incorporating the option of waiting to take on more control measures. With a hierarchic structure of MDP, decisions of different time-horizon can be simultaneously optimized and generate a contingency plan on strategic, tactic and operational level. This project confirms the great potential of MLHMP in providing decision support to complex real-life decision problems.

The project develops and applies the theory of real options to a new genre of real-life problem: the control of contagious animal diseases. The results of this project will be of great fundamental value as it will provide a coherent analytical and computational framework for decision-making in the case of contagious animal disease control like FMD or management of similar crisis events.

References

Alvarez, L.H.R., Stenbacka, R., 2001. Adoption of uncertain multi-stage technology projects: a real options approach. J. Math. Econ. 35, 71-97.

Anderson, I., 2002. Foot and Mouth Disease 2001: Lessons to be learned inquiry report. London, The Stationery Office.

Dixit, A.K., Pindyck, R.S., 1994. Investment under Uncertainty. Princeton, New Jersey, Princeton University Press.

European Union, 2003. Council Directive 2003/85/EC of 29 september 2003 on Community measures for the control of foot-and-mouth disease repealing Directive 85/511/EEC and Decisions 89/531/EEC and 91/665/EEC and amending Directive 92/46/EEC. Official Journal of the European Union L306.

Ge, L., Kristensen, A.R., Mourits, M., Huirne, R.B.M., 2006. The "Curse of Animal Disease" and the "Curse of Dimensionality": A New Decision Support Framework for the Control of Foot-and-mouth Disease Epidemics. XXI EURO Conference, Reykjavik

Ge, L., Mourits, M.C.M., Huine, R.B.M., 2006. Towards flexible decision support in the control of animal epidemics. Rev. Sci. Tech. Off. int. Epiz. Revision Submitted.

Ge, L., Mourits, M.C.M., Huirne, R.B.M., 2005. Valuing Flexibility in the Control of Contagious Animal Diseases. The 9th Annual International Conference on Real Options, Paris.

Hammond, J.S., Keeney, R.L., Raiffa, H., 1999. Smart Choices: A Practical Guide to Making Better Life Choices. Boston, Harvard Business School Press.

Keeling, M.J., Woolhouse, M.E.J., Shaw, D.J., Matthews, L., Chase-Topping, M., Haydon, D.T., Cornell, S.J., Kappey, J., Wilesmith, J., Grenfell, B.T., 2001. Dynamics of the 2001 UK Foot and Mouth Epidemic: Stochastic Dispersal in a Heterogeneous Landscape. Science 294, 813-817.

Kristensen, A.R., Jørgensen, E., 2000. Multi-level hierarchic Markov processes as a framework for herd management support. Ann. Operat. Res. 94, 69-89.

Mourits, M., 2000. Economic Modelling to Optimize Dairy Heifer Management. Farm Management. Wageningen, WUR.

Toft, N., 2000. Elements of decision support systems in pig production. Dina KVL. Copenhagen, The Royal Veterinary and Agricultural University Copenhagen: 92.

Tomassen, F.H.M., de Koeijer, A., Mourits, M.C.M., Dekker, A., Bouma, A., Huirne, R.B.M., 2002. A decision-tree to optimise control measures during the early stage of a foot-and-mouth disease epidemic. Prev. Vet. Med. 54, 301-324.

Trigeorgis, L., 1996. Real options: managerial flexibility and strategy in resource allocation. London, The MIT Press.

Woolhouse, M., Donaldson, A., 2001. Managing foot-and-mouth. Nature 410(6), 515-516.