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FARM-LEVEL MICROSIMULATION MODELLING

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Dedicated to the staff of Teagasc and to Farmers of the National Farm Survey

Preface

This work represents an overview of the model development in relation to farm-level micro-simulation modelling that I undertook over a 10-year period in Teagasc, the Irish Agriculture and Food Development Authority, an important research and extension institution in Ireland. The book builds upon my career expertise in the development of simulation models to understand distributional consequences of policy, market and societal changes.

As a sector, very strongly influenced by public policy and with very significant distributional implications of policy, market and societal changes, agriculture has substantial scope and potential for model development. I was glad to have worked with colleagues in Teagasc who were very experienced in other forms of modelling.

I am very proud to have worked for Teagasc. Teagasc's staff members are hugely dedicated to their client base of farmers, food businesses and rural dwellers. Most of the models developed in this book draw upon the Teagasc National Farm Survey. I would like to express my appreciation for the work of the members of the survey team, who have generated one of the highest quality micro data sets I have ever worked with and for the farmers who have volunteered their time and their confidential farm management data for over 40 years.

Most of all, this book builds upon work with my Ph.D. students and collaborators of my Policy Lab. As in all large-scale modelling efforts, the work is a team effort. It has been a pleasure working with the many Ph. D. students and post-docs over the years. Within my lab, everyone benefits from the infrastructure that has been built and everyone contributes. Thus, many have contributed to the development of the models in this book. I would like to express my appreciation in particular to Ursula Colohan who was my PA, Programme Administrator for the decade, John Lennon, who undertook a lot of the data preparation and Mary Ryan who co-authored 3 of the chapters and whose forensic eye helped with the editing.

In each chapter, I acknowledge collaborating partners and co-authors. In all models, I have made the major or a major contribution to their development. Most of the analyses in this book extend work done in collaboration with the Ph.D. students. In the cases of Chaps. 5, 9 and 10, the first collaborator is the lead author on the chapter, reflecting their contribution to these chapters. In the remaining chapters, I am the lead author. However, all are collaborative efforts in one form or other. I am grateful for their efforts. Chapter 2 represents an update of work previously published in O'Donoghue (2016).[1]

Athenry, Ireland Cathal O'Donoghue

Note

1. O'Donoghue, C., Farm Level Microsimulation Models in Shrestha, S., Barnes, A., & Ahmadi, B. V. (Eds.). (2016). Farm-level Modelling: Techniques, Applications and Policy. CABI.

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Author and Contributors

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Geraldine Johnston is a Postdoctoral Researcher with the ERC-funded Effective Nature Laws project in the UCD Sutherland School of Law. Her background is multidisciplinary, having a BA (Mod) in Natural Sciences, an MSc (Agr) in Environmental Resource Management and a Ph.D. in Economics from TCD, UCD and NUIG, respectively. While working with SEMRU, the Socio-Economic Marine Research Unit, Galway (pre-doctoral), and Teagasc, Dublin (postdoctoral), Geraldine further developed her skills in non-market valuation, discrete choice modelling and structural behavioural modelling. She has published in Ecological Economics, Land Use Policy and Ecosystem Services.

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Stephen O'Neill is a Lecturer in Economics (Health Economics and Ageing) at NUI Galway and is now a Visiting Research Fellow at the London School of Hygiene and Tropical Medicine, having previously been a Research Fellow there (September 2014–November 2016). Stephen's primary research interests are in health economics and micro-econometric methods. Stephen is particularly interested in translating methods from other fields within economics and from disciplines such as biostatistics, epidemiology, political analysis and sociology to the health economics domain.

Mary Ryan is an Environmental Economist in Teagasc and leads the Rural Development Team. She was formerly a Forestry Specialist and Acting Head of the Forestry Department. She has a Masters in Environmental Management from UCD and her Ph.D. is in Forestry Economics from the National University of Ireland, Galway. Her research interests include applied environmental/natural resource economic and behavioural analysis in relation to the cost-effectiveness and likelihood of adoption of water quality, biodiversity and carbon sequestration measures. Mary is currently involved in a range of Department of Agriculture Food & Marine (DAFM), Environmental Protection Agency (EPA) and Teagasc-funded projects and was a member of the FP7-funded FLINT (Farm-Level Indicators for New policy Topics) team.

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Introduction

1.1 Introduction

Agriculture in OECD countries is one of the most regulated industries, most heavily dependent for income upon political expenditures, has special rules in the tax code. The sector also has one of the most complex mixes of outcomes from market goods such as food to non-market goods such as environmental services. It is a land-based business of heavy goods, and so the spatial dimension is important, and depends upon long-term investment decisions such as land purchase, land improvement or long-term land use changes such as forestry. There is very significant heterogeneity amongst farmers from small-scale hobby producers with off-farm income sources, to very poor low-income farmers, to highly mechanised, large-scale operations with multi-million euro investments.

Given the importance of food production in the provision of goods that are essential for survival, that agriculture is a biologically based sector that is prone to risk and volatility, that faces pressures in meeting the food requirements of the growing world population particularly in the face of climate and environmental constraints and that it is a sector that impacts upon the wider environment as one of the most significant land

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uses; it is unsurprising that a modelling field has developed to look at these issues at farm level.

Microsimulation Modelling

Thus, there is stakeholder interest in both the private and the public sectors, for information in relation to the ex-ante impact of market and policy changes across the distribution of farms and across the dimensions discussed above, including spatial and temporal. Ex-ante assessments of all European Commission proposals are now required within the policy development process. These include agricultural sector behavioural models like FARMIS (Offermann et al. 2005) or FSSIM, see Ciaian et al. (2013) for a discussion of these models. This book focuses on the development of farm-level models and discusses their evolution and application over recent years.

Microsimulation modelling is a simulation-based tool with a micro unit of analysis that can be used for ex-ante analysis. It is a micro-based methodology, utilising micro units of analysis such as individuals, households, firms and farms, using surveys or administrative data sets. It is a simulation-based methodology that utilises computer programmes to simulate public policy, economic or social changes on the micro population of interest (O'Donoghue 2014). It is essentially a computer-based laboratory for running policy and market experiments, whose development has been facilitated by the advent of the personal computer in the 1980s and the availability of micro-data that has allowed the field to grow very rapidly.

For most of its history as a field, since Orcutt (1957, 1960) the focus has been on the household unit of analysis and focus on related policy such as tax, social policy, pensions etc. There is now a growing literature based on firms (Buslei et al. 2014) or farms (Richardson et al. 2014). Whether formally called microsimulation modelling or not, micro-based ex-ante simulation-based analysis is now used extensively around the world for policy analysis and design (Shrestha et al. 2016).

The field is multidisciplinary, reflecting the different policy focuses, but is bound together by researchers who utilise computer-based simulation models to simulate the impact of public policy and/or economic and social change on micro units such as households, firms and farms. Depending upon the policy area, the discipline has different names. For some, particularly those working in public finance, social policy and rural development, the field is called microsimulation; for others in the agricultural policy, it is farm-level modelling, while for others in labour economics, it is a branch of applied micro econometrics. However, methodologically, there is much in common and much that can be learned from the different fields. It is particularly appropriate in this time of economic crisis to focus on methodologies that can facilitate better policy design.

Modelling Complexity

As a modelling framework, microsimulation modelling is a mechanism of abstracting from reality to help us understand complexity better. Figure 1.1 outlines potential sources of complexity in a static, single time period microsimulation model.

In the context of policy design and evaluation, complexity can take the form of

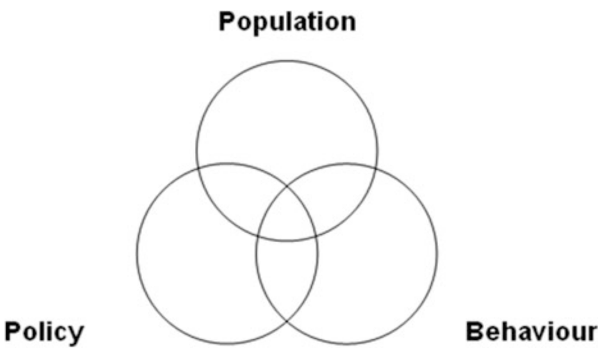

Fig. 1.1 Sources of complexity in policy design and evaluation. *Source* O'Donoghue (2014)

- Population structure of the population,
- Behavioural response to the policy
- Policy structure

These levels of complexity themselves interact with each other, resulting in a degree of complexity that is difficult to disentangle without recourse to a model.

Consider first the dimension of population complexity. The first dimension of complexity in relation to population is whether an analysis takes place on a population with limited or extensive heterogeneity. The former equates to a typical farm model (Hemme et al. 2014), while the latter includes distributional farm models such as Louhichi et al. (2010). The next dimension of complexity is policy complexity. This relates to the range of different policy or socio-economic impacts and the degree of policy complexity as many microsimulation models try to replicate the fine detail of legislation in modelling policy to the different types of policy modelled as in implemented CAP policy or agri-environmental policy. The third dimension of complexity is behaviour. Models that abstract from behavioural response are known as static microsimulation models. However, many policies are explicitly aimed at influencing policy as in the case of attempts to improve environmental outcomes on farms (Hynes et al. 2008; Ramilan et al. 2011).

In the case of models that incorporate either spatial dimensions or inter-temporal dimensions, the level of complexity is increased further (Fig. 1.2). Land use and spatially targeted policy (Miller and Salvini 2001; Lau and Kam 2005) or spatially targeted socio-economic effects (van Leeuwen and Dekkers 2013) require spatial models. Policies which depend upon long-term horizons such as afforestation models (Ryan et al. 2015) utilise inter-temporal or dynamic models.

1.2 Farm-Level Microsimulation

Farm-level simulation modelling has historically developed as a parallel field to microsimulation modelling in that relatively few farm-level papers appear in microsimulation conferences or journals or vice versa (Shrestha

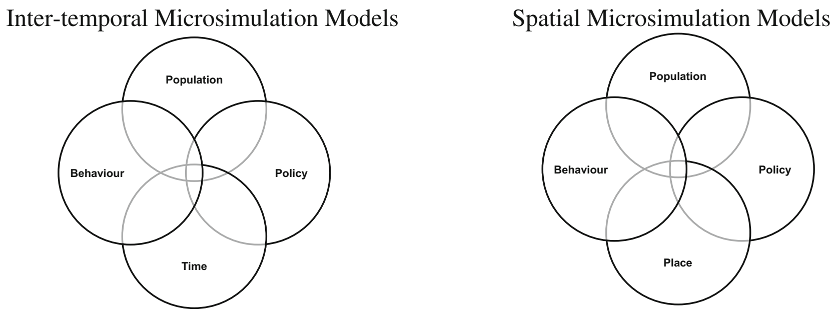

Fig. 1.2 Enhanced complexity in inter-temporal and spatial microsimulation models. *Source* O'Donoghue (2014)

et al. 2016). However, fundamentally, the objectives are similar, micro-level simulations of policy and economic change. Farm-level micro-simulation combines biological, business and policy modelling. Farm-based micro-level simulation modelling differs from other microsimulation-based models in that incomes partially derive from biological processes. Farms also have specific business structures, but in concept, in terms of profit, output and costs, are not much different from firm-level models. The farming sector in much of the world is also affected by distinct agricultural policy.

- Biological modelling involves the simulation of farm production of crops, meat and milk production.
- Farming is also a business, so one must simulate the monthly or annual generation of receipts, payment of expenses, principal payments, interest and income taxes as well as accounting for asset appreciation, depreciation and replacement.
- Public policy can affect farm incomes in a number of ways via direct income supports, policies that affect market prices, regulatory policy that constrains or incentivises particular on-farm activities and subsidy or tax policy that incentives more environmentally sensitive agriculture (Richarson et al. 2014).

Parallel models have been developed for farm-level units of analysis that are similar to those applied at the household level in other chapters of this handbook, from Hypothetical Farm Models to Static Incidence to Cross-country comparative analyses, to Behavioural Response to Expenditure Demand to Macro Impact to dynamic inter-temporal modelling to Spatial Impact to Environmental Impact modelling. Thus, while the objectives and modelling types have been similar, there has been relatively little mutual learning between the fields. This chapter aims to communicate some of the areas in common and difference to those in the other fields.

Models used in agriculture can focus on the simulation of outputs, given a change in policy or market parameters (positive models) or optimisation of inputs and outputs to maximise profits (normative models). Positive impact analysis has similar objectives to the rest of the literature, whether it is a static incidence analysis of an economic or policy change on a heterogeneous population, and/or the behavioural response to those changes. Farm-level modelling, however, places a higher emphasis on optimisation than most other sub-fields of microsimulation (Richardson et al. 2014).

Comparing farm-level microsimulation models, with the more mainstream farm-level simulation literation, we compare the models developed in this book with an example farm simulation model developed at the European Commission, the EU-wide Individual Farm Model for Common Agricultural Policy Analysis (IFM-CAP) (Louhichi et al. 2015).

Both systems are similar in that both use Farm Accountancy Data Network (FADN) type data sets; the data used in this book are from the Teagasc National Farm Survey, which is the Irish component of the FADN. Both models aim to represent the heterogeneity of farm populations.

Methodologically, they are different however. IFM-CAP is a static positive mathematical programming model. IFM-CAP consists of solving, at given prices and subsidies, a general maximisation problem in terms of input choice and land decisions, subject to a set of constraints representing production, technology and policy restrictions (Louhichi et al. 2015). Microsimulation models, on the other hand, do not tend to optimise and usually include less behaviour than farm-level simulation models (FLSM) or agent-based models (ABM). Over the spectrum of complex processes and complex behaviour, microsimulation models tend to be closer to the former, while FLSMs and ABMs tend to be closer to the latter; however, there is a clear spectrum between the two.

From a mathematical point of view, the IFM-CAP model maximises profit subject to resource and policy constraints:

$$\pi = p.y.x + s.x - \mathrm{Cx} - \mathrm{dx} - 0.5\mathrm{xQx}$$

s.t.

$$\mathrm{Ax} \leq b\rho$$

where

- π is profit
- p are product prices
- y are the yields expressed on a per hectare basis
- s are production subsidies
- C are input costs per hectare
- d is the linear part of the behavioural function
- Q is a symmetric, positive (semi-) definite matrix of the quadratic part of the behavioural activity function
- A is the matrix of coefficients for M resource and policy constraints (land, obligation set-aside and quotas)
- b is the $(M \times 1)$ vector of available resources (arable and grassland) and upper bounds to the policy constraints, and
- ρ is the vector of their corresponding shadow prices (Louhichi et al. 2015).

In this book, the models start off initially from a static basis, deriving behavioural drivers rather than being used for behavioural simulation. However, the models build up to incorporate partial-equilibrium behavioural simulations.

With reference to the process or population complexity difference, while IFM-CAP focuses at the farm level, in a farm microsimulation model, we may be interested in looking beneath the farm level at the enterprise level. Thus a farm can be categorised as a series of enterprises, i:

$$\pi_j = \sum_{i=1}^{n} \pi_{j,i} = \sum_{i=1}^{n} p_{j,i}.y_{j,i}.x_{j,i} + s_{j,i}.x_{j,i} - C_{j,i}x_{j,i}$$

As individual farmers face different prices, noting in Chap. 3 that farmer to farmer prices have much greater variability than business to farmer prices, we allow output (p) and input (C) prices to vary by farm j.

In addition, for animal enterprises, we decompose the yield per hectare (y) into the yield per livestock unit (y_l) and the stocking rate or intensity, livestock unit per hectare i_h. Costs can also be decomposed into volume $e_{j,i}$ and price $c_{j,i}$

$$\pi_j = \sum_{i=1}^{n} \pi_{j,i} = \sum_{i=1}^{n} p_{j,i}.y_{lj,i}.i_{hj,i}.x_{j,i} + s_{j,i}.x_{j,i} - c_{j,i}e_{j,i}x_{j,i}$$

From a policy complexity point of view, microsimulation models may want to unpick in finer detail, the complexity of farm subsidies $(s_{j,i})$ in understanding behavioural and distributional drivers.

Incorporating the temporal dimension of complexity, a microsimulation model may want to model and understand time varying characteristics of a decision such as a long-term land use change such as from agriculture a_j to forestry f_j or an investment return for a hectare of land:

$$\Delta \mathrm{NPV}\pi_j = \sum_{t=0}^{T} \frac{f_{j,t}}{(1+r)^t} - \sum_{t=0}^{T} \frac{a_{j,t}}{(1+r)^t}$$

In recent decades, farm households have diversified their activities, with most farms now have sources of off farm income h_j. Rural development programmes are becoming increasingly important as are regional development programmes. Access to off-farm can influence on-farm productivity (Behan et al. 2007) and also the other way (Mishra and Goodwin 1997). Therefore, a measure of farm household income $\left(n_j\right)$ is