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A Game-Theoretic Approach to Modelling Crop Royalties

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Contents

Acronyms and Abbreviations	xv
List of Symbols	xvii
1 Introduction	1
2 Background	7
2.1 Introduction	7
2.2 The protection of IP in crop breeding	8
2.2.1 Market failure	11
2.2.2 Overcoming non-excludability	13
2.2.3 Why crop breeding is different	18
2.2.4 Royalties	24
2.3 The practice of plant variety protection	29
2.3.1 The international history of PVP legislation	29
2.3.2 Australia	32
2.3.3 Other institutional changes in Australia	35
2.3.4 Royalties on wheat in selected countries	36
2.4 The Australian wheat breeding sector	39
2.5 Plant breeder's rights models	48
2.5.1 Research question	49
2.5.2 Date of study	51
2.5.3 Country of interest	51
2.5.4 Crops covered	52
2.5.5 Type of PVR protection	52
2.5.6 Static or dynamic	53
2.5.7 Methodologies employed	53
2.5.8 Results and conclusions	65

2.6	Outlook	68
3	A game-theoretic model with full declaration	71
3.1	Introduction	71
3.2	The full-declaration model	75
3.2.1	Simplifying the model to a steady-state	89
3.2.2	Maximising social welfare	95
3.2.3	A monopolist breeder	100
3.2.4	Discussion	103
3.3	Policy implications	110
3.4	An alternative specification	111
3.5	Conclusion	114
4	A game-theoretic model with less than full-declaration	115
4.1	Introduction	115
4.2	The model with less than full-declaration	125
4.2.1	Social welfare	131
4.3	Solving the game	133
4.3.1	Enforcement effort	133
4.3.2	Declaration rates	134
4.3.3	Seed quality and purchases	136
4.3.4	Maximising social welfare	140
4.3.5	Royalty rates	141
4.3.6	The outcome of the scheme with three royalties	142
4.3.7	Less than three royalties	147
4.3.8	Discussion	147
4.4	Comparison of full and less than full declaration	154
4.5	Policy implications	156
4.6	Conclusion	158
5	A Principal-Agent model without enforcement costs	161
5.1	Introduction	161
5.2	The model	164
5.2.1	The timing of the game	164
5.2.2	The game	166
5.3	The first-best outcome	180
5.3.1	Implementing first-best	181
5.4	The best implementable outcome	185

5.4.1	The farmer problem	186
5.4.2	The breeder problem	189
5.4.3	The optimal solution	189
5.5	Comparison of best-implementable and first-best outcomes .	196
5.6	Conclusion	199
6	A Principal–Agent model with enforcement costs	203
6.1	Introduction	203
6.2	Enforcement costs	207
6.3	Numerical methods	214
6.3.1	The wheat output price	215
6.3.2	The marginal product of wheat	217
6.3.3	The coefficient of risk aversion of farmers	218
6.3.4	The marginal cost of farmers	219
6.3.5	The variance of yields	221
6.3.6	The breeder’s marginal cost of production	222
6.3.7	Enforcement costs	223
6.3.8	The results	224
6.4	Discussion	228
6.5	Conclusion	232
7	Policy implications and conclusions	235
	Appendices	241
A	Appendix to Chapter 2: Background	243
A.1	Source of data for EPR rates	243
A.2	Papers	249
B	Appendix to Chapter 3: A game-theoretic model with full decla- ration	255
B.1	Interior conditions in the baseline model	255
B.2	Comparative statics in the baseline model	258
B.3	Farmer profit in the steady-state model.	260
B.4	The comparative statics of the steady-state model	263
B.5	Breeder optimisation	266
B.6	The Social Welfare Optimum Solution	267
B.7	A monopoly breeder with all three royalties	269

B.8	A monopoly breeder with less than three royalties	271
C	An alternative specification of the full-declaration model	283
C.1	Introduction	283
D	Appendix to Chapter 4: A game-theoretic model with less than full-declaration	313
D.1	The optimum declaration rates	313
D.2	Farmer profits with the three royalties	318
D.3	The comparative statics for declaration rates	319
D.4	Less than three royalties	321
E	Appendix to Chapter 5: A Principal–Agent model without enforcement costs	329
E.1	Unconstrained maximization	329
E.2	Kuhn Tucker maximization	331
E.3	Checking the implementability constraint	334
E.4	Derivation of comparative statics results	335
E.5	Derivations of inequalities for Table 5.2	346

List of Figures

2.1	EPR rates over time Source: See Appendix A.1 for source of data	44
6.1	Optimum royalties for different fixed and marginal enforcement costs.	213
6.2	The enforcement costs frontier	225
6.3	The enforcement costs frontiers as parameter values vary . .	229
C.1	The breeder's profit for different EPRs.	303

List of Tables

2.1	Australia's private wheat breeding companies	42
3.1	Comparative statics for the baseline model	87
3.2	Comparative statics for the steady-state model	93
3.3	Results of the full-declaration model	104
3.4	Summary of the full-declaration model	106
4.1	Results of the model with less than full-declaration	145
4.2	Summary of the model with less than full declaration	146
4.3	Ranking of schemes with respect to social welfare in the models with full declaration and less than full declaration. .	149

4.4	Re-allocating the surplus: less than full-disclosure, social planner.	150
4.5	Schemes in which less than full declaration may occur. . . .	151
4.6	Ranking of schemes with respect to breeder profit in the models with full declaration and less than full declaration, monopolist breeder.	152
4.7	Re-allocating the surplus: less than full-disclosure, monopolist breeder.	153
5.1	Comparative statics in the Principal–Agent model	193
5.2	Results of the partial-insurance model compared to first-best	197
6.1	Illustrative numerical values	216
6.2	Values of the marginal product of wheat	218
6.3	Values of the farmer’s marginal cost coefficient	220
6.4	Values of the variance of yields	222
A.1	EPR rates over time	248
A.2	Summary of papers	253
C.1	Results of the alternative full-declaration model	308
C.2	Summary of the alternative full-declaration model	311
C.3	Comparison of the two formulations of the full-declaration model	312

Abstract

Plant variety rights assist crop breeders to appropriate returns from new varieties and incentivise varietal improvement. Royalties are one form of plant variety rights and this dissertation asks which combination of the available royalty instruments is best from the perspective of consumers, farmers, crop breeders, and the overall economy.

We use a game-theoretic approach to model strategic interactions between breeders and farmers. The model allows farmer privilege, whereby farmers save seed one year to plant in the future, and we show a point-of-sale royalty with either or both of the remaining royalties is optimal, whether or not we allow the possibility of farmers under-paying royalties through under-declaring output or saved seed.

We also develop a Principal–Agent model, in which risk-neutral breeders share the risk with risk-averse farmers. In this model, the optimum royalty depends on various parameters, including the costs of compliance and enforcement.

KEYWORDS: game-theory; economic model; end-point royalty; point-of-sale royalty; saved seed; farmer privilege; principal–agent model.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Acronyms and Abbreviations

ACCC	Australian Competition and Consumer Commission
ACIP	Advisory Council on Intellectual Property
AGT	Australian Grain Technologies
AVC	Average variable costs
AWB	Australian Wheat Board
Bt	Bacillus thuringiensis
CARA	Constant absolute risk aversion
COGGO	Council of Grain Grower Organisations Ltd
CRS	Constant returns to scale (production function)
CV	Coefficient of variation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EPR	End-point royalty
EU	European Union; Expected utility
FAO	Food and Agriculture Organisation of the United Nations
GM	Genetically modified
GRDC	Grains Research Development Corporation
IC	Incentive compatibility constraint of the farmer
ImpC	Implementability constraint of the farmer
IP	Intellectual property
IPR	Intellectual property rights
IR	Individual rationality constraint of the farmer
MV	Mean-variance (model)
NVT	National variety trials
NZPFR	New Zealand Institute for Plant and Food Research
PBR	Plant Breeder's Rights
POS	Point-of-sale royalty
PVP	Plant variety protection
PVPA	Plant Variety Protection Act of 1970, US
PVR	Plant variety rights
R&D	Research and development
RDC	Research development corporation
RR	Royalty revenue
SARDI	The South Australian Research and Development Institute

SSP	Saved-seed royalty
SW	Social welfare, the sum of farmer and breeder profits
TRIPS	(agreement on) Trade-Related Aspects of Intellectual Property Rights
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
US, USA	United States of America
UPOV	International Union for the Protection of New Varieties of Plants

Symbols

Game-theoretic models

a	enforcement costs parameter, $a > 0$, \$
b	proportion of farm sown to bought, new, seed, $b \in [0, 1]$; may be indexed by time period t
C	farmer's costs, \$
d	output-declaration rate, $d \in [0, 1]$
f	fine factor on cheating, $f > 1$
F	production function of wheat
g	marginal breeding cost, $g > 0$, \$ per kilogram of seed produced
K	fixed cost of wheat breeding, \$
m	saved-seed declaration rate, $m \in [0, 1]$
P_b	point-of-sale royalty, $P_b \geq 0$, \$ per kilogram of bought seed
P_s	saved-seed royalty, $P_s \geq 0$, \$ per kilogram of seed saved
\bar{q}	quality of new, bought, seed, tonnes of output per unit area
q	quality of the seed mix, tonnes of output per unit area; may be indexed by time period t
Q	production, output of wheat, tonnes; may be indexed by time period t
r	end-point royalty rate, $r \in [0, 1]$, \$ per tonne of output
X	enforcement cost function, \$

Greek symbols

β	discount factor, $\beta \in [0, 1]$
ϕ	probability of the farmer being investigated, $\phi \in [0, 1]$
ψ	seeding rate, tonnes of seed per unit area sown, $\psi > 0$
π_f	profit of the farmer, \$; may be indexed by time period t
π_B	profit of the breeder, \$; may be indexed by time period t
Π	discounted sum of future expected profits of farmer, \$
θ	quality of saved seed relative to new seed, $\theta \in (0, 1)$

Principal–Agent models

<i>a</i>	marginal enforcement costs, \$ per kilogram of seed
<i>A</i>	fixed enforcement costs, \$
<i>b</i>	quantity of seed bought by the farmer, kilograms
<i>c, \tilde{c}</i>	cost parameter of wheat growing, \$ per kilogram ² of seed input
<i>e</i>	effort of the farmer in labour units
<i>F</i>	production function of wheat
<i>g</i>	marginal cost of wheat breeding, \$ per kilogram of seed
<i>h</i>	marginal product of farmer effort, tonnes of output per unit of labour effort
<i>K</i>	fixed cost of wheat breeding, \$
<i>l</i>	license fee, fixed up–front payment, \$
<i>L</i>	risk premium
<i>N</i>	numeraire unit of money = output price
<i>p</i>	point-of-sale royalty, $p \geq 0$, \$ per kilogram of bought seed
<i>q</i>	production, output of wheat, tonnes
<i>r</i>	end-point royalty rate, $r \in [0, 1]$, \$ per tonne of output
<i>v</i>	marginal product of seed, \$ of output per kilogram of seed
<i>Z</i>	certainty equivalent of the farmer’s wealth; Z is such that $EU(Y) = U(Z)$, if Y denotes the farmer’s wealth, \$

Greek symbols

ϵ	uncertainty of production, a random variable with mean 0 and variance σ^2 , \$ of output per kilogram of input
γ	coefficient of risk aversion of the farmer
π_f	profit of the farmer, \$
π_B	profit of the breeder, \$
σ^2	variance of ϵ , (\$ per kilogram of seed) ²
