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Implications of Off-Farm Income for Farm Income Stabilization Policies

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IMPLICATIONS OF OFF-FARM INCOME FOR FARM INCOME
STABILIZATION POLICIES

DISSERTATION

A dissertation submitted in partial
fulfillment of the requirements for
the degree of Doctor of Philosophy
in the College of Agriculture at the
University of Kentucky

By
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Director: Dr. David Freshwater, Professor of Agricultural Economics
Lexington, Kentucky 2013

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ABSTRACT OF DISSERTATION

IMPLICATIONS OF OFF-FARM INCOME FOR FARM INCOME STABILIZATION POLICIES

This dissertation examines to what extent off-farm diversification may be an appropriate and accessible tool to mitigate the adverse effects from market failures and incompleteness in the crop and farm income insurance market. While the influence of the nonfarm sector has long been recognized as a primary force in shaping farm structure, off-farm income is rarely acknowledged as a risk management tool for operators and households of commercial farms. The dissertation develops a dynamic model that includes capital market imperfections, economies of scale in farm production, and the presence of adjustment costs in labor allocation decisions. The model provides a realistic characterization of the environment defining income and financial risks faced by farm operators, as well as the risk management alternatives available to them.

It is found that introducing off-farm labor can substantially mitigate the adverse effects of farm income risk on farm operators' and households' welfare, even for larger commercial farms. However, the diversification of labor by the main operator seems to impose labor and managerial constraints that can reduce the intensity and technical efficiency of the farm production. Alternatively, diversification at the household level through the allocation of spousal labor off the farm provides benefits in mitigating the adverse effects of farm income risk on farm production and efficiency, and on operators and households welfare. It thus provides an efficient risk management alternative that is consistent with most rationales that are invoked to justify farm policies.

Results suggest that the increasing incidence and importance of off-farm income within the farm population of most OECD countries is highly relevant in the design of effective farm policies. This form of diversification can reduce the need and effectiveness of farm income stabilization policies. While it has been argued elsewhere that broader economic policies had a large influence in closing the income gap between farm and urban households, such policies may also have a role to play in addressing

farm income risk issues and, in some cases, may represent more sustainable and efficient policy alternatives.

KEYWORDS: Off-farm Income, Agricultural Policy, Risk Management, Distance Function, Dynamic Programming

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TABLE OF CONTENTS

Acknowledgments	iii
Table of Contents	iv
List of Tables	vi
List of Figures	vii
Chapter 1 Introduction	1
1.1 Impact of Off-farm Employment on Farm Households	1
1.2 Risk Management Policies	2
1.3 Dissertation Overview	3
Chapter 2 Off-farm Income and Farm Policies	5
2.1 Off-farm Income: Trends and Determinants	5
2.2 Policy Implication of Off-farm Diversification	12
2.3 Conclusion	19
Chapter 3 Modeling the Impact of Off-farm Income on Farm Decisions	20
3.1 A Review of Buffer Stock Saving Models	20
3.2 A Farm Level Buffer Stock Model	23
3.3 Conclusion	32
3.4 Model Summary	33
Chapter 4 Farm Production and Off-Farm Diversification: Empirical Estima- tion	34
4.1 Off-farm Work and Farm Production: A Literature Review	34
4.2 Distance Functions	37
4.3 Data and Variables	43
4.4 Econometric Model	49
4.5 Estimation Results	50
4.6 Implications and Conclusions	57
Chapter 5 Numerical Analysis	64
5.1 Model Calibration	64
5.2 Full-time Operation and Adjustment Costs	71
5.3 Part-time Farming Under Uncertainty	79
5.4 Spousal Income	83
5.5 Implications and Conclusions	86
Chapter 6 Conclusions	89

Bibliography	96
Appendix A: Profit Maximization and the Input Distance Function	108
Appendix B: Output Distance Function	110
Appendix C: Approximation of Risk Premium	116
Appendix D: Numerical Analysis: Further Results	118
Vita	119

LIST OF TABLES

2.1	Composition of farm household income in OECD countries	6
4.1	Summary Statistics	44
4.2	Parameter Estimates	52
4.3	Violation of regularity conditions in Model 1	53
5.1	Parameters	66

LIST OF FIGURES

2.1	Mean Farm, Off-Farm and Total Operator Household Income, 2004 . . .	7
2.2	Off-farm labor supply and demand	8
3.1	Interest rate on borrowed funds	28
4.1	Land Tenure	46
4.2	Rental Agreements	47
4.3	Farm production	54
4.4	Marginal Farm product of Inputs (Model 3)	55
4.5	Economies of Scale (Model 2 and 3)	58
4.6	Economies of Scale (Model 2 and 3)	59
4.7	Shadow output cost $\left(\frac{dF}{dY}\right)$ (Model 3)	60
4.8	Efficiency (Model 2 and 3)	61
5.1	Optimal Production under certainty	68
5.2	Optimal Farm Production under certainty	69
5.3	Profitability of Farm level under certainty	70
5.4	Optimal Production Decisions under Uncertainty	72
5.5	Profit and Welfare under Uncertainty	73
5.6	Marginal Value Product of Variable Input	74
5.7	Risk Premium on Farm Variable Inputs	74
5.8	Debt-to-Equity ratio under different levels of insurance coverage	75
5.9	Welfare under different levels of insurance coverage	76
5.10	Changes in Expected Variable Inputs	78
5.11	Production under Uncertainty	80
5.12	Risk Premium of Part-time Operators	81
5.13	Return on Equity of Part-time Operators	82
5.14	Welfare of Part-time Operators	83
5.15	Impact of Spousal Income on Farm Production	84
5.16	Impact of Spousal Income on Welfare	85

Chapter 1

Introduction

The influence of the nonfarm sector has long been recognized as a primary force in shaping farm structure (Ruttan and Hayami, 1984; Chavas, Chambers, and Pope, 2010). And it is widely acknowledged that general economic growth and off-farm work opportunities have played a central role in resolving the equity issues that motivated farm policies in their inception (Gardner, 2000; Tweeten, 2002; Schmitz, Moss, and Schmitz, 2010). By now, the majority of OECD farm households are now earning an important share of their income from off-farm activities (Dimitri, Effland, and Conklin, 2005; OECD, 2009b; Fernandez-Cornejo et al., 2007; Statistics Canada, 2008).

Policies now tend to focus on farm income risk issues and much of the policy debates center on the efficiency of subsidized crop and farm revenue insurance programs. Many economists argue that these programs are inefficient because they tend to crowd out private initiatives, including off-farm income. Hence, the role of off-farm income as a private risk management tool has generated some interest. However, the use of off-farm income as a risk management tool is usually presumed to be limited to smaller farms. Nevertheless, data suggest that off-farm income represents more than 20% of the total income of large and very large U.S. commercial farms on average (USDA, 2006; Park et al., 2011). Based on current policy concerns and the growing importance of off-farm income as a component of farm households' total income, this dissertation set out to examine the extent to which off-farm diversification can mitigate the adverse effect of farm income risk on resource allocation and welfare. Since commercial farms represent the focus of such policies, the focus of the dissertation is put on the potential of off-farm employment as a risk management tool for such farms.

1.1 Impact of Off-farm Employment on Farm Households

Off-farm income can affect farm production and households' welfare in a number of ways. First of all, the off farm wage defines the opportunity cost of farm labor, thus establishing a link between off-farm wages and farm labor allocation decisions, which will in turn influence farm expansion decisions. As a result, labor market integration tends to strengthen this link and to make these farm decisions more responsive to changes in the terms of trade between farm and nonfarm sectors (Foltz and Aldana, 2006).

The decision to work off the farm also affects the farm operation and technology choices through the labor constraint that it may impose (Fernandez-Cornejo, 2007). For example, it is suggested that the substitution effect between labor and capital

would lead part-time operator to have more capital intensive operations (O'Brien and Hennessy, 2008). And, in turn, input choices may influence the environmental impact of the farm operation (Phimister and Roberts, 2006). Yet, the most prominent effect of the constraints imposed by off-farm employment may be their negative impact on the overall efficiency of the farm operation as they could preclude the achievement of economies of scale.(Paul et al., 2004; Paul and Nehring, 2005; Nehring, Fernandes-Cornejo, and Banker, 2005)

And the financial implications of off-farm work are numerous. While off-farm income provides a more diversified source of income (Mishra and Goodwin, 1997; Mishra and Holthausen, 2002; Andersson, Ramamurtie, and Ramaswami, 2003; Da-Rocha and Restuccia, 2006; Blank and Erickson, 2007), its importance as a source of liquidity supporting farm investment and capital gains cannot be overlooked (Blank et al., 2004, 2009; Briggeman, 2011). At the same time, labor constraints may also leads to the operation of smaller farms, thus reducing the need for farm capital and equity and allowing part-time operators to diversify their investment portfolio off the farm more easily (Foltz and Aldana, 2006; O'Brien and Hennessy, 2008).

Overall, the net impact of off-farm work on farm production and operators' welfare can be ambiguous. The diversification and liquidity benefits that it provides bolster the financial position of farm households. But the constraints it imposes on farm operations may also reduce expected returns. This trade-off determines the extent of the potential role of off-farm work in resolving the alleged farm income risk issues that underly farm policies.

1.2 Risk Management Policies

In both, the U.S. and Canada, central policy instruments targeted at reducing farm income instability include crop insurance and farm revenues insurance (OECD, 2009a). These farm insurance programs are heavily subsidized and their legitimacy is usually defended based on the incompleteness of insurance markets (e.g. Miranda and Glauber, 1997; Goodwin, 2001). It is then argued that, if not for farm insurance programs, the welfare of farm operators and the level of investment in farm production would be suboptimal, and that rural communities would lose direct and indirect economic benefits from farm production.

However, the virtues of those programs have been called into questions by many economists (e.g. Tweeten, 2002; OECD, 2009a; Goodwin and Smith, 2013). It is argued that those programs are inefficient and are crowding out a number of private risk management initiatives, including off-farm diversification. Some even argued that the social cost of those programs is greater than the cost of relying only on incomplete private risk management tools (e.g. Tweeten, 2002; Gardner and Sumner, 2007; Glauber, 2007).

For the most part, the analyses of these policies have focused on adverse selection and moral hazard issues using mean-variance and expected utility models (e.g. Duncan and Myers, 2000; Coble and Knight, 2002; Mahul and Wright, 2003; Barnett et al., 2005; Power, Vedenov, and Hong, 2009). However, this theoretical framework may not be suited for the analysis of interactions between off-farm diversification and farm insurance programs. As mentioned by Blank et al. (2009), standard mean-variance and expected utility models implicitly make the unrealistic assumption that all income and wealth is consumed during one period. This may be a trivial assumption when focusing on annual production or insurance decisions, but is inappropriate when focusing on multiperiod financial issues.

1.3 Dissertation Overview

Chapter 2 of the dissertation provides an in-depth review of the literature pertaining to the role and incidence of off-farm income among the farm community, and its relationships with farm policy objectives and instruments. This literature provides a few empirical studies indicating a positive relationship between off-farm diversification and farm income risk (Mishra and Goodwin, 1997; Mishra and Holthausen, 2002; Mishra and Sandretto, 2002; Jette-Nantel et al., 2011). While these studies attest to the role of off-farm diversification as a useful risk management tool, their capacity to quantify the benefit of off-farm diversification and its capacity to attenuate the adverse effect of farm income risk remain limited.

In order to address the central question of the dissertation, Chapter 3 is devoted to the development of a theoretical model that attempts to capture the nature of the interactions between farm income risk and off-farm labor. While risk studies and farm insurance program analysis commonly use mean-variance and expected utility models in a static setting, I draw from the buffer stock saving models presented in the finance and macroeconomic literature to develop a dynamic farm life-cycle model. A key advantage of such a model is the capacity to integrate the effect of capital market imperfections and to combine production and financial risks within a single model. This is of particular interest here since farm insurance programs are targeting production risk while off-farm diversification does not affect farm production risk directly, but rather provides a source of liquidity that can reduce financial risk. In such models agents are allowed to endogenously balance the two sources of risk and labor income tends to act as a risk free asset, allowing for consumption smoothing, more aggressive investment in risky assets, and for reduction in the demand for insurance. In Chapter 3, I adapt this framework in a farm-life cycle model and I argue that such a dynamic model provides a more thorough and realistic characterization of the level of risk faced by farm operators, and is thus better suited to assess the potential interactions between off-farm diversification and farm insurance programs.

Aside from its impact on farm financial decisions and household's welfare, diversification of labor off the farm may also impose constraints on farm production. Some

of the studies reviewed in Chapter 2 suggest a negative relationship between farm production efficiency and off-farm diversification. In Chapter 4, Kentucky farm data are used to estimate the relationship between farm production and off-farm diversification. First, the estimation results allows the testing of whether off-farm diversification imposes a loss of farm production efficiency and also if some rebalancing of farm inputs can reduce this loss. Second, it allows the derivation of the parameters necessary to calibrate the farm production function included in the dynamic farm model.

Within the estimation procedure, particular attention is given to the theoretical consistency of the estimates, something that was not done in previous literature (Paul et al., 2004; Paul and Nehring, 2005; Nehring, Fernandes-Cornejo, and Banker, 2005). The estimation is performed using a Bayesian algorithm which provides the flexibility to impose the appropriate theoretical restrictions. It is found that imposing theoretical consistency on the estimates can have large impact on parameters and elasticity estimates.

In Chapter 5, numerical solutions and simulations of the calibrated model are used to examine the impact of off-farm diversification on the adverse effect of reductions in the coverage offered by farm revenue insurance programs. The analysis seeks to understand the balance between the cost of diversification, reflected in the estimated function in Chapter 4, and the financial benefits of diversification. More specifically, solutions and simulations results are used to answer the following questions:

- Can off-farm employment effectively reduce the adverse effect of incomplete risk markets on farm production and investment?
- Can off-farm employment effectively reduce the adverse effect of incomplete risk markets on farm operator's and household's welfare?

Finally, Chapter 6 provides concluding thoughts on the results from this study and the relationship between off-farm diversification trends and current policy objectives and instruments. Limitations are also addressed and possible directions for future research are discussed.

Chapter 2

Off-farm Income and Farm Policies

This chapter reviews the literature related to off-farm work and its relation with farm policies. The first section reviews trends in off-farm income and the theoretical frameworks that have been developed to understand the forces explaining farm and off-farm labor allocation decisions. The empirical literature is also covered, providing the actual evidence relating to the theory of farm labor allocation. The second part focuses on the implications of the increasing incidence of off-farm income for different farm policy objectives and instruments.

2.1 Off-farm Income: Trends and Determinants

Over the last 50 years off-farm income has become an increasingly important component of farm households' income. Across OECD countries, the majority of farm households are now diverting some of their resources, either capital or labor, towards off-farm activities (Huffman, 1977; Dimitri, Effland, and Conklin, 2005; Fernandez-Cornejo et al., 2007; Statistics Canada, 2008; OECD, 2009b) (see Table 2.1). In the U.S. the share of total farm household income coming from off-farm sources rose from 50% in 1960 to more than 80% in recent years (Fernandez-Cornejo et al., 2007). Similarly, in Canada the percentage of operators reporting off-farm work went from 34% in 1976 to 48.4% in 2006 (Statistics Canada, 2008). These trends strongly suggest that off-farm diversification can be beneficial to farm households and that a growing number of these households have been able to take advantage of off-farm opportunities.

The accessibility and desirability of off-farm income varies depending on farm and farm household characteristics and location. As a result, off-farm income is likely to play a different role among different farm households, and may have different policy implications across regions. For example, off-farm income is more common among operators and households of smaller farms. Yet, as Figure 2.1 shows, in 2004 off-farm income still represented about 36% of the total income of large U.S. commercial farms, and 17% of the total income of very large farms (USDA, 2006)¹.

Bollman (1979) provides a basic theoretical framework that captures the main forces explaining the allocation of labor on and off the farm (see Figure 2.2). The main components of that framework are the labor supply curve (S_{OL}), the farm labor demand curve (VV_1) and the off-farm wage rate (W_B). While simple, this framework

¹The 2010 statistics reported by Park et al. (2011) indicate that off-farm income represented 24% of total income for large and very large commercial farms in the U.S.

Table 2.1: Composition of farm household income in OECD countries

		Farming	Off-farm labour activities	Investment and property	Transfers	Other sources	Total	Definition of a farm	Household members whose income is taken into account	Definition a farm household
Australia	2004/05-2006/07	68	nri	nri	nri	32	100	Minimum sales:	Operator and spouse	Narrow
	1995/96-1997/98	65	nri	nri	nri	35	100	AUD 22 500 (AUD 40 000 from 2005/06		
	1986/87-1988/89	78	nri	nri	nri	22	100	USD 18 825 (USD 33 467 from 2005/06)		
Austria	2004-06	54	30	nri	nri	17	100	Minimum SGM:	Operator and spouse	Narrow
	1995-97	63	22	nri	nri	15	100	EUR 7 200 or USD 10 000		
Canada	2003-05	7	64	8	16	5	100	Minimum revenue:	Operator and spouse	Broad
	1995-97	24	53	8	10	5	100	CAD 10 000 or USD 9 300		
	1985-87	30	49	10	9	2	100			
Denmark	2004-06	42	43	7	7	0	100	Minimum area:	All members under the same dwelling	Broad
	1996-98	47	34	11	8	0	100	10 ha		
Finland	2003-05	27	42	18	13	0	100	Minimum area:	Operator and spouse	Broad
	1996	28	39	17	16	0	100	2 ha		
France	2003	53	31	9	8	0	100	Minimum area: 12 ha	All members declaring income for tax purpose together	Narrow
	1997	67	19	6	8	0	100	Minimum labour unit: 0.75		
Germany	2003/04-2005/06	80	nri	nri	nri	20	100	Minimum SGM: 16 ESU or USD 26 300	Operator and spouse	Narrow
	1995/96-1997/98	85	nri	nri	nri	15	100	Minimum labour unit: 1		
Ireland	2004/05	32	45	2	19	2	100	Any gain from agricultural activity	All members	Broad
	1995	51	31	2	13	3	100			
	1987	49	24	2	19	6	100			
Japan	2004-06*	25	33	nri	29	13	100	Minimum area: 0.3 ha	All members From 2004, only those engaged in agriculture	Broad
	1995-97	15	65	nri	nri	20	100	Min. sales: JPY 500 000 or USD 4 250		
	1985-87	14	65	nri	nri	21	100			
Korea	2004-06	39	32	nri	29	0	100	Minimum area: 0.1 ha	All members	Broad
	1995-97	46	34	nri	20	0	100	Minimum sales: USD 1 000		
	1985/87	64	18	nri	18	0	100			
Mexico	1996	41	31	13	nri	16	100	Rural areas	All members	Narrow
	2006	29	40	9	nri	23	100	Main economic activity in agriculture		
Netherlands	2004-06	74	11	nri	nri	15	100	Minimum SGM:	Operator and spouse	Narrow
	1996	73	nri	nri	nri	27	100	16 ESU or USD 26 300		
Norway	2004-06*	31	50	14	5	0	100	Any agricultural taxable income	Operator and spouse	Broad
	1999-2001	33	50	11	6	0	100			
Poland	2003-06	67	8	0	21	3	100	Main source of income from agriculture	All members	Narrow
	1998-2000	73	2	0	22	3	100			
Switzerland	2004-06	72	nri	nri	nri	28	100	Minimum area: 16 ha	All members	Narrow
	1995-97	81	nri	nri	nri	19	100	Minimum number of cows: 6		
United Kingdom	2002/03-2004/05	40	28	21	11	0	100	Any income from agricultural activity	Operator and spouse declaring income together	Broad
	1995/96-1997/98	53	18	21	8	0	100			
	1985/86-1987/88	57	19	20	5	0	100			
United States	2006	11	65	6	13	6	100	Minimum sales:	All members	Broad
	1995-97	11	nri	nri	nri	89	100	USD 1 000		
	1985-87*	35	nri	nri	nri	65	100			

nri: not reported independently; SGM: Standard Gross Margin; ESU: European Size Unit.

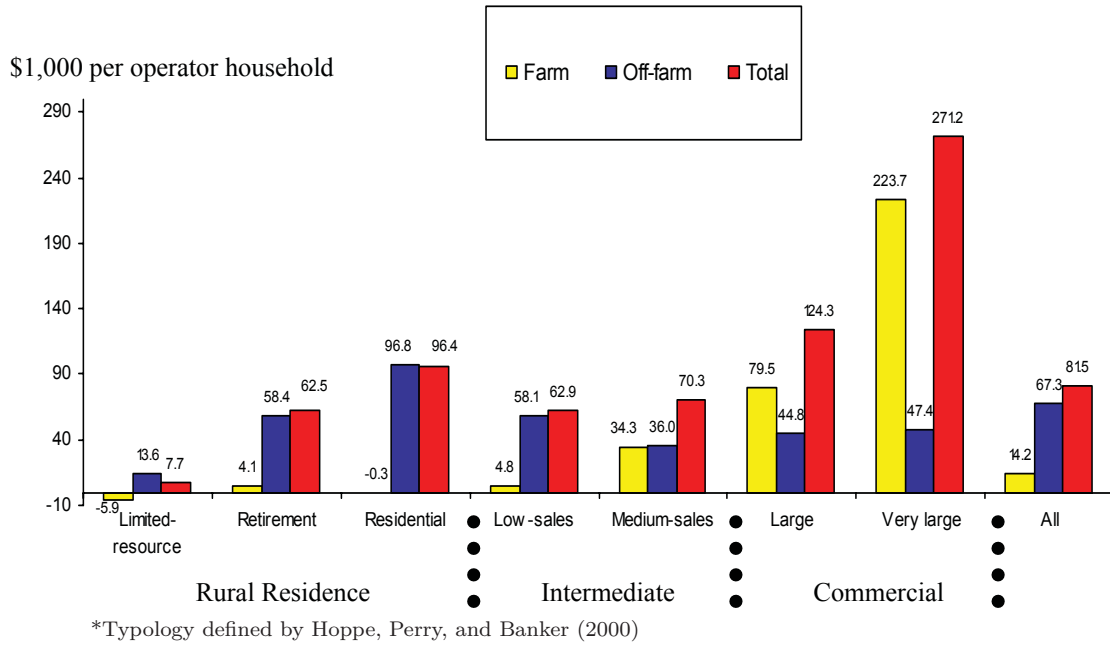
Data are not comparable across country as definitions of farm households and methodologies differ.

* change in methodology, see Annex 8.1.

Source: National statistics as reported in Annex II.1.

Source: OECD(2009),p.86

Figure 2.1: Mean Farm, Off-Farm and Total Operator Household Income, 2004



Source: USDA (2006, p.6)

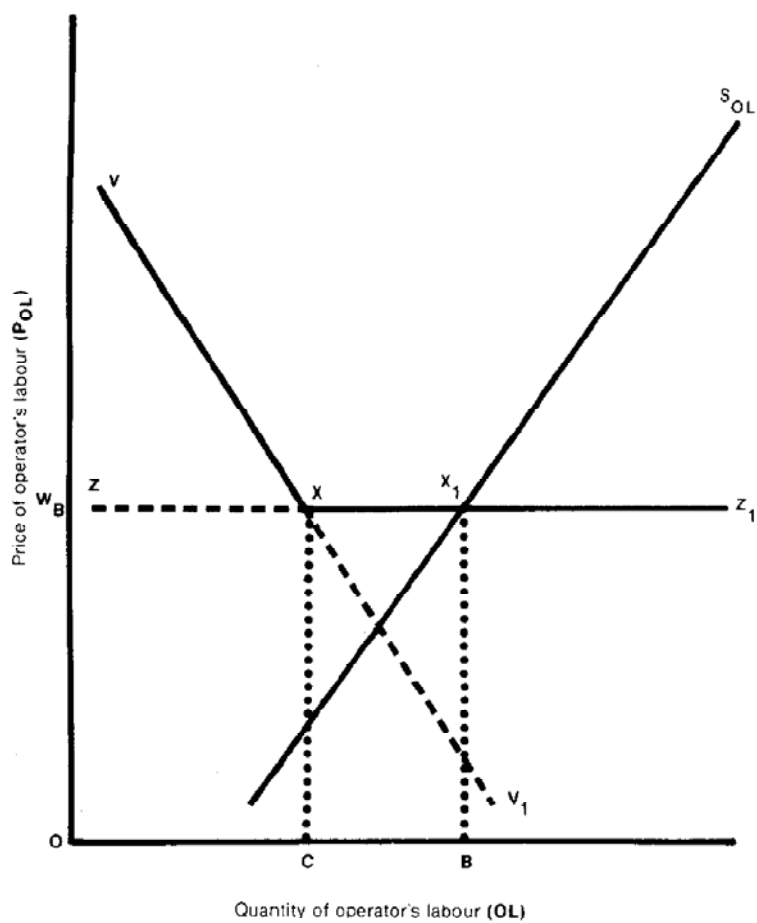
provides a basic structure to understand the various factors that can potentially affect the allocation between on and off the farm employment.

Labor supply

The labor supply of farm operators and households reflects choices between labor and leisure consumption. According to labor economic theory, the elasticity of labor supply is defined by the substitution and income effect. At lower wage levels the labor supply is more elastic as increase in wages will lead to a substitution of leisure for more work hours. At higher level of wages, the supply becomes inelastic since the income effect dominates thus favoring an increase in leisure instead of worked hours (Ehrenberg and Smith, 1993; Blundell and MaCurdy, 1999). Wealth and unearned income are also key factors in defining labor supply. Through an income effect, unearned income will reduce labor supply. For example, in a situation similar to what is depicted in figure 2.2, Chang, Huang, and Chen (2012) showed that a change in direct payments would be expected to shift the labor supply leading to a change in the number of hours worked off the farm and leaving the farm labor supply untouched.

Another key element in defining operators and household labor supply is the number of household members and the decision of the operator's spouse to work off-farm or not. The empirical literature suggests that the labor allocation of the operator

Figure 2.2: Off-farm labor supply and demand



Source: Bollman (1982)

and the spouse are joint decisions (Lass, Findeis, and Hallberg, 1989; Kimhi and Lee, 1996; Kimhi and Bollman, 1999; Benjamin and Kimhi, 2006; El-Osta, Mishra, and Morehart, 2008). Since the spouse's on-farm labor contribution is often secondary, the labor allocation decision of spouses are usually not directly connected with farm labor supply making the possible interactions between farm production and spousal labor allocation much more limited (Kimhi and Lee, 1996; Benjamin and Kimhi, 2006). These interactions are more likely to be indirect through the financial and liquidity contribution of spousal income. For example, Bjornsen and Mishra (2012) find that spousal off-farm work tends to increase farm efficiency while Moss, Mishra, and Uematsu (2012) find that spousal off-farm work is related to lower farm debt levels. In 2010, 82 percent of farm operators reported being married and about half of their spouses worked off the farm (Ahearn, February 23, 2012).

Demand for farm labor and management

Theoretically, the demand for farm labor is derived from the marginal value product of farm labor ($MP_{labor} \cdot P_y$). As such, any factor affecting farm productivity will shift the farm labor demand. Hence, the farm labor demand will depend on farm technology and constraints. More labor-demanding enterprises, such as dairy, will shift the demand outwards compare to other enterprises like grain production. The empirical literature has provided numerous studies supporting the theory (Bollman, 1979; Furtan, Van Kooten, and Thompson, 1985; Mishra and Goodwin, 1997; Howard and Swidinsky, 2000; Mishra and Holthausen, 2002; Alasia et al., 2007; El-Osta, Mishra, and Morehart, 2008).

Technological change is recognized as a key driver behind farm structural changes, including trends in off-farm income (Huffman, 1977; Cochrane, 1987; Gardner, 1992; O'Brien and Hennessy, 2008). A key aspect of technology in determining farm labor demand is the degree of substitution between operators' labor and other farm inputs. Benjamin and Kimhi (2006) found, based on data from French farm households, that hired labor tends to be a substitute for farm household labor. They further indicate that these results contrast with previous studies (e.g. Benjamin, Corsi, and Guyomard, 1996), which found hired labor to complement farm operators' labor. They also found that this substitutability increased with the level of human capital of the farm operator. This may reflect the greater degree of integration between farm and non-farm labor market induced by the ease of commuting and higher education of operators. But it may also reflect the development of better human resource management skills among farm operators (e.g. Canadian Agricultural Human Resource Council (2013)).

The substitutability between farm capital and labor is also well documented (e.g. Binswanger, 1974; Lopez, 1980; Chavas, Chambers, and Pope, 2010). However, the interaction between off-farm diversification and farm capital is more complex. For example, Ahituv and Kimhi (2002) find an ambiguous relation between farm capital

and off-farm work. They found a relationship that is in general negative except for a group of "high ability" operators that are able to work off the farm while maintaining a capital-intensive farm enterprise. The use of variable inputs may also be affected by the decision to work off the farm. Phimister and Roberts (2006) find that off-farm work reduces the use of fertilizer and increases the use of crop protection inputs. Fernandez-Cornejo, Hendricks, and Mishra (2005) finds that adoption of herbicide-tolerant crops is positively related to off-farm work and to an increase in overall household income.

Yet, the most prominent effect of off-farm employment on the farm labor demand may be due to the presence of economies of scale. In the presence of economies of scale, diversification of labor would imply a loss of farm efficiency. Some studies of U.S. farms from the 1980's found no evidence that part-time operators were less efficient than full-time farmers (Singh and Williamson Jr, 1981; Bagi, 1984). But more recent studies of U.S. farm households concluded that there is a significant trade-off between farm efficiency and off-farm labor supply (Paul et al., 2004; Paul and Nehring, 2005; Nehring, Fernandes-Cornejo, and Banker, 2005; Fernandez-Cornejo, Nehring, and Erickson, 2007). They attribute this efficiency loss to the presence of economies of scale in U.S. agriculture. However, most of the empirical evidence suggest that economies of scale are limited to a range of relatively small farms, while average cost are constant for medium to large farms (Chavas, Chambers, and Pope, 2010). In addition, it appears that economies of scale are more important in the livestock sector than in the crop sector (MacDonald, O'Donoghue, and Hoppe, 2010).

For crop farms, Nehring, Fernandes-Cornejo, and Banker (2005) also conclude that including off-farm income as an output of the household makes the efficiency of households specialized in off-farm activities comparable to that of household specialized in farm enterprises. They attribute these results to the presence of economies of scope between farm and off-farm enterprises. These may occur if, for example, period of higher labor demand from off-farm enterprises coincides with downtimes on the farm. In line with this hypothesis, Fernandez-Cornejo, Nehring, and Erickson (2007) confirmed that off-farm income increases the overall efficiency of households operating crop farms, but found that it decreases efficiency of households operating dairy farms. Overall, these results would imply that, on average, off-farm diversification may impose an efficiency loss in terms of farm production, but, at least for crop farms, it does not imply an efficiency loss in terms of the contribution of the household to the overall economy.

Demand for off-farm labor

The influence of the nonfarm sector has long been recognized as a leading force in shaping farm structure (Ruttan and Hayami, 1984; Chavas, Chambers, and Pope, 2010). Economic growth, increasing demand for off-farm labor, and increasing off-farm wages have induced technological development that led to a large outflow of

labor from the farm sector. However, some degree of farm labor fixity, induced for example by transfer or moving costs and the non-monetary value of farming, prevented a full adjustment of the farm sector to the economic conditions (Tweeten, 1970).

The integration and diversification of the rural economy has increased the accessibility of off-farm employment. In general, the likelihood of off-farm work and the level of off-farm income depends on local and regional socio-economic characteristics as well as the proximity to urban centers and access to urban labor markets (Alasia et al., 2007). Foltz and Aldana (2006) actually report that local economic conditions and wages may have a greater impact on farm investment than agricultural policies. Finally, human capital is another key variable that can affect the off-farm wage. The empirical literature reports a positive relationship between education and off-farm work (Huffman, 1980; Howard and Swidinsky, 2000; Benjamin and Kimhi, 2006; Alasia et al., 2007). The impact of human capital on off-farm work could be ambiguous as it is also expected to have a positive impact on farm labor demand. But, Sumner (1982) reports that the effect is larger on off-farm labor demand.

Labor allocation and life-cycle dynamics

Labor allocation decisions are part of a lifetime decision-making process (MaCurdy, 1981; Blundell and MaCurdy, 1999). A number of elements contribute to the dynamic nature of labor supply. For example, adjustment costs involved in change of employment may induce some degree of fixity in labor resource allocation. Human and financial capital accumulation can also play a role in defining labor supply and the life cycle patterns of employment and earnings (Sumner, 1982; Blundell and MaCurdy, 1999). As a result, off-farm work decision can be expected to follow some common life-cycle patterns.

Off-farm work is often thought of as a transitory step that can either help younger farmers to enter the farm sector or smooth the transition of older operators towards farm exit (Tweeten and Zulauf, 1994; Stiglbauer, Weiss et al., 1999; Weiss, 1999; Kimhi and Bollman, 1999; Kimhi, 2000). However, there is evidence that off-farm work is more than a transitory phase within the farm life-cycle, and that it is an enduring feature for many farm operators and families (Bollman and Steeves, 1982; Olfert and Stabler, 1994; Kimhi, 2000). In fact, off-farm work is thought to have a stabilizing effect on farm structure (Gardner, 1992). The empirical results tend to show that off-farm work reduces the likelihood of farm exit. For example, Bollman (1982) report that a small amount of off-farm work reduces the probability of farm exit while a larger amount increases that probability. While Kimhi and Bollman (1999) does not discriminate based on the level of off-farm income, simply stating that off-farm income in general reduces the tendency to exit farming. Similar conclusions were also reached by Glauben, Tietje, and Weiss (2006).

2.2 Policy Implication of Off-farm Diversification

The fact that farm operators and families take part in other economic activities is not new to agriculture. Farmers at all times have sought to complement farm income by diversifying labor to other activities and the increasing importance of off-farm income and part-time farming can be traced back at least to the 1930's (Salter and Diehl, 1940; Huffman, 1977; Bollman, 1979). What may have changed over time is the economic and policy context in which it takes place, and with it the importance of the phenomenon in both economic and political terms has also changed.

An historical perspective

The rightful place of part-time farming and its appropriate consideration under farm policies has been a source of debate for a long time. At times, part-time farming and off-farm diversification have been considered as either irrelevant to farm policy objectives or inconsistent with them. An early example is provided by Salter and Diehl (1940), who wrote: "[a]ttempts to promote part-time farming have been popularly referred to as 'abolishing' the farmer or 'plowing him under'" (p.585). In the aftermath of the Great Depression, the perception was that part-time operators could represent an unfair competition that weakened the output market of the full-time farmer. On the other hand, the perceived advantage of encouraging part-time farming was "that the agricultural activities of part-time farmers [...] act as an economic cushion in periods of industrial unemployment" (p.586).

Needless to say, the economic and political context has changed dramatically. Since then, part-time farming and off-farm income have played a key role in shaping actual farm structure. Off-farm work has been recognized as an important mechanism to transfer wealth and resources between agriculture and other sectors of the economy. Historically, low returns to farm resources have been the central issue underlying farm income policy (Gardner, 1987, 1992, 2000; Schmitz, Moss, and Schmitz, 2010). These low returns suggested the presence of excess resources in the farm sector and a disequilibrium between farm and non-farm sectors. This chronic overcapacity is usually explained by some combination of technological improvement, labor-saving technology in particular, the presence of economies of scale, and a low income elasticity of farm outputs. These are central forces underlying the industrialization and commercialization process of agriculture and led to the diminishing relative contribution of primary agriculture in terms of employment and economic activity for the global, and even the rural economy. Meanwhile, the inability of the farm sector to adjust to these pressures have been explained by, some degree of asset fixity, low opportunity costs of farm resources, and some disconnection between farm and non-farm resource markets (Johnson, 1950; Johnson and Pasour, 1981).

The ongoing decrease in farm numbers reflects the constant pressure to transfer labor resources out of the farm sector. However, the degree of integration between

farm and non-farm labor markets has seemingly increased. The non-farm sector has increased in volume compared to the farm sector, making it easier to absorb excess farm labor. And commuting between rural areas and urban centers has also become easier, in part due to improvement in infrastructures and to the urban sprawl that took place over the last decades and likely reduced the distance between urbanized areas and farmers (Alasia et al., 2007). The increasing level of education of farm operators and their families is also a potent candidate in explaining the higher degree of mobility of farm labor resources.

Over the last 50 years, these adjustments in resource allocation were strongly linked to the debates underlying the development of agricultural policies, as the following statement illustrates.

Agricultural policy is currently up for review and revision. The dramatic long-term changes in the interaction between farm and nonfarm labor markets between 1950 and 1970 should be recognized in drafting new legislation. It will be easy to draft legislation that effectively attempts to protect agriculture from needed long-term resource adjustments, especially the reduction of labor in agriculture. To the extent that protection is successful, it only delays the time when resource adjustment must occur.

Huffman (1977) p.1060

Although Huffman's policy recommendations have been ignored for the most part, the overcapacity of the farm sector remained and maintained pressure for resource adjustments. And, by now, data shows that farm families have an average income level comparable to other families (Park et al., 2011), such that the traditional farm income problem is no longer a policy concern. This adjustment in resource allocation is generally attributed to off-farm income and the improving economic conditions in non-farm sectors.

... farmers' incomes benefited from the sector's becoming better integrated with a growing rural nonfarm economy, through off-farm jobs and opportunities to leave farming altogether, which increased the marginal value of labor of those lower-income households that remained in farming. If government policies are to be credited for this, they are the overall macroeconomic and industrial policies that permitted the U.S. market economy generally to develop and to flourish.

Gardner (2000) p.1073

Part-time farming and modern policies

Despite the acknowledged role of labor mobility in solving previous policy issues, there remain some policy debates surrounding off-farm diversification and, most importantly, part-time operations. Because farm structural changes can affect farms' societal value and their economic performance, these changes have long fueled farm policy debates. And, given complex and often ill-defined policy objectives, it is not surprising to find that off-farm diversification still generates some debates.

Some economists have expressed concerns over the inconsistency of part-time operation with farm policies. For example, Blank (2002) observed that small farms are generally not profitable and must therefore be "subsidized" by off-farm work. The author then argues that the objective of operators cannot be pure profit maximization. Instead, operators of small farms must see farming as a hobby or a "way-of-life", and to the extent that off-farm diversification is induced by such objectives it is inconsistent with alleged policy objectives which tend to focus on farm production, efficiency, and competitiveness (Blank, 2002).

On the other hand, Cochrane (1987) states that rural communities dominated by "factory" farms offer poor quality of life while "a rural community with a heavy concentration of medium to modest sized farmers with a high degree of land ownership by the farmers involved results in a rural community with a high quality of life" (p.7). This passage basically amounts to a statement of the longstanding Goldschmidt thesis (Lobao, 1990; Lobao and Meyer, 2001). In addition, Cochrane argues that part-time operators have been "short-changed" by commodity programs and that policies should be targeted at "modest-size" operations to support them in developing successful farming enterprises. While there has been some attempts to improve the targeting of commodity programs by imposing payment limits, improvement in the distributional aspect of commodity programs have been modest at best (Sumner, 1991; Gundersen et al., 2000).

The apparent divergence of opinion on the rightful treatment of part-time and smaller farm operations by public policies appears to hinge heavily on what one sees as the ultimate objective behind farm policy and the criteria on which to judge farm programs. If the policy objective can be narrowed down to the stimulation of farm investment and competitiveness, then farm efficiency may be a relevant criteria and supporting part-time "hobby" operations, through either commodity programs, direct payments or fiscal advantages, may be counterproductive (Blank and Erickson, 2007). However, if the ultimate policy objective remains broader and encompasses some distributional concerns, then it may be best defined with respect to the efficient allocation of resources within the wider economy. Consequently, the impact of part-time farming should be assessed not only with respect to their contribution to the farm sector but with respect to their contribution to the broader rural and national economy. Assessing this contribution is much more complex, as it spans multiple

economic sectors and involves spatial and sectoral interdependencies which may not be fully understood (Kilkenny and Partridge, 2009).

Therefore, because off-farm diversification may have some implications for farm structure, which may in turn affect farm performance and local communities, some of the interactions between farm policy objectives and off-farm diversification can be seen as part of a larger debate on the appropriate balance between place-based rural policies and sector-based agricultural policies. While current farm sectoral policies are leaning increasingly on the incompleteness of risk markets to justify public intervention (Goodwin and Smith, 2013), champions of place-based policies argue that location and resource immobility are likely to create greater distortions and efficiency losses than any failure in commodity and risk markets (Kraybill and Kilkenny, 2003).

Given the declining economic importance of agriculture in most regions, some have argued that it might be advantageous to recognize the contribution of various economic sectors to rural livelihood and to shift the policy focus away from agricultural and sectoral policies and towards a more broad-based approach (Anderson, 1998; Freshwater, 1997; OECD, 2001; Kraybill and Kilkenny, 2003; OECD, 2006a,b). Moreover, much in the same way that in the aftermath of the Great Depression part-time farming was seen as a potential stabilizing force to help rural populations cope with possible industrial downturns (Salter and Diehl, 1940), some authors have proposed to use rural development policies as a tool to help stabilize farm households' income (Kostov and Lingard, 2001, 2003). In both cases, the interdependencies among sectors of a regional economy and the mobility of resources between sectors is recognized and put forward as a key mechanism to cope with economic shocks.

Despite the interest in issues relating farm structure to rural development and the broader economic impact of the agricultural sector, these are not directly addressed in this dissertation. Knowledge of these arguments and debates is crucial to understand the different views and criticisms that might be raised when discussing the policy implications of off-farm diversification, but this dissertation is mainly concerned with commercial agriculture, as opposed to "hobby" farms, and the role that off-farm income may have in addressing the alleged issues underlying risk management policies currently in place. Thus, an empirical assessment of the impacts and ramifications of off-farm diversification and part-time farming for rural development and broader economic issues is well beyond the scope of this dissertation.

Off-farm income and farm income risk

By the 1990's, the equity and distributional concerns over chronically depressed farm income had faded and the policy focus shifted towards other issues including farm income risk (Gardner, 1987, 1992; Knutson, Penn, and Flinchbaugh, 1998; Tweeten, 2002). While depressed income among farm families reflected the need for long-term adjustments in resource allocation between farm and non-farm sectors, the issue of

farm income risk relates to the difficulties of the farm sector to adjust to, and to cope with, short-term income shocks. Implicitly, the policy paradigm based on farm income risk assumes that long-term returns to farm operation are adequate or, at the very least, that resources can adjust to long-term changes in farm returns.

Theoretical foundations underlying the concerns over short-term adjustments are usually based on large price and yield variability, over which individual farmers have little control. The arguments typically build on the inelastic nature of supply and demand for agricultural commodities, which exacerbate price swings induced by shifts in supply, and on producers' exposure to financial risks. It suggests that farmers are exposed to unusually large income risks that are uncontrollable at the firm level. But, most importantly, the argument builds on the uninsurability of these risks due to their spatial and serial correlation. It is then argued that, if farmers are risk averse, their welfare and the level of investment in farm production would be suboptimal, and that rural communities would lose direct and indirect economic benefits from farm production. Hence, uncertainty, combined with the risk aversion of farmers and the failure of private markets to supply adequate risk transfer mechanisms motivates public intervention (Gardner, 1987; Miranda and Glauber, 1997; Knutson, Penn, and Flinchbaugh, 1998; Goodwin, 2001; Schmitz, Moss, and Schmitz, 2010).

In both the U.S. and Canada, central policy instruments targeted at reducing farm income instability include subsidized crop insurance and farm revenue insurance programs. However, the virtues of those programs have been called into questions by many economists (e.g. Tweeten, 2002; OECD, 2009a; Goodwin and Smith, 2013). It is argued that those programs are inefficient and are crowding out a number of private risk management initiatives, including off-farm diversification. Many have argued in favor of major reforms and reductions in the level of subsidies provided in the programs, and some even argued that the social cost of the programs is greater than the cost of relying only on incomplete private risk management tools (Tweeten, 2002; Babcock and Hart, 2006; Gardner and Sumner, 2007; Glauber, 2007).

In itself, off-farm income does not affect the variability of farm income. It may, however, dampen the adverse effects attributed to farm income risk. The empirical literature provides a number of studies suggesting the existence of a relationship between farm income risk and the incidence of off-farm income (Kyle, 1993; Mishra and Goodwin, 1997; Mishra and Holthausen, 2002; Jette-Nantel et al., 2011). These empirical results hint that either farmers respond to farm income shocks by diversifying their income portfolio via off-farm activities, or that diversified farm households tend to venture into more risky farm enterprises. In both cases, this would imply that farm production decisions are conditioned on the risk and return of an income portfolio that includes off-farm components. This, then, suggests that assessing the impact of farm policy on farm households' welfare and on farms' resource allocation decisions should be done in an holistic framework, including off-farm income, especially if policies are targeted at income stabilization (OECD, 2009a).

The diversification provided by off-farm income may have a substantial effect on farm households and operators' decisions. In order to provide diversification benefits in mitigating the effect of farm income shocks, farm and non-farm activities must share a low correlation, which they usually do. For most OECD countries, Da-Rocha and Restuccia (2006) report that agriculture has counter-cyclical properties such that one would expect most off-farm income and investments to be unrelated or even negatively related to farm income shocks.

However, the value of off-farm diversification will be defined in part by its impact on farm structure and farm performance. To the extent that off-farm diversification imposes labor or managerial constraints, it could impose an efficiency cost that would reduce the potential benefits of off-farm diversification as a risk management tool. In other words, the diversification premium related to off-farm work may be relatively high.

There may also be additional financial benefits from off-farm diversification. In trying to define the benefits of diversification, one must keep in mind that while the empirical literature indicates that farmers alter their behavior in presence of risk and that off-farm diversification is one alternative amid a list of possible responses, the underlying cause leading to this risk response remains mostly unknown (Just and Pope, 2003). Although most economists surmise that risk aversion is an important factor, estimating and testing for the presence of risk aversion has turned out to be a challenging enterprise that remains largely unsuccessful (Lence, 2009; Just, Khandachavana, and Just, 2010). At the same time, a number of competing alternatives can explain farmers' behavior, including credit constraints, and the benefits of diversification may depend in part on the origins of farmers' risk response.

In fact, a part of the empirical literature would suggest that off-farm income may play a key role in providing sufficient liquidity to ensure farm financial viability and to smooth household consumption over time. Kwon, Orazem, and Otto (2006) found empirical evidence of a relationship between off-farm income and temporary farm income shocks. This suggests that U.S. farm households face liquidity constraints and use off-farm income to smooth consumption.

And, returns to farm investment appear to be defined in great part by capital gains on land and other farm assets (Blank, 2005; Blank et al., 2009). To the extent that returns to farming are defined by capital gains, their realization requires the ability to generate enough income to satisfy liquidity requirements over the lifetime of the farm. Blank and Erickson (2007) argues that off-farm income has only a minor impact in determining farm household wealth, but that "it enables farm households to 'pay the bills' while capital gains accumulate over time through the appreciation of farm capital - mostly farmland."(p.11).

In addition, there are a number of empirical studies that found evidence of capital market imperfections and credits constraints within the farm sectors of OECD

countries (Phimister, 1995; Bierlen and Featherstone, 1998; Bierlen, Ahrendsen, and Dixon, 1998; Benjamin and Phimister, 2002; Briggeman, Towe, and Morehart, 2009). Other empirical evidence directly relates off-farm income to the presence of financial constraints. The empirical findings of Weersink (2008), based on Canadian data, suggest a positive relation between farm debt-to-equity ratio and off-farm work while Briggeman (2011) shows that many U.S. farms depend heavily on off-farm income to service their debt.

Nevertheless, the expected utility model remains the workhorse of risk analysis and a few authors have used it to analyze off-farm diversification decisions. First, applying a standard expected return-variance model, Blank and Erickson (2007) show that increases in return to off-farm labor would lead operators to increase off-farm work and also to opt for riskier farm production plans. They also show how, in a static framework under complete markets, the presence of economies of scale would lead operators of larger farms to reduce their level of off-farm work.

Andersson, Ramamurtie, and Ramaswami (2003) analyzed off-farm diversification using a dynamic portfolio optimization model under the assumption of perfect capital and labor markets. The model assumes risky off-farm income, and risky farm and non-farm assets. The authors show that off-farm income generates a wealth effect that stimulates farm investment. The presence of off-farm income also induces a portfolio rebalancing effect, the sign of which depends on the correlations between the different assets and off-farm income. Given the low correlation between farm asset return and other financial assets, a positive rebalancing effect is most likely, leading to a further increase in farm investment. Consequently, the authors conclude that even if farm assets are riskier than other assets, if the correlation between farm assets and off-farm income is low compared to the correlation with other assets, off-farm work will induce an increase in farm investment.

These theoretical models did not consider the possibility of either labor or capital market imperfections. Foltz and Aldana (2006) imposed a hard constraint on labor within a deterministic dynamic model. They showed that if farm investment and labor are complements, an increase in the wage rate has a negative effect on farm investment, while the effect of an increase in farm output price is ambiguous. The difference in results between Andersson, Ramamurtie, and Ramaswami (2003) and Foltz and Aldana (2006) can be explained by the presence of the labor constraint. Foltz and Aldana (2006) assumed that farm production is limited by the labor of the operator, precluding access to hired labor. In a way this difference illustrates the impact of imperfect markets and the non-separability of consumption and production. An imperfect labor market will make operators' labor more valuable to the farm than hired labor, which could result in either lower farm productivity or smaller farm size. On the other hand, imperfect capital would make internal funds more valuable and would likely result in an increase in the value of off-farm diversification.

2.3 Conclusion

This chapter reviewed current trends in off-farm work among OECD countries and presented the main factors influencing farm operators' and households' labor allocation decisions. It indicates that the farm sector is heavily influenced by the rest of the economy. In particular, economic growth and technological development have a strong influence in defining farm and off-farm labor demands and farm structure. As a result, no matter whether farm policy objectives focus more heavily on farm households' welfare, or on farm production and efficiency, it appears that the off-farm sector has a role to play in determining the efficiency of the policy instruments and the need for public intervention. It thus provides an argument to take off-farm diversification possibilities into consideration in the policy making process. However, how to integrate off-farm diversification and the nonfarm rural economy in the policy development remains an open question.

Properly defined policy objectives would certainly help in improving our understanding of the interactions between the off-farm sector and farm policies. Taking farm income stabilization as the central objective of farm policy, it appears that a better understanding of the nature of farm income risks, the potential contribution of off-farm income, and also the trade-offs and constraints in terms of combining farm and off-farm activities would be helpful. In particular, the relationship between off-farm diversification and efficiency appears to be of importance. Also, the potential for a "crowding out" effect between off-farm diversification and farm policy seems to be a key factor in determining the impact of off-farm activities on farm programs.

Chapter 3

Modeling the Impact of Off-farm Income on Farm Decisions

The previous chapter highlighted the key elements influencing labor allocation decisions and off-farm diversification. In particular, attention was given to the financial benefits of diversification in the farm context. A review of the literature showed that the few theoretical models proposed to assess off-farm diversification benefits did not account for the presence of capital market imperfections. Yet, it was shown that part of the argument explaining the incidence of off-farm work is that it can help mitigate the effect of credit market imperfections by attenuating the impact of liquidity constraints (Kwon, Orazem, and Otto, 2006; Blank and Erickson, 2007; Briggeman, 2011). This chapter proposes a model, borrowed from the consumption and finance literature, which integrates capital market imperfections and labor allocation decisions, and thus provides a more accurate assessment of the benefits of diversification.

3.1 A Review of Buffer Stock Saving Models

Most risk management studies in agriculture have focused on static models, mainly using expected utility or mean-variance frameworks (e.g. Duncan and Myers, 2000; Coble and Knight, 2002; Mahul and Wright, 2003; Barnett et al., 2005; Power, Vedenov, and Hong, 2009). This framework implies an ad hoc relationship between consumption and income, precluding consumption smoothing. On the other hand, standard dynamic portfolio models (e.g. Merton, 1969), rely on the assumption of perfect markets. In order to examine the interactions between farm risk management programs and off-farm diversification, I chose to use a dynamic model with imperfect markets. This is motivated by a desire to capture the impact of off-farm work not only on production risk, but also on exposure to financial risk and the presence of capital market imperfections.

The modeling choice is guided by a number of theoretical results emanating from the finance and macroeconomic literatures based on the buffer stock saving model which is mostly attributed to Deaton (1991) and Carroll, Hall, and Zeldes (1992). Under an assumption of imperfect markets and borrowing constraints, agents in these models make consumption, investment and borrowing decisions in order to balance the need for precautionary savings, their impatience for consumption, and the possibility of investing in risky assets. As a result, the approach provides a framework that captures the value of a steady flow of liquid labor income in smoothing consumption and relaxing borrowing constraints. It also captures the impact of such income flow on investment incentives and insurance demand.

The original paper of Deaton considered optimal consumption and savings in the presence of labor income and one asset. Deaton’s buffer-stock model was intended to capture the impact of borrowing constraints on consumption and saving behavior in an attempt to address some of the shortcomings of consumption models and the apparent violation of the permanent income hypothesis. Further developments of the model focused on the introduction of risky assets and portfolio choices (e.g. Heaton and Lucas, 1997, 2001, 2002; Haliassos and Michaelides, 2003; Gomes and Michaelides, 2005; Cocco, Gomes, and Maenhout, 2005; Willen and Kubler, 2006). This branch of literature shows that, in the presence of uncorrelated – or weakly correlated – labor income and stock returns, buffer stock models predict an optimal portfolio specialized almost exclusively in stocks (e.g. Heaton and Lucas, 1997, 2001). Although this theoretical result is at odds with observed behavior, since most U.S. households do not hold stocks, a number of model modifications that could account for these discrepancies were offered. These included the addition of stock market participation costs (Haliassos and Michaelides, 2003; Gomes and Michaelides, 2005), more realistic borrowing constraints (Cocco, Gomes, and Maenhout, 2005; Willen and Kubler, 2006), higher correlation between labor income and asset returns (Heaton and Lucas, 2002), the possibility of catastrophic labor income shocks (Cocco, Gomes, and Maenhout, 2005), or alternative utility specification (Gomes and Michaelides, 2005). But the main conclusion remained: when labor income is weakly correlated with risky investment returns, the flow of labor income acts as a substitute for a risk free investment and increases the incentives to invest in risky assets.

The finite horizon version of the model, the life-cycle savings and portfolio model, draws from the work of Merton(1969) and Samuelson(1969). These early studies assumed perfect markets and did not include labor income. However, Bodie, Merton, and Samuelson (1992) expanded Merton’s model by including labor income and showed that the possibility of adjusting labor effort and income *ex-post* increases the demand for risky assets *ex-ante*. These results not only reinforce the idea that labor income increases incentives to invest in the risky asset, but show that the possibility to readjust labor income after lifting some of the investment uncertainty provides further insurance benefits even under perfect market assumptions. In fact, Merton’s original portfolio rule can be modified to account for labor income. Merton’s rule can be expressed as $\alpha = \mu / ((1 - \omega)\sigma^2)$, which represents the share of wealth invested in the risky asset (α) as a function of risk aversion ($1 - \omega$) and risky asset’s expected return and variance, μ and σ^2 . Including labor income leads to the expression:

$$\alpha_t = \alpha \cdot \frac{W_t + PVY_t}{W_t}$$

where W_t is the financial wealth at time t and PVY_t is the present value of future labor income (Cocco, 2005). This rule specifies that if the discounted value of future labor income is zero, i.e. $PVY_t = 0$ which implies that human capital no longer has value, then Merton’s rule should be followed. But when the value of human capital is positive, the share of wealth invested in the risky asset increases, i.e. $\alpha_t > \alpha$. Hence,

this rule explicitly accounts for the value of human capital and offers an explanation as to why younger investors will tend to invest more in risky assets.

Having established the impact of labor income on the optimal portfolio allocation, it becomes natural to expect that labor income will also affect other risk related decisions. The relationship between insurance demand and labor income under imperfect capital markets was investigated by Gollier (2003). His study showed that in a life-cycle buffer stock model, demand for income insurance is much lower than in a static model. The results showed that endogenous demand for insurance¹ remains limited to catastrophic risk, unless there is a binding liquidity constraint. These results strongly suggest that static models would underestimate the impact of labor income on insurance demand and benefits.

While most studies focused on wage earners, a few also considered the case of entrepreneurs, which is closer to that of farm operators. First, entrepreneurs' income is generally riskier and more closely correlated with stock returns, such that they have less incentive to invest in equity markets compared to wages earners. Following the human capital argument of Bodie, Merton, and Samuelson (1992), Polkovnichenko (2003) also argued that young entrepreneurs have a greater capacity to cope with risks compared to their older counterparts because their human capital provides them with greater flexibility and limits the potential consumption shocks induced by business risk. Hintermaier and Steinberger (2005) added the presence of a persistent idiosyncratic risk to entrepreneurs' return on private equity and found that uncovering information about this shock led younger entrepreneurs to accept even greater risk. The authors concluded that younger entrepreneurs hold an exit option that is more valuable than that of an older entrepreneur, simply because of the time value of their option. As such they are willing to undertake/accept greater risk in starting a business.

On the other hand, entrepreneurs tend to invest most of their equity in their own business. The preference of entrepreneurs for internal equity capital is likely to limit entrepreneurs' participation in public equity markets. The case is similar to households who invest most of their equity in housing. In both cases, internal funds may be preferred due to imperfect capital markets and the cost of debt. In a study including housing equity, Cocco (2005) shows that, under imperfect markets, younger and poorer investors have very little wealth to invest in stocks. Borrowing to invest reduces greatly the potential benefits of owning stocks, and housing price risk tend to crowd out investment in other risky assets.

Extrapolating some of these theoretical implications to farm operators would suggest that, the negative correlation between farm income and the rest of the economy, should increase incentives of farmers to invest in stocks. Also, younger farmers would be willing to undertake greater financial risk in starting a farm operation. But, at

¹Gollier (2003) assumed a 0.3 loading factor to derive his main conclusion.

the same time, because farm operations are capital intensive and access to equity capital remains limited in most cases, we could expect that most farmers – especially younger ones – would not hold stocks, despite the potential diversification benefits they represent. Furthermore, the aforementioned results, with respect to insurance demand, would indicate that the benefits from public risk management programs would be much lower for operators with off-farm income. Not because they typically operate smaller farms, or because they own a farm for non-business purposes, but because their need for insurance products is lowered by the financial benefits of a steady income flow and the flexibility that their human capital provides them.

In summary, the buffer stock model has shown to be an interesting framework in explaining investment and consumption choices for a number of different settings and could offer interesting insights regarding farming decisions, ranging from insurance demand to entry and exit decisions. Admittedly, introducing market imperfections makes these dynamic models much more complex than traditional expected utility or mean-variance static models. From a farm modeling point of view, a key advantage of such models is the capacity to capture the effect of capital market imperfections and to combine production and financial risks within a single model, thus allowing agents to endogenously balance the two sources of risk. The importance of this trade off between financial and production risk was highlighted by a few authors (e.g Gabriel and Baker, 1980; Featherstone et al., 1988; Turvey and Baker, 1989) but most of the empirical literature on farm income risk continues to ignore it. Even the few efforts just mentioned either fail to properly endogenize the trade-off between financial and production risk, or they ignore borrowing constraints and liquidity risk and thus underestimate the importance of financial risk. The buffer stock model could fill this important gap.

Overall, I contend that buffer stock dynamic models provide a more thorough and realistic characterization of the level of risk faced by farm operators. And, by allowing operators to adjust labor allocation, they also include a more complete set of risk management tools. By ignoring many of those aspects, a static expected utility framework would likely understate the effect of off-farm income on farm households' decisions and welfare. Hence, I consider such a dynamic framework as most appropriate to assess the impact of off-farm income on farm decisions and farm households' welfare; and, consequently, most appropriate to assess the potential interactions between off-farm diversification and risk management provided through government programs.

3.2 A Farm Level Buffer Stock Model

In this section a life-cycle dynamic farm management model including farm and off-farm enterprises is defined. As mentioned above, the key objective is to design a model that will capture the financial implications of off-farm income. The model borrows various concepts from the buffer stock literature and adapts them to the farm context

by incorporating various elements of the farm structure, such as economies of scale and scope. The model also includes realistic borrowing constraints as well as an insurance scheme that mimic the effect of public risk management programs. In addition, the model allows some labor allocation flexibility by letting the agent choose to become, or remain, a full-time farm entrepreneur, to adopt part-time off-farm employment, or to exit farming altogether. This is done by solving the model over three different regimes: full-time farming, part-time farming, and full-time off-farm employment.

The first step is to model the operator and farm household consumption decisions. It is assumed that farm operators are risk averse and maximize utility of consumption (C) at time $t \in [0, T - 1]$, which is defined as:

$$U(C_t) = \frac{C_t^{1-\omega}}{1-\omega} - I(R_t, E_t) \mathbf{SC}$$

where \mathbf{SC} is a vector of transaction costs associated with changes in regime and $I(R_t, E_t)$ is an indicator function taking values of one when a regime switch has taken place and zero otherwise. It is assumed that at any time farm operators can switch either to part-time farming ($E = 1$), in which case they maintain their farm operation and additionally earn some off-farm income, or they can switch to full time off-farm work ($E = 2$) in which case they must abandon farming. The amount of off-farm labor can only take a value θ_y in the case of part-time farming or one if the operator exits the farming sector. As outlined by Bodie, Merton, and Samuelson (1992), the introduction of labor mobility provides further insurance benefits.

In each case the mobility of labor in and out of the farm sector is assumed to be reduced by the presence of transaction costs, and for simplicity we assume that exiting farming is irreversible. The transaction costs \mathbf{SC} can be thought of as representing both monetary costs linked to job hunting and training, and non-monetary costs associated with a change in life style and forgoing some of the advantages of "being your own boss". The presence of transaction costs can reflect the access and propensity to work off the farm, which may influence farm decisions and investments. These costs are likely to vary significantly across the farm population depending on personal preferences and operators' access to off-farm jobs, which may in turn depend on factors such as location, age and education.

Under the off-farm regime, the sources of income include labor income Y and interest on stocks S and bonds B . Under the farm regime, investments in stocks and bonds are still possible and it is assumed that the operator is either fully employed by the farm operation or works part-time off the farm in which case he or she earns a fraction $\theta_y = 1/2$ of the full employment labor income Y .

Farm output (F) is defined as part of a multi-input multi-output relationship. The objective of this approach is to include operators off-farm income (Y) as an output,

thus reflecting the potential interactions between farm and off-farm enterprises.² The function also captures the relationship between these two activities and a set of inputs including farm capital (K), farm hired labor (H), variable costs (VC), and farmland LD . The following translog distance function is used to model the multi-input multi-output relationship:

$$\begin{aligned}
\ln D &= \alpha_0 + \alpha_f \ln(F) + \alpha_o \ln(\theta_y Y) + \dots \\
&\dots + \frac{1}{2} \left(\alpha_{f,f} \ln(F)^2 + \alpha_{o,o} \ln(Y)^2 - 2\alpha_{f,o} \ln(F) \ln(\theta_y Y) \right) \\
&\dots + \beta \ln(X) + \frac{1}{2} \sum \beta_{k,l} \ln(X_k) \ln(X_l) \\
&\dots + \sum \gamma_{k,f} \ln(X_k) \ln(F) + \sum \gamma_{k,o} \ln(X_k) \ln(\theta_y Y)
\end{aligned}$$

where $X = [H, K, VC, LD]$ and D is a distance measure as defined in Chapter 4.

It is well known that translog approximation of distance and cost functions are not globally regular (Diewert and Wales, 1987; O'Donnell and Coelli, 2005), which may cause trouble in finding a numerical solution. Although there exist alternative functional forms on which global curvature can be imposed, the estimation of translog distance functions is more common and offers some key advantages (Coelli, 2000; Kumbhakar, 2011). Therefore, regularity conditions are imposed locally in the estimation of the translog distance function, such that regularity should hold over a sufficient range to obtain a robust numerical solution to the dynamic model. Details of the estimation procedure and results are presented in Chapter 4.

The farm gross output (F) is then derived from the distance function and multiplied by a stochastic index including yield and market price variability. The stochastic index is assumed to be a simple stochastic variable:

$$P_t = e^{\epsilon_t}, \quad \epsilon \sim N(0, \sigma_\epsilon)$$

Government payments take the form of a revenue insurance, similar to U.S. farm program ACRE or the Canadian Agristability program. When farm revenues fall below a certain threshold, government payment takes a value defined as a percentage of the difference between the expected farm revenues and actual revenues. More specifically, it can be defined as $gov_t = f(\Phi, \epsilon_t)$, where Φ is a set of parameters defining program trigger and coverage levels. Then, an adjusted price per unit of farm output capturing market revenues and government payment can be defined as:

$$Pg_t = P_t + gov_t$$

² Given the limitations of the data used to calibrate the model, it is assumed that spouse labor allocation decision is not directly related to farm production.

To refine the analysis of the impacts of government subsidized risk management programs, the payments are decomposed into two parts, a constant direct payment, equivalent to expected payments; and fair-priced revenue insurance. The premium for the insurance component is computed as:

$$\pi(\Phi) = \int f(\Phi, \epsilon_t) d\epsilon \quad (3.1)$$

and the direct payment is

$$DP = \int f(\bar{\Phi}, \epsilon_t) d\epsilon - \bar{\pi} \quad (3.2)$$

where $\bar{\pi}$ represents the premium paid by farmers under current policy conditions, and $\bar{\Phi}$ is the vector of parameters representing current policy triggers and payment parameters. Therefore, policy parameters Φ can be changed without affecting the total support level and one can then evaluate the impact of either reducing only the risk management component of current policy or reducing both the support and risk management components.

For simplicity, stocks returns are defined as a simple stochastic variable:

$$r_s = \bar{r}_s + \nu_t, \quad \nu \sim N(0, \sigma_\nu)$$

and following the findings of Da-Rocha and Restuccia (2006) it is assumed that farm income shocks and stocks are independent. i.e. $Cov(\nu, \epsilon) = 0$.

Liquidity constraints

The impact of borrowing constraints on portfolio choices within life cycle models has been analyzed by a number of authors. (e.g. Alvarez and Jermann, 2001; Cocco, Gomes, and Maenhout, 2005; Davis, Kubler, and Willen, 2006; Willen and Kubler, 2006). Not surprisingly, borrowing constraints are found to affect the financial risk households are willing to take. Much of the literature on life-cycle portfolio choices seeks to explain participation in equity markets. It is found that the low participation of households in equity markets could well be explained by the limited access and increasing cost of borrowed funds, which reduce substantially the benefits of equity ownership. For example, the results of Willen and Kubler (2006) indicate that realistic borrowing constraints greatly reduce the benefit of equity holding when one must borrow funds to invest, and therefore attributes much greater value to liquidity than does a standard model with unrealistic constraints such as a simple positive wealth or solvency constraint.

Because the value of liquidity depends highly on credit constraints and leverage capacity, imposing realistic constraints becomes important in attempting to value

the stream of liquidity provided by off-farm labor income. Willen and Kubler (2006) argue that borrowing constraints are more realistically reflected by cross asset restrictions. In other words, the possibility to hold a short sale position in one asset should be conditional on holding a long position in other collateral assets. Willen and Kubler (2006) make the case to restrict short sales of risky assets and make short sales of riskless assets conditional on holding an appropriate long position in risky assets, i.e. one can borrow an amount D at a constant rate if one also holds a sufficiently large position RA in a risky asset. Typically, we would require $RA > D$ to minimize solvency risk and the borrowing rate would decrease as $\theta = \frac{RA}{D}$ increases.

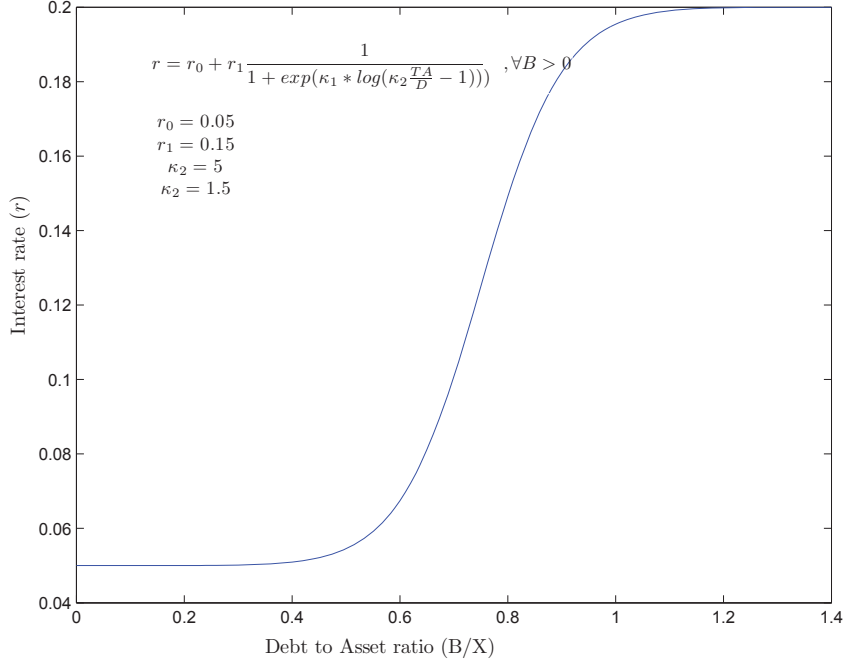
Within this framework, the two extreme approaches often found in the literature can be represented as special cases. First, imposing short-sale restrictions (i.e. $D > 0$) on all assets prevents borrowing altogether and ignores the possibility of using assets to secure loans and get more favorable borrowing rates. On the other hand, imposing a positive wealth constraint without regard for the positions in individual assets amounts to assuming that $\theta = 1$, and short sales are allowed for all assets. In other words, all assets can be used as collateral for other assets and 100% of their value is usable as collateral. This would amount to a very lax borrowing constraint where the specific risk of each asset is not taken into account by lenders.

In the case of farm operations, one could consider investment in farm production inputs as potential collateral that can be pledged for borrowed funds. Hence, given some level of future farm income as collateral, a certain share of farm inputs can be bought on credit. This is the typical operating credit that most farm operators use. This constraint can be imposed either by limiting the quantity of credit available, say $D < \theta RA$ where D is the amount borrowed and RA is the total amount of farm inputs and stock holdings, or by making the borrowing rate an increasing function of some proxy of the debt-to-asset ratio, e.g. $r = g\left(\frac{D}{RA}\right)$ where g is a monotonically increasing function. This latter approach is chosen based on the farm financial standards (Miller et al., 1994). The interest rate function is defined as:

$$r_{debt} = r_0 + r_1 \frac{1}{1 + \exp(\kappa_1 * \log(\kappa_2 \frac{RA}{D} - 1))}, \forall D > 0 \quad (3.3)$$

Figure 3.1 shows the interest rate as a function of the debt-to-asset ratio. This calibration shows that as long as the debt-to-asset ratio is less than 0.5 the rate increases at a fairly low pace reflecting the relatively low financial risk to the lender. But the rate increases much more rapidly thereafter towards a maximum rate of \bar{r} . One important implication of such a constraint is that it does not amount to a strict solvency constraint since there is a possibility that the agent will end up in an insolvent position if the realized farm income is low enough. In such case the rate on borrowed funds becomes \bar{r} if $\frac{RA}{D} \leq 1$, i.e. the rate on unsecured debt.

Figure 3.1: Interest rate on borrowed funds



Budget constraints and state transition equation

Consumption of goods (C), investment in stocks (S), and all farm inputs, including farm variable costs (VC), hired labor (H) farm capital (K) and land (LD), are bounded below at zero. Land is assumed to be rented through cash rental agreements, thus eliminating the potential for capital gains on land and the use of land as collateral. The budget constraint is balanced by variable B , which can represent investment in bonds when positive and borrowed funds when negative. The budget constraint is defined as:

$$B_t = -W_t + C_t + VC_t + H_t + K_t + S_t + \theta_y Y \quad (3.4)$$

This constraint states that borrowed funds must cover any consumption, farm expenses, and stock investment exceeding wealth W . This constraint excludes land rent, which is assumed to be paid at the end of the period. For each period, the wealth W_t is defined as the sum of farm and off-farm revenues minus all expenses, including interest on borrowed funds int_B as defined by equation 3.3. In cases where available funds exceed the sum of expenses, the surplus is assumed to be invested in bonds at the risk free rate (\tilde{r}) $< r_s < \bar{r}$, such that

$$r_b = \begin{cases} r_{debt} & \text{if } B > 0 \\ \tilde{r} & \text{if } B < 0 \end{cases} \quad (3.5)$$

Under the off-farm regime, all farm inputs are nil and the model boils down to a simple buffer stock model with two assets and a deterministic labor income. For simplicity, the model abstracts from the typical stochastic labor income profile that varies with age.

$$W_{t+1} = Pg_t \cdot F(Y_t, VC_t, H_t, K_t, LD_t) \dots \\ + (1 - \delta)K_t - \text{int}_B + S_t r_s - LD_t \cdot \text{rent} \quad (3.6)$$

Spousal income

As was mentioned in section 2.1, labor supply decisions of a farm operator depend in part on the composition of the household and the labor supply decision of the spouse. And there is some evidence that spouse labor allocation is related to farm income. For example, in Midwestern states a number of spouses went to work off the farm in response to the 1980's farm crisis (Barlett, Lobao, and Meyer, 1999; Lobao and Meyer, 2001). And this risk coping strategy may still be fairly common among large crop farms, as this comment made in 2011 by a Kansas farmer would suggest: "most of the larger farmers either have a wife working full-time who has a college degree, or the wife is also running the combine and everything else on the farm" (Beach, 2013, p.222). This suggest that the spouse contributes to improve farm liquidity and income by either reducing the cost of operation by substituting for hired labor, or by bringing additional income from off-farm employment.

A simple modeling approach is to represent the household as a single decision making unit where resources of all members are pooled and decisions are based on aggregate consumption and labor supply. This would imply that the off-farm income from a spouse would be included in Y in equation 3.6. Alternatively, the household model can be disaggregated to account for the consumption, labor supply, and budget constraint of each spouse. For example, a household model can be formulated as:

$$\max_{C_1, C_2} w_1 U_1(C_1) + w_2 U_2(C_2) \\ \text{s.t. } C_1 + C_2 < Y_1 + Y_2 + M \quad (3.7)$$

where Y_i is the income of spouse i and M is a common pool of wealth available for consumption, and w_i is the weight associated with utility of spouse i .

Following Blundell and MaCurdy (1999), this model can be reinterpreted as a single operator model given a budget constraint that includes a sharing rule $h(Y_1, Y_2, M)$:

$$\begin{aligned} \max_{C_1} \quad & U_1(C_1) \\ \text{s.t.} \quad & C_1 \leq h(Y_1, Y_2, M) \end{aligned} \quad (3.8)$$

A simple sharing rule can take the form $\frac{1}{1+\vartheta}(Y_1 + \vartheta Y_2 + M)$, $\vartheta \in [0, 1]$, such that when $\vartheta = 0$ there is no sharing and the operator can consume all of his income and wealth ($C_1 \leq Y_1 + M$), and when $\vartheta = 1$ there is complete sharing and the operator will consume half of total consumption, $C_1 \leq \frac{1}{2}(Y_1 + Y_2 + M)$.

Applying this rule to the budget constraint in eq. 3.4, we get a new constraint:

$$B_t = -W_t + C_t + VC_t + H_t + K_t + S_t + \theta_y Y_1 + \vartheta Y_2 + (1 + \vartheta)C \quad (3.9)$$

which explicitly accounts for the contribution of spouse income to the budget constraint and also includes his or her consumption. The main advantage of this formulation is that it makes possible the comparison between different sharing rules, and thus between single operators and operators with a spouse working off the farm.³

Retirement value

Finally, it is assumed that the operator or household retires after T periods of operation and benefits from the consumption of accumulated wealth W_T . For simplicity, the model abstracts from the potential pension benefit related to off-farm employment. The utility in period T depends uniquely on accumulated wealth W_T and the retirement value R_T is based on a preference parameter ρ , and a constant interest rate of \tilde{r} over N periods and is defined as:

$$\begin{aligned} R_T &= \max_{C_T} \sum_{i=0}^N \rho^i U(C_{T+i}) \quad \text{s.t.} \quad \sum_{i=0}^N \frac{C_{T+i}}{(1 + \tilde{r})^i} = \frac{W_T}{1 + \vartheta} \\ &\Rightarrow C_{T+i} = C_T ((1 + \tilde{r})\rho)^{-i/\omega} \\ &\Rightarrow C_T = \frac{W_T}{1 + \vartheta} \cdot \left[\sum_{i=0}^N \frac{((1 + \tilde{r})\rho)^{-i/\omega}}{(1 + \tilde{r})^i} \right]^{-1} \\ &C_T = \frac{W_T}{1 + \vartheta} \cdot Z(\rho, \tilde{r}, N, \omega) \\ R_T &= \sum_i^N \rho^i \left(\frac{W_T}{1 + \vartheta} \cdot Z(\rho, \tilde{r}, N, \omega) \cdot ((1 + \tilde{r})\rho)^{-i/\omega} \right)^{1-\omega} \end{aligned} \quad (3.10)$$

³For simplicity, this formulation ignores leisure as a component of the utility function. If leisure is included then the potential complementarity between spouse leisure time must also be taken into account in the maximization of utility.

Bellman equation

The resulting Bellman equation takes the form:

$$V_t(W_t, R_t) = \max_{\mathbf{A} \in A(\mathbf{S})} \left\{ \frac{C_t^{1-\omega}}{1-\omega} - SC(E_t, R_t) + \rho \int^\nu \int^\epsilon V_{t+1}(W_{t+1}, R_{t+1}) \right\} \quad (3.11)$$

and, given the budget constraint in eq. 3.9, we get the first order conditions:

$$\frac{C^{-\omega}}{1-\vartheta} = \rho \mathbf{E} \left[V'_W(W_{t+1}, R_{t+1})(Pg_t \cdot F'_{VC} - 1) \right] \quad (3.12)$$

$$= \rho \mathbf{E} \left[V'_W(W_{t+1}, R_{t+1})(Pg_t \cdot F'_H - 1) \right] \quad (3.13)$$

$$= \rho \mathbf{E} \left[V'_W(W_{t+1}, R_{t+1})(Pg_t \cdot F'_K - \delta) \right] \quad (3.14)$$

$$= \rho r_b \mathbf{E} \left[V'_W(W_{t+1}, R_{t+1}) \right] \quad (3.15)$$

$$= \rho \mathbf{E} \left[V'_W(W_{t+1}, R_{t+1}) \cdot r_s \right] \quad (3.16)$$

The relationship between financial and production risk is defined by the implied relationship between the cost of debt (r_b) and the risk premium⁴ on farm inputs as defined by the covariance between future marginal value and current marginal product of farm inputs:

$$r_b(W, \mathbf{A}) = \mathbf{E} \left[Pg_t \cdot F'_{VC} \right] - 1 + \text{Cov} \left(Pg_t \cdot F'_{VC}, V'_W(W_{t+1}, R_{t+1}) \right) \quad (3.17)$$

Hence, increases in farm production risk will be reflected by a higher covariance – in absolute terms – and will induce a decrease in the cost of debt, i.e. a reduction in leverage and financial risk. The diversification benefits of off-farm work and investment will be reflected in a lower covariance – in absolute terms – between future marginal utility and farm income shocks, thus reducing the premium on farm input marginal product and increasing the demand for farm inputs and investment.

Finally, the formulation as a regime switching model implies that certain conditions should hold at the switching point. Namely, the value-matching (eq.3.18) and smooth pasting (eq.3.19) conditions imply that at the optimal switching point from regime 1 to regime 2 ($\mathbf{S}_{1,2}^*$), the value under regime 1 should be equal to the value in regime two minus switching cost $SC_{1,2}$, and the derivative of the value function should be equal in the two regimes (Dixit and Pindyck, 1994).

$$V_1(\mathbf{S}_{1,2}^*) = V_2(\mathbf{S}_{1,2}^*) - SC_{1,2} \quad (3.18)$$

$$V'_1(\mathbf{S}_{1,2}^*) = V'_2(\mathbf{S}_{1,2}^*) \quad (3.19)$$

⁴This term is closely related to the *beta* defined in CAPM models. It is often referred to as the *consumption beta* (Breedeen, 1979; Romer, 2001)

3.3 Conclusion

In summary, the model integrates a number of potential sources of inefficiency and causes of resource misallocations that are thought to influence farm structure and its performance. These include: farm income risk, imperfect risk and capital markets, and some degree of labor immobility due to adjustment costs. Most importantly, it also includes off-farm diversification as a mechanism that can potentially mitigate the adverse effect of some of those market imperfection on operators welfare and farm efficiency.

Within this framework, the potential cost of incomplete risk markets are captured by the potential farm household welfare loss induced by the variability of farm income, including the potential of farm failure. At the aggregate level, another manifestation of resource misallocation may be reflected in sub-optimal farm production levels. But how this affects aggregate farm production and its indirect economic impact is less clear since unused inputs (e.g. land) would be used either by other operators or other sectors. Hence, given the microeconomic nature of the model, the potential indirect costs implied by changes in farm production and shifts of resources between sectors are not included.

Nevertheless, this model can be used to explore the interactions between farm revenue insurance programs and off-farm diversification and their impact on operators welfare as well as their farm production decisions. The availability and coverage of farm revenue insurance programs is defined by $\bar{\Phi}$. The parameters defining accessibility and level of off-farm income for farm operators and households is defined by: 1) the presence of a spouse working off the farm ϑ , 2) the presence of adjustment costs \mathbf{SC} , and 3) the level of off-farm income associated with full-time employment Y .

3.4 Model Summary

State dimensions

1. $W \in [0, \infty]$ - Wealth/Cash on hand
2. $R \in \{0, 1, 2\}$ - Regime

Thus defining the state variable $\mathbf{S} = W, R$

Action variables and action space

The action variables are $\mathbf{A} = \{C, VC, H, K, LD, B, St, E\}$, and the action space $A(\mathbf{S})$ is defined by the following constraints:

1. $K_t, C_t, H_t, VC_t, St_t \geq 0$
2. $E_t \in \{0, 1, 2\}$
3. $(1 + \vartheta)C_t + H_t + K_t + VC_t + St_t - B_t = W_t + \theta_y Y + \vartheta Y_2$

State transition function

$$W_{t+1} = Pg_t \cdot F(Y_t, VC_t, H_t, K_t, LD_t) \dots + (1 - \delta)K_t - \text{int}_B + St r_s - LD_t \cdot \text{rent} \quad (3.20)$$

$$R_{t+1} = E_t \quad (3.21)$$

Reward function

$$f(\mathbf{A}, \mathbf{S}) = \frac{C^{1-\omega}}{1-\omega} - SC(E, R) \quad (3.22)$$

Bellman equation

The Bellman equation takes the form:

$$V_t(W_{t+1}, R_{t+1}) = \max_{\mathbf{A} \in A(\mathbf{S})} \left\{ f(\mathbf{A}, \mathbf{S}) + \rho \int^\nu \int^\epsilon V_{t+1}(W_{t+1}, R_{t+1}) \right\} \quad (3.23)$$

Chapter 4

Farm Production and Off-Farm Diversification: Empirical Estimation

The previous chapter developed a theoretical model that provides a framework to assess the effect of imperfect markets on farm labor supply decisions. The other important element that was discussed in Chapter 2 is the presence of a diversification premium that is thought to reflect the presence of farm labor and managerial constraints. The effect of off-farm work on farm production will depend heavily on the characteristics of the farm production technology. On the one hand, the presence of economies of scale may increase the diversification premium by preventing part-time operators to achieve an efficient farm size. Naturally, this will depend on the magnitude of economies of scale and the range of farm size over which these economies might prevail. At the same time, the ability of operators to substitute other inputs for their labor may dampen the impact of economies of scale on a potential diversification premium. However, other inputs, such as hired labor, may require managerial time and skills which may also be constrained by off-farm work. On the other hand, the presence of economies of scope, where operators may take advantage of downtimes on the farm to work off the farm for example, could reduce the diversification premium.

Given the important role these production technology characteristics are presumed to play in defining the cost of diversification, this chapter is devoted to the empirical estimation of the production technology relating farm production and off-farm work. Theoretically consistent estimates, to be used for the calibration of the model presented in Chapter 3, are derived from a data set of commercial Kentucky grain farms. The next section provides a short review of different approaches found in the literature to account for the impact of off-farm activities on farm production. It is followed by the presentation of the econometric model, the data, and the estimation results. A discussion of the results and their implications conclude the chapter.

4.1 Off-farm Work and Farm Production: A Literature Review

Production and efficiency estimation has a long tradition in agricultural economics, although it often focused on the estimation of production and cost functions with a single or aggregate farm output. However, the recent literature proposes a number of empirical frameworks to account for the impact of off-farm activities on farm production. In some cases, the impact of off-farm diversification is embedded in the measure of efficiency estimated by the model, while in other cases off-farm activities are explicitly modeled as part of the production technology, providing estimates of their impact on the productivity of inputs and economies of scale and scope.

First, a review of the literature on the impact of off-farm work on farm activities offers mixed results, with some studies suggesting the presence of a diversification premium, while others find no evidence of such premium. For example, an early study by Bagi (1984) finds no evidence that part-time farmers in Western Tennessee were less efficient¹ compared to full-time farmers. For small scale Norwegian farmers, Lien, Kumbhakar, and Hardaker (2010) even found that a low level of off-farm income would have a positive impact on farm production, but higher levels of off-farm work would reduce productivity. The authors surmise that this effect could be related to the financial benefits of off-farm work and its positive impact on farm investment. However, in a study of U.S. farms Goodwin and Mishra (2004) found that off-farm work had a negative impact on farm efficiency, as defined by the ratio of farm variable input costs to the value of farm production. Other studies based on U.S. farm data (Paul et al., 2004; Paul and Nehring, 2005; Nehring, Fernandes-Cornejo, and Banker, 2005) also conclude that farm operators and households with some off-farm employment tend to be less efficient in terms of farm production, but that accounting for off-farm income as an output of the household increases their efficiency to a level close to that of full-time operators. Their result also lends support to the presence of economies of scale in farming and economies of scope between farm and off-farm enterprises.

From a methodological point of view, this literature provides two main approaches to empirically estimate the relationship between farm and off-farm enterprises. One approach is to estimate the farm production function and the labor allocation decisions via a system of equations. Typically, a first equation seeks to explain the amount of labor allocated off the farm as a function of farm size and other household, operator and socio-economic characteristics while a second equation explains the production of farm output enterprises as a function of farm inputs, off-farm labor supply, and operators' characteristics. This is the approach followed by Goodwin and Mishra (2004) and Lien, Kumbhakar, and Hardaker (2010) among others.

Some drawbacks of this approach include the difficulties in identifying the system of equations and the need to address censoring issues in the off-farm equation within the context of simultaneous equation estimation. Goodwin and Mishra (2004) used a Tobit model to estimate the off-farm labor supply, while the second equation consisted of a linear regression of farm operator characteristics and farm size variables on a measure of farm efficiency. This framework provided an estimate of the relationship between off-farm labor allocation and a proxy of farm efficiency (i.e. ratio of variable costs to farm sales), but does not provide a detailed production function, nor does it account for possible interactions between off-farm employment and inputs other than variable costs.

¹Unless otherwise mentioned, efficiency in these models refers to *economic efficiency* of farm operators. That is, their capacity to transform dollars of inputs into revenues. In most cases revenues only included farm revenues.

On the other hand, Lien, Kumbhakar, and Hardaker (2010) use a two-stage least squares approach to estimate a farm production function, while accounting for the impact of endogenous off-farm labor allocation decisions on farm efficiency. In this case, identification was made possible mainly due to the non-linearity of the stochastic frontier equation used to estimate farm production. The drawback of this approach is that the sample had to be limited to observations with off-farm work in order to avoid censoring issues.

The other approach considers farm and off-farm enterprises as drawing from a common pool of resources and, thus, as part of a multi-input multi-output production function. This approach was followed by Coelli and Fleming (2004), Paul et al. (2004), Paul and Nehring (2005), and Fernandez-Cornejo, Nehring, and Erickson (2007). In such cases, the production function, including farm and off-farm components, is estimated either via a distance function or a cost function, depending on the availability of data and the behavioral assumptions one is willing to make. Both distance and cost function approaches have the capacity to accommodate multiple outputs and can provide estimates of economies of scale and economies of scope while accounting for off-farm income as an output of the farm operator or household. In the case of flexible functional forms, they can also be used to estimate the potential interactions between inputs and off-farm enterprises.

Compared to the cost function approach, the main advantages of using a distance function is that it allows the modeling of multi-output and multi-input production relationships without having to rely on duality and behavioral assumptions of cost minimization, nor does it require price information (Fare and Primont, 1995; O'Donnell and Coelli, 2005). The disadvantage, however, is that it may be more prone to endogeneity issues. Coelli (2000) and Kumbhakar (2011) provide in-depth discussions of endogeneity issues in such models, with particular emphasis on the translog functional form. Most of these issues come from the use of stochastic frontier estimation, which is usually employed to estimate distance functions. An important insight from these articles is that particular care has to be given to what one considers as tenable assumptions about the data-generating process, e.g. whether the assumption of cost-minimization or a profit-maximization behavior is most appropriate. According to Kumbhakar (2011), in the case of a translog input distance function under the assumption of profit-maximization, the endogeneity issue mainly focuses on output terms while normalized input terms are unlikely to be correlated with the error term.

In this section, I follow the distance function approach to develop a multi-output multi-input model estimated using the Bayesian approach proposed by O'Donnell and Coelli (2005). The input distance is preferred to the output distance function since the input orientation provides greater parameter flexibility to estimate the interaction with off-farm income. The model accounts for the production impact of off-farm activities as well as family, operator, and farm characteristics. In particular, the model is designed to provide insights on 1) the trade-offs between off-farm diversification and farm efficiency, and 2) the substitutability between farm labor and farm inputs.

The Bayesian estimation approach allows the imposition of regularity conditions at each data point, a feature of great interest given that the estimated parameters are to be used in a dynamic optimization model. At the same time, potential endogeneity issues with output terms are acknowledged but the introduction of instrument variables within the Bayesian framework of O’Donnell and Coelli (2005) is left for further research. An interesting contribution, however, is the treatment of zero-valued inputs and outputs in the imposition of regularity issues, which draws from Battese (1997).

4.2 Distance Functions

The multi-output multi-input production function is estimated using a distance function. In the multi-output case, the *input* distance function can be expressed as:

$$D_{it}^I(\mathbf{x}_{it}, \mathbf{y}_{it}, \mathbf{z}_{it}) = \sup_{\theta} \left\{ \theta > 1 : \left(\mathbf{y}_{it}, \frac{\mathbf{x}_{it}}{\theta} \right) \in T(\mathbf{z}_{it}) \right\} \quad (4.1)$$

where \mathbf{x}_{it} , \mathbf{y}_{it} are the set of inputs and outputs, respectively, for farm household i in year t . Where T is a technology set defining the possible combinations of outputs \mathbf{y}_{it} , and inputs \mathbf{x}_{it} , given the set of socioeconomic, demographic, and agro-climatic characteristics \mathbf{z}_{it} . Hence, an input distance function estimates by how much the input set could be contracted while maintaining the same output set.

Distance functions have been estimated for the farm sector (e.g. Coelli and Fleming, 2004; Paul and Nehring, 2005; Nehring, Fernandez-Cornejo, and Banker, 2005; Fernandez-Cornejo, Nehring, and Erickson, 2007). A key aspect of the distance function is that, given a flexible functional form, it can provide measures of economies of scale and economies of scope between outputs. For example, Coelli and Fleming (2004) used a distance function framework to estimate the economies of specialization and diversification between coffee and food production among smallholder farms of Papua New Guinea. In a more closely related context, Paul and Nehring (2005) as well as Fernandez-Cornejo, Nehring, and Erickson (2007) estimated distance functions using aggregated US farm data and provided estimates of economies of scale and the impact of off-farm income on farm household efficiency.

Translog input distance function

The most common functional form for distance functions found in the literature is the translog. It has the advantage of being a flexible functional form, and given inputs \mathbf{x}_{it} , outputs \mathbf{y}_{it} , and exogenous factors \mathbf{z}_{it} , the distance function is expressed as:

$$\begin{aligned}
\ln D_{it} = & \beta_0 + \sum_j^J \beta_j \ln x_{j,it} + \sum_n^N \alpha_n \ln y_{n,it} + 0.5 \cdot \sum_j^J \sum_k^K \beta_{jk} \ln x_{j,it} \ln x_{k,it} \\
& + 0.5 \cdot \sum_n^N \sum_j^J \gamma_{nj} \ln x_{j,it} \ln y_{n,it} + 0.5 \cdot \sum_n^N \sum_m^M \alpha_{nm} \ln y_{n,it} \ln y_{m,it} \\
& \sum_l^L \phi_l \ln z_{l,it} + v_i t
\end{aligned} \tag{4.2}$$

From this framework one can derive the effect of exogenous factors (e.g. demographic or financial factors) on efficiency, and also gather information on the relationships between inputs and outputs, including input shares, economies of scale, economies of scope, and other elasticity measures.

Input elasticities and interactions

Interactions among inputs and between inputs and outputs depend on parameters β_{ij} and γ_{ik} . Negative (positive) input interaction terms β_{ij} indicate a some degree of complementarity (substitutability), while negative (positive) input-output interaction terms γ_{ik} indicate that input i favors (reduces) productivity in output k . The degree of substitutability is, however, data dependent. The partial input and output elasticities represent the percentage increase in distance(efficiency) due to a 1% increase in a particular input or output and, in the case of a translog function, they are computed as:

$$s_{x_j} = \frac{\partial \ln(D)}{\partial \ln(x_j)} = \beta_j + \sum_k^K \beta_{j,k} \ln(x_k) + \sum_n^N \gamma_{j,n} \ln(y_n) \tag{4.3}$$

$$r_{y_n} = \frac{\partial \ln(D)}{\partial \ln(y_n)} = \alpha_n + \sum_m^M \alpha_{n,m} \ln(y_m) + \sum_j^J \gamma_{j,n} \ln(x_j) \tag{4.4}$$

From these input shares, a number of other elasticity measures can be derived to characterize the input and output relationships (Youn Kim, 2000).

Economies of scale and scope

From a distance function, an appropriate measure of economies of scale can be defined by the scale elasticity as follows (Fare and Primont, 1995):

$$\eta^{scale} = \frac{\sum S_i}{\sum r_n} \tag{4.5}$$

Where η^{scale} provides a measure of the percentage change in output due to a one percent change in inputs, assuming that the input mix remains constant. In the case

of an input distance function, homogeneity in inputs implies that $\sum s_i = 1$ so that $\eta^{scale} = (\sum r_n)^{-1}$.

Using an input distance approach, Paul et al. (2004) report the presence of economies of scale among U.S. farms. Results for output- and input-oriented distance functions for a similar pseudo-panel of U.S. farms are reported by Paul and Nehring (2005). They also find significant economies of scale, although the estimated elasticity of scale is lower when off-farm income is included in the model.

The output interaction terms ($\alpha_{i,j}$) can also inform us regarding the relationship among outputs. A positive interaction term indicates the presence of output jointness between output i and j . For example, positive estimates lead Paul and Nehring (2005) to conclude that economies of scope exist between off-farm work and most farm enterprises of U.S farms. However, the extent of economies of scope is data dependent, and Paul and Nehring (2005) did not report on the variation in economies of scope within their data.

Finally, the impact of off-farm work on farm production can be measured by the shadow output cost :

$$\frac{dF}{dY} = -\frac{r_y \cdot F}{r_f \cdot Y} \quad (4.6)$$

This can be interpreted as a measure of off-farm diversification premium since it reflects the change in expected farm output due to a increase in off-farm output.

Regularity conditions

Production theory suggests that the distance function should satisfy a number of regularity conditions (Fare and Primont, 1995; Coelli et al., 2005). An input distance function should be:

1. homogeneous of degree one in inputs;
2. monotonically increasing in inputs;
3. monotonically decreasing in outputs;
4. concave in inputs;
5. quasi-concave in outputs.

The homogeneity in input condition is an artifact from the definition of the input-oriented distance function in equation (6). Since it measures the contraction of input from the efficient frontier, the distance must be linearly related to any rescaling factors affecting the input mix. Monotonicity conditions simply state that higher inputs,

and/or lower outputs, lead to higher input distance and thus a lower efficiency measure.

The concavity in inputs condition implies a diminishing rate of substitution among inputs. Assuming rational input choices, competitive input markets and input divisibility, the concavity in input space of the distance function should hold. Similarly, quasi-concavity in outputs would be required under rational choice, divisibility and competitive output markets.

In practice, imposing all regularity conditions on the translog function has proved to be technically difficult and Diewert and Wales (1987) showed the existence of a trade off between flexibility and the imposition of regularity conditions. In fact, most empirical analyses using translog functions have ignored some regularity conditions – mostly monotonicity and curvature – and consequently failed to fulfill some of those conditions (Coelli and Fleming, 2004; Paul and Nehring, 2005; Nehring, Fernandes-Cornejo, and Banker, 2005; O’Donnell and Coelli, 2005; Sauer, 2006).

However, O’Donnell and Coelli (2005) provide a Bayesian estimation approach allowing the imposition of all regularity conditions locally at each data point (or a selected subset of data points), thus allowing the generation of coefficient estimates that are consistent with economic theory. Given the ultimate motive of the estimation effort, which is to generate estimates that can be used in a simulation model, the choice is made to use the O’Donnell and Coelli (2005) framework to explore the impact of imposing regularity conditions in the estimation, to ensure that the estimated distance function will be well behaved and suitable for the simulation model.

Regularity and optimization conditions

The input distance function is the dual of the cost function. The cost function is derived from a cost-minimization problem, and as such must satisfy first- and second-order conditions of such an optimization problem. The concavity in inputs, as required by the input distance function, will also satisfy the second-order condition associated to a cost minimization problem, although it falls short of imposing equi-marginality between marginal value product and input prices. The relation between cost-minimization and the input distance function can be expressed as :

$$C(y, w) = \min_x w \cdot x \quad \text{s.t.} \quad D(x, y) \geq 1 \quad (4.7)$$

Conversely, the output distance function would require convexity in output, which would satisfy the second-order condition of a revenue-maximization problem. However, neither the input distance nor output distance regularity conditions are sufficient to satisfy the second-order conditions of a profit-maximization problem of the type:

$$\max_{y,x} p \cdot y - w \cdot x \quad \text{s.t.} \quad D(x, y) \geq 1 \quad (4.8)$$

Following Simon and Blume (1994, p.467), the second-order condition for such a problem requires checking the sign of the leading principal minors of the bordered Hessian²:

$$BH = \begin{bmatrix} \mathbf{O} & -\mathbf{D}_y & -\mathbf{D}_x \\ -\mathbf{D}'_y & \lambda_L \mathbf{D}_{yy} & \lambda_L \mathbf{D}'_{yx} \\ -\mathbf{D}'_x & \lambda_L \mathbf{D}_{yx} & \lambda_L \mathbf{D}_{xx} \end{bmatrix}$$

The Bayesian framework of O'Donnell and Coelli (2005) can be modified to impose this condition on the estimation of the input distance function. Once again, imposing this condition is motivated by the intent to use estimated parameters to calibrate the dynamic model in which the farm operator solves a profit-maximization problem.

As shown in Appendix A, this condition does not preclude the presence of economies of scale. It amounts to imposing decreasing marginal returns. The monotonicity condition only requires that producers are not in stage III of production (Doll and Orazem, 1984), while the second-order condition of the profit-maximization problem limits the producer to operate under decreasing marginal return to inputs, which may occur in part of stage I and throughout stage II of production.

Zero-valued entries and regularity conditions

When some observations have zero-valued entries, as is the case with the data used in this dissertation since many observations have zero off-farm income, it is problematic for the translog form (or the Cobb-Douglas special case) since the log of zero is undefined. Some common strategies to deal with zeros in log-linear models are 1) to drop observations with zeros, or 2) to zero out the log entries by replacing the zeros with ones, or 3) to impute some small values to replace the zeros. The appropriateness of each approach often depends on the data and the cause of data censoring. When too many zeros occur in the data the cost of dropping observations quickly becomes prohibitive. On the other hand, if the imputation approach is favored then the choice of the small value to be imputed can affect the results and should be made with care.

In the case of a production or distance function, observing an input level of zero is contrary to the nature of a translog or Cobb-Douglas production function, since it should imply an output of zero. Imputing ones or small values to replace the zero-valued observations could be an option. But when considering the monotonicity and curvature conditions, this approach is not fully satisfying. In fact, replacing the zero-valued observations with the assumption that a very small amount of input is being used may lead to significant increase in the range of data covered, thus reducing the flexibility of the translog function tremendously (Diewert and Wales, 1987).

²The last $n - k$ leading principal minors should alternate in sign with the largest principal leading minor of the same sign as $(-1)^n$ where n is the size of BH and k is the number of constraints (1 in this case)

However, following Battese (1997), zero-valued observations can be interpreted as an indicator of different technologies being available to producers, and thus can be thought of as different models. In this approach, dummies are used to discriminate among models which leads to a clear answer on how to treat zero-valued observations in imposing regularity conditions. The distance function is then expressed as:

$$\begin{aligned}
\ln D_{it} = & \beta_0 + \sum_j^J \beta_j \ln x_{j,it} + \frac{1}{2} \sum_j^J \sum_k^K \beta_{jk} \ln x_{j,it} \ln x_{k,it} + \sum_l^L \phi_l \ln z_{l,it} \\
& + \alpha_f \ln F_{it} + \sum_j^J \gamma_{fj} \ln x_{j,it} \ln F_{it} + \frac{\alpha_{ff}}{2} (\ln F_{it})^2 \\
& + \lambda_{it} \left(\beta_y + \sum_j^J \tilde{\beta}_j \ln x_{j,it} + \tilde{\alpha}_f \ln F_{it} + \alpha_y \ln y_{it} \right. \\
& \left. + \sum_j^J \gamma_{yj} \ln x_{j,it} \ln y_{it} + \frac{\alpha_{yy}}{2} (\ln y_{it})^2 + \alpha_{f,y} \ln F_{it} \ln y_{it} \right) + v_{it} \quad (4.9)
\end{aligned}$$

Where, λ_{it} is the dummy variable indicating whether or not off-farm income is zero-valued for observation i in time t . Implicit in this formulation is the assumption that the technology used by operators with off-farm employment is comparable to the one used by full-time operators, such that higher order coefficients (β_{jk}, γ_{fj}) are the same for both functions.

However, the coefficients ($\beta_y, \tilde{\beta}_j, \tilde{\alpha}_f$) allow for difference in linear coefficients between the two regimes. This is done mainly to facilitate estimation by using normalized (demeaned) data. Supposing that parameters $\tilde{\beta}_j, \tilde{\alpha}_f$, and β_y are all set to zero, then equation 4.9 would be the same when $\lambda = 0$ and $y = 1$, implying that there is no difference between the case without off-farm income, and the case of average off-farm income. Allowing these parameters to take non-zero values provides estimates of the difference between those two cases. While $\tilde{\beta}_j$ is a simple shift parameter, to capture difference in distance between the two cases, $\tilde{\alpha}_f$, and β_y can be used to test whether there are changes in the effect of inputs and farm output between the two cases.

Deriving the regularity conditions with respect to equation 4.9, monotonicity conditions are expressed as:

$$s_{x_j} = \beta_j + \sum_k^K \beta_{j,k} \ln(x_k) + \gamma_{f,j} \ln(F) + \lambda \left(\tilde{\beta}_j + \gamma_{y,j} \ln(y) \right) \geq 0 \quad (4.10)$$

$$r_F = \alpha_f + \alpha_{f,f} \ln(F) + \sum_j^J \gamma_{f,j} \ln(x_j) + \lambda \left(\tilde{\alpha}_f + \alpha_{f,y} \ln(y) \right) \leq 0 \quad (4.11)$$

$$r_y = \lambda \left(\alpha_y + \alpha_{yy} \ln y + \sum_j^J \gamma_{y,j} \ln(x_j) + \alpha_{f,y} \ln F \right) \leq 0 \quad (4.12)$$

The Hessian defining the concavity in input remains unchanged. In the case of full-time farms, the distance function has only one output and quasi-concavity in output is implied by monotonicity in output (Simon and Blume, 1994). In the case of

part-time farms, quasi-concavity in output can be defined either based on the Hessian or bordered Hessian (Morey, 1986).

4.3 Data and Variables

The model is estimated using data from 94 farm operations participating in the Kentucky Farm Business Management (KFBM) program between 1998 and 2010. The KFBM data include thorough budgeting and financial statements information for farm businesses and operators. While it does not provide a random sample, the farms included in the data set are representative of *typical* commercial farms within Kentucky (Kentucky Farm Business Management Program, 2009). Consequently, using this data set provides an opportunity to investigate the presence of a diversification premium and economies of scale among commercial farms, which are the focus of stabilization programs.

The data provides information for each operator and for each farm operation. Operators' records are used in this study since they contain the information about off-farm income. Operators' records also include information on their contribution to farm activities in the form of farm revenues, costs, and assets and liabilities. But this provides only partial farm information when multiple operators are involved for a particular farm. Hence, the sample used is limited to the farms with a unique operator.

The sample was also chosen based on geographical and farm type criteria to be relatively homogeneous in terms of production patterns, and representative of commercial grain farms of Western Kentucky. Hence, only grain farms³ located in the western part of the state and for which grain revenues accounted for at least 60% of total farm revenues are used. This selection process generated a sample of 523 observations covering 94 grain farms between 1998 and 2010. The summary statistics for the key variables are presented in Table 4.1

The output and input variables were defined based on the requirements of the simulation model developed in Chapter 3. Output variables include: 1) gross farm revenues, including crop and livestock sales, changes in inventories, and other farm income, and 2) off-farm employment income excluding interests and dividends. Input variables include: hired and family labor, farm capital, quality adjusted farmland, and other variable costs.

Hired labor is the amount in dollars of paid labor during the year plus the value of family labor excluding the operator. It is assumed that each operator provides a

³Grain farms are defined by KFBM as "farms on which the value of feed fed was less than 40 percent of the crop returns and the value of feed fed to dairy was less than one-sixth of the crop returns." (Kentucky Farm Business Management Program, 2009)

fixed amount of labor and management, which can then be allocated either to farm or off-farm activities. Capital is measured based on the market value of the total stock of machinery and equipment, breeding livestock, and buildings and improvements at the beginning of the year. It is assumed that the flow of capital used during a year is a function of the total capital stock. Variable costs include costs such as seeds, chemicals, and fuel. To avoid double-counting inputs, variable costs exclude cash rent paid for land, machine hire, and hired labor, as these are covered by other input variables.

Table 4.1: Summary Statistics

	Full Sample		Part-Time only	
	Mean	Std. Dev.	Mean	Std. Dev.
Operators with OFI>1000 (%)	9.9	n/a		
Off-farm income(\$)	3,041.7	10,891.2	33,777	16,107
Farm Revenues(\$)	673,306	568,547	316,105	220,493
OFI/Farm gross revenues(%)	n/a	n/a	19.6	21.9
OFI/NOFI*(%)	n/a	n/a	126.6	472.4
Hired labor(%)	43,837	48,696	22,503	38,099
Variable costs(\$)	403,205	313,450	227,863	157,166
Capital(\$)	487,193	396,074	250,961	105,599
Land owned (acres)	395	469	228	171
Land Operated (acres)	1,560	1,074	1,056	662
Current Ratio	3.86	8.75	2.76	7.48
Debt-to-Asset ratio	0.39	0.22	0.44	0.23
ROA	6.30	8.21	3.19	6.43
Age	50.6	10.4	51.4	8.9
Household size	2.95	1.42	3.08	1.05
Crop Revenues (%)	0.83	0.13	0.77	0.09
Land under Crop Share (%)	0.37	0.28	0.42	0.28
Land under Cash rented (%)	0.32	0.26	0.24	0.22
Rented acres (%)	0.69	0.24	0.66	0.23

*Net operating farm income is computed as: gross farm income minus variable costs(excluding rent) and hired labor. Hence, it provides a measure of return to land, capital, and management.

Land tenure

An important source of heterogeneity in the KFBM data is land tenure. As can be seen from Figure 4.1 and Figure 4.2, most farms in the sample rent a large share of the land they operate, and the rental agreements seem to vary a lot among farms, with some renting exclusively through crop sharing agreement, others exclusively through

cash rent, and many having a combination of both. This is not really surprising, but it does have an impact on the information reported within the KFBM data set.

Under cash rental agreements, revenues will be handled in the same way as under land ownership, but variable costs will include the cash rent paid for land services. On the other hand, revenues from land under crop sharing agreements will be deflated significantly, since the share belonging to the landlord will not be included in the records. And, in some cases, variable costs will also be deflated if landlords are covering part of those costs. And, finally, owned land will not show anywhere in the income statement, other than through interest paid on mortgage loans, if there are any.

To make all farm operations more comparable, and account for land service as an input to the farm production process, we include total acreage operated as an input, assuming that land service is a linear function of soil quality adjusted acreage. The soil quality measure used is the soil quality index reported in the KFBM data. Cash rent is then excluded from variable costs to avoid double counting for land inputs.

Similarly, adjustments are made to account for crop sharing agreements. First, variable cost are adjusted for the cost covered by the landlord which is available from the KFBM data⁴. Crop revenues are also adjusted to account for the fact that a share of revenues goes to landlords. It is assumed that under most crop share agreements, 1/3 of the crop revenues goes to the landlords. Hence, given information about the total acreage and acreage under crop sharing, and assuming that crop return on crop shared land is similar to return on other land, adjusted crop revenues \tilde{C}_{rev} is computed as follows:

$$\begin{aligned}
 C_{rev} &= \pi \left(LD_{operated} \left(1 - \frac{\theta}{3} \right) \right) \\
 \tilde{C}_{rev} &= \pi LD_{operated} \\
 &= \frac{C_{rev}}{1 - \theta/3}
 \end{aligned}$$

where C_{rev} is the observed crop revenues, θ is the share of land under crop sharing agreement for a given observation, and π are revenues per acres assumed to be constant for all acres of a given farm in a given year.

Farm and operator characteristics

In addition to the input and output variables, the model also includes a number of demographic and financial characteristics. A time variable is also included in the

⁴For observations reporting crop sharing, KFBM data provide an estimate of "leasing cost" which is meant to capture the cost covered by landlords.

Figure 4.1: Land Tenure

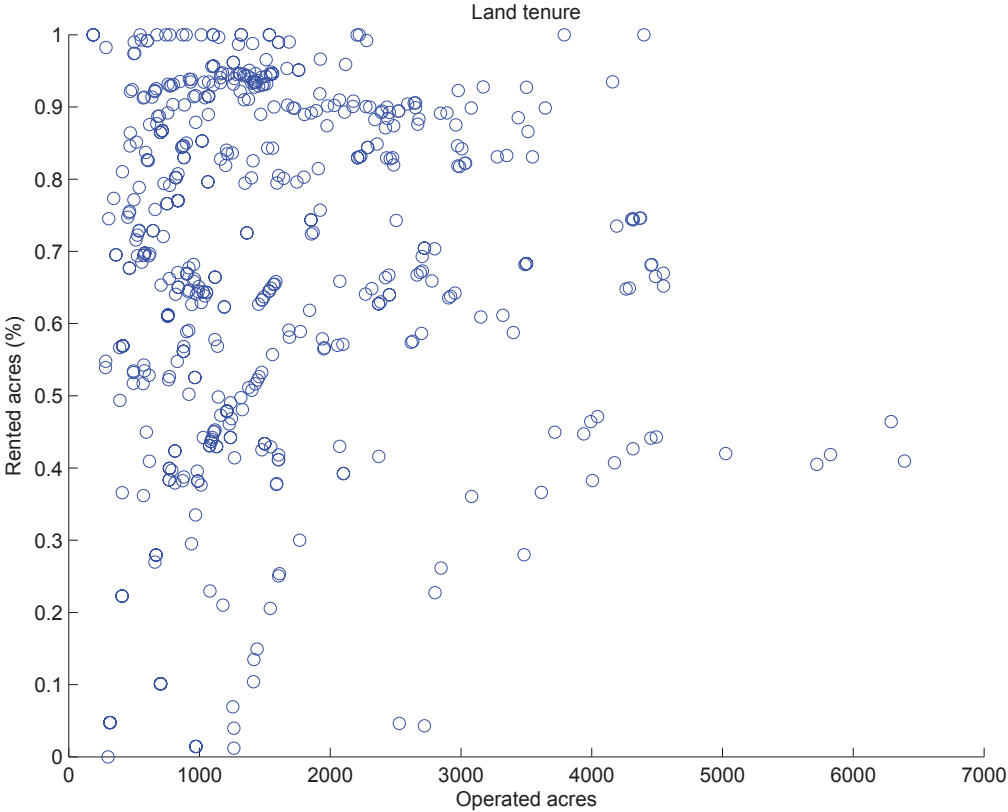
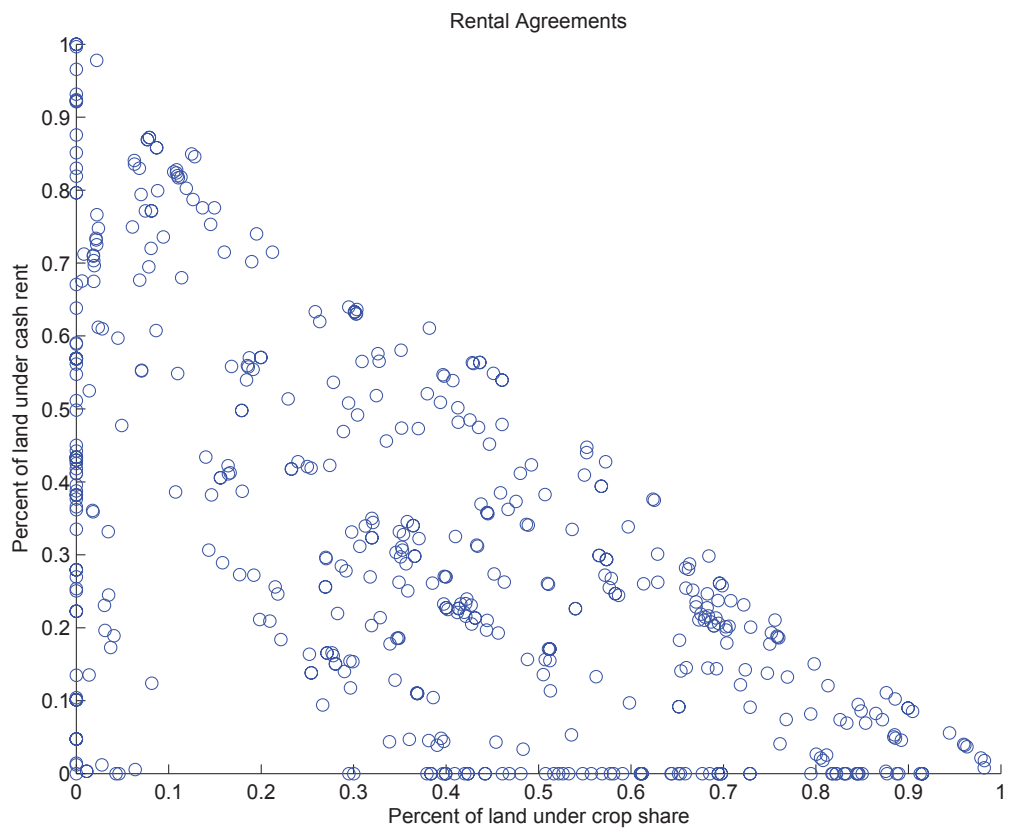


Figure 4.2: Rental Agreements



model to capture any trend in farm efficiency. The age of the operator is also included in linear and quadratic terms. These two variables can be seen as a proxy for farming experience and human capital. It is expected that human capital would increase production levels and efficiency, but at a decreasing rate. However, human capital variables have been found to be mostly insignificant in previous empirical studies using distance functions (e.g. Paul et al., 2004; Paul and Nehring, 2005; Fernandez-Cornejo, Nehring, and Erickson, 2007).

Other studies have found evidence of a liquidity constraint affecting production choices (Bierlen et al., 1998; Hart and Lence, 2004; Kwon, Orazem, and Otto, 2006). To control for possible impacts of liquidity on production choices and efficiency, the current ratio at the beginning of the year is also included in the model. Paul and Nehring (2005) also included a solvency measure, the debt-to-asset ratio, and found it to be insignificant for the output distance and to have a negative impact on efficiency for the estimated input distance function. The effect of such a variable on efficiency might, in fact, be ambiguous. Highly efficient farms have incentives to leverage their equity, leading them to have high debt-to-asset ratios. On the other hand, less efficient farms may also have a high ratio, not because they are trying to leverage their equity but rather because they have low profitability and difficulties in paying back their debt. To discern between these two cases, we include the debt-to-asset ratio at the beginning of the year through an interaction term with the return on asset. One would expect this interaction term to have a positive effect on productivity.

Operators reporting off-farm income

The sample includes 48 observations reporting an operator off-farm income higher than \$1000. For the majority of these operators, off-farm income is a non-trivial source of income. On average, off-farm income is larger than their net operating farm income and represents almost 20% of gross farm sales. The median also indicates that for 50% of these operators, off-farm income represents more than 76.2% of their net operating farm income.

Operators reporting off-farm income tend to operate smaller farms, present significantly lower measures of profitability (ROA), and appear to be more liquidity constrained as indicated by their lower liquidity ratio. A natural explanation would be that these operators are beginning farmers, with less experience, highly leveraged capital structures, and facing financial constraints. However, the operators reporting off-farm employment in this sample do not appear to differ from the rest of the sample in terms of age, or household size. Another potential explanation would be that these operators differ significantly in terms of financial management strategy and objectives. As implied by the buffer stock model developed in Chapter 3, off-farm income is expected to reduce exposure to financial risk and would allow the farm

operator maintain lower farm liquidities or, as suggested by Blank (2005), to support investments providing illiquid returns such as capital gains on farmland.

4.4 Econometric Model

Since distance D is unknown, for estimation we can rearrange the input distance function D^i as follow

$$\begin{aligned}
-\ln x_{1it} &= \beta_0 + \sum_j^J \beta_j \ln x_{j,it}^* + \frac{1}{2} \sum_j^J \sum_k^K \beta_{jk} \ln x_{j,it}^* \ln x_{k,it}^* + \sum_l^L \phi_l \ln z_{l,it} \\
&+ \alpha_f \ln F_{it} + \sum_j^J \gamma_{fj} \ln x_{j,it}^* \ln F_{it} + \frac{\alpha_{ff}}{2} (\ln F_{it})^2 \\
&+ \lambda_{it} \left(\beta_y + \sum_j^J \tilde{\beta}_j \ln x_{j,it}^* + \tilde{\alpha}_f \ln F_{it} + \alpha_y \ln y_{it} + \alpha_{f,y} \ln F_{it} \ln y_{it} \right. \\
&\left. + \sum_j^J \gamma_{yj} \ln x_{j,it}^* \ln y_{it} + \frac{\alpha_{yy}}{2} (\ln y_{it})^2 \right) + v_{it} - \ln D_i \\
-\ln x_{1it} &= \beta \mathbf{X}_{it} + \gamma \mathbf{XY}_{it} + \alpha \mathbf{Y}_{it} + \phi \mathbf{Z}_{it} + v_{it} + u_i
\end{aligned} \tag{4.13}$$

where * indicates inputs that are normalized by the numeraire input x_1 . This transformation is possible given the homogeneity of the distance function in inputs, which implies that $\theta D(y, x) = D(y, \theta x)$. Equation 4.13 is obtained by letting $\theta = \frac{1}{x_1}$ and transferring the efficiency term to the right hand side. The last line represents a more compact formulation where v_{it} is a standard error term while $\ln D_i = u_i \geq 0$ provides a measure of the distance and technical efficiency, $D_i \approx TE_i^{-1} = e^{u_i}$.

The model is estimated as a random effect model following the Bayesian approach developed by O'Donnell and Coelli (2005). In this framework, the random variable u_i is assumed to follow an exponential distribution with parameter λ . The standard error term v_i is assumed to follow a normal distribution centered at zero and with variance h^{-1} .

This Bayesian framework allows the imposition of the regularity conditions discussed earlier, by defining the prior $p(\beta) \propto I(\beta \in R)$ for the parameter values β , where I is an indicator function which takes the value one if $\beta \in R$ and zero otherwise, and R is the set of permissible parameter values under a given set of regularity conditions. The prior $p(h) \propto h^{-1}$ is used for the variance of the standard error term and, following O'Donnell and Coelli (2005), the proper prior $p(\lambda^{-1}) \propto f_G(\lambda^{-1}|1, -\ln(\tau^*))$ is used as the parameter of the gamma distribution of u_i .⁵ Parameter τ^* is the prior median of the efficiency distribution which we set to 0.9 based on efficiency parameters reported

⁵ $f_G(a|b, c)$ indicates that a follows a the gamma distribution with parameters b

in previous literature (Paul et al., 2004; Paul and Nehring, 2005; Fernandez-Cornejo, Nehring, and Erickson, 2007).

The joint prior is then:

$$\begin{aligned} p(\beta, h, u, \lambda^{-1}) &= p(\beta) p(h) p(u|\lambda^{-1}) p(\lambda^{-1}) \\ &\propto I(\beta \in R) f_G(\lambda^{-1}|1, -\ln(\tau^*)) \prod_{i=1}^N f_G(u_i|1, \lambda^{-1}) \end{aligned}$$

And the likelihood function is :

$$p(\mathbf{y}|\boldsymbol{\theta}, h, \mathbf{u}, \lambda^{-1}) \propto h^{n/2} e^{\left(-\frac{h}{2}(\mathbf{y}-\beta\mathbf{X}-\gamma\mathbf{X}\mathbf{Y}-\alpha\mathbf{Y}-\phi\mathbf{Z}_{it}-\mathbf{u})'(\mathbf{y}-\beta\mathbf{X}-\gamma\mathbf{X}\mathbf{Y}-\alpha\mathbf{Y}-\phi\mathbf{Z}_{it}-\mathbf{u})\right)}$$

where $\boldsymbol{\theta} = \{\beta, \gamma, \alpha, \phi\}$.

The goodness of fit of the different models are tested using the deviance information criteria (DIC) proposed by Spiegelhalter et al. (2002). This measure includes a measure of goodness of fit based on the log likelihood and a measure of complexity reflecting the number of free parameters. Specifically, the DIC is measured as:

$$DIC = \text{goodness of fit} - \text{complexity} \quad (4.14)$$

$$= 2 \cdot \log(p(\mathbf{y}|\bar{\boldsymbol{\theta}})) - 4 \cdot E[\log(p(\mathbf{y}|\boldsymbol{\theta}))] \quad (4.15)$$

4.5 Estimation Results

Parameter estimates are presented in table 5.1. These estimates are obtained by sampling from the posterior distribution using the Gibbs sampler and Metropolis-Hastings algorithm defined in O'Donnell and Coelli (2005). Results for each model are based on 50,000 draws with a burn in of 10,000 draws. Model 1 is the base unconstrained model, while curvature and monotonicity in inputs and outputs are imposed on model 2. Model 3 also imposes the second-order condition related to the assumption of profit maximization. Hence, model 2 would be consistent with standard economic theory, but does not impose any profit maximization behavior. On the other hand, model 3 is consistent with a framework where operators optimize total farm and off-farm income.

Model comparison and goodness of fit

Table 5.1 reports the DIC calculated based on equation 4.15. Unsurprisingly, the DIC identifies the unconstrained model as providing the best fit, followed relatively closely by model 2 and 3. The relatively modest increase in the DIC induced by regularity

and optimization constraints can suggest that these conditions are not rejected by the data, although the unconstrained model violates many of them.

Table 4.3 provides a summary of the violations of the regularity conditions in the unconstrained model. The monotonicity conditions are respected in most cases, but violations of quasi-concavity in output and concavity in inputs are much more common. As could be expected, imposing these regularity conditions comes at a cost in terms of goodness of fit and will affect some of the coefficient estimates, elasticity measures, and efficiency estimates derived from the model.

Table 4.2 shows that the main difference between model 1 and 2 is the magnitude of input interaction parameters which tends to be much lower when regularity constraints are imposed. Given that most violations relate to second-order conditions, it is to be expected that most changes in estimates will affect second-order terms. For example, the interaction term between variable input and off-farm income ($\gamma_{VC,Y}$) is much larger in model 1, implying that off-farm work would lead to a much larger increase in the importance of variable inputs in farm production. Only the parameters $\beta_{K,K}$ and $\beta_{H,H}$ change sign when imposing regularity conditions.

Parameter estimates from model 2 and 3 appear much closer with the exception of parameters α_f and $\alpha_{f,f}$. In fact, the main impact of imposing a profit maximization second-order condition is to reduce economies of scale by shifting the linear and quadratic parameter related to farm output. All other parameters are similar although their significance is altered in some cases.

Farm and operator characteristics

Looking at the coefficient estimates on farm and operator characteristics, age is found to have a negative linear impact on efficiency while family size has no significant impact. The estimates on farm financial characteristics are significant and of expected signs. The current ratio estimates implies a negative relation between liquidity constraints and farm production. On the other hand, high return-to-asset and debt-to-asset ratios would be linked to higher efficiency levels, likely reflecting farms that can effectively leverage their equity. On the other hand, either low return-to-asset or low debt-to-asset ratio would be linked to lower efficiency. Also, over the 1998 to 2010 period there appears to be a clear positive trend in productivity for Western Kentucky grain farms.

Part-time operators

The model presented in equation 4.13 allows for differences in linear parameters between part-time and full-time operators. First of all, the constant associated with part-time operation $\tilde{\beta}_{dy1}$ would suggest a slightly lower efficiency for part-time oper-

Table 4.2: Parameter Estimates

Parameters	Model 1	Model 2	Model 3
β_0	0.1269 **	0.1536 **	0.0324
β_{dy1}	-0.0189	-0.0590	-0.1000 **
α_Y	-0.0324	-0.0828 **	-0.0605 **
α_F	-0.7905 **	-0.8190 **	-0.9447 **
$\tilde{\alpha}_F$	-0.0730	-0.0978 **	-0.1312 **
β_H	0.0588 **	0.0233 **	0.0282 **
β_{VC}	0.4809 **	0.5279 **	0.5722 **
β_K	0.1521 **	0.1133 **	0.1341 **
$\tilde{\beta}_H$	0.0218	0.0129	0.0169
$\tilde{\beta}_{VC}$	-0.0552	0.0220	-0.0353
$\tilde{\beta}_K$	0.0439	0.0864 *	0.1045 **
$\beta_{H,H}$	0.0233 **	-0.0011 **	-0.0012 **
$\beta_{H,VC}$	0.0327 **	0.0086 *	0.0090 **
$\beta_{H,K}$	0.0024	-0.0030	-0.0037
$\gamma_{H,Y}$	-0.0538 **	-0.0002	0.0001
$\gamma_{H,F}$	-0.0125	-0.0015	0.0016
$\beta_{VC,VC}$	-0.1611 **	-0.0715 *	-0.0621
$\beta_{VC,K}$	-0.0928 **	0.0161	0.0112
$\gamma_{VC,Y}$	0.3518 **	0.1054 **	0.0759 **
$\gamma_{VC,F}$	0.0294	0.0257	0.0362 **
$\beta_{K,K}$	0.1093 **	-0.0079 **	-0.0095 **
$\gamma_{K,Y}$	0.2466 **	0.0241	0.0223
$\gamma_{K,F}$	0.0254	0.0023	0.0075
$\alpha_{Y,Y}$	-0.0605	-0.0079	-0.0036
$\alpha_{Y,F}$	-0.1924 **	-0.0816 **	-0.0295
$\alpha_{F,F}$	-0.0017	-0.0296	-0.1331 **
β_{LD}^\dagger	0.3083 **	0.3355 **	0.2655 **
$\tilde{\beta}_{LD}^\dagger$	-0.0105	-0.1213 **	-0.0861 *
$\beta_{H,LD}^\dagger$	-0.0584 **	-0.0045	-0.0041
$\beta_{VC,LD}^\dagger$	0.2211 **	0.0468 *	0.0419
$\beta_{K,LD}^\dagger$	-0.0189	-0.0052	0.0020
$\beta_{LD,LD}^\dagger$	-0.1438 **	-0.0370	-0.0399
$\gamma_{LD,Y}^\dagger$	-0.5446 **	-0.1293 **	-0.0982 **
$\gamma_{LD,F}^\dagger$	-0.0423 **	-0.0265	-0.0453 **
ϕ_{age}	-0.0010	-0.0019 *	-0.0019 *
$\phi_{famsize}$	0.0016	-0.0011	0.0040
$\phi_{curr.ratio}$	0.0038 **	0.0037 **	0.0043 **
ϕ_{ROADA}	0.0192 **	0.0203 **	0.0219 **
ϕ_{year}	0.0154 **	0.0190 **	0.0243 **
DIC	22.79	25.78	27.53

[†] Indicate the parameters derived from the homogeneity property of the distance function..

** Indicate that $\Pr(\beta < 0 | y) < 0.05$ for positive estimates and $\Pr(\beta > 0 | y) < 0.05$ for negative estimates.

* Indicate that $\Pr(\beta < 0 | y) < 0.1$ for positive estimates and $\Pr(\beta > 0 | y) < 0.1$ for negative estimates.

Table 4.3: Violation of regularity conditions in Model 1

	Violation rate*
Monotonicity in hired labor	16.8%
Monotonicity in variable costs	1.05%
Monotonicity in capital	7.20%
Monotonicity in land	2.12%
Monotonicity in Farm revenues	0.01%
Monotonicity in Off-farm income	19.09%
Quasi-Concavity in outputs	25.04%
Concavity in inputs	70.36%

*Violation rates are based on $E[violation] = \int_n^N \int_k^K violation_{n,k} dkdn$ where $N=523$ is the number of observations in the data, $K=40,000$ is the number of draws from the posterior distribution, and $violation=1$ if the constraint is violated and zero otherwise.

ators. The constrained models also imply that farm production requires more inputs when working off the farm ($\tilde{\alpha}_f < 0$). The exact relationship between off-farm work and farm production depends, however, on other interactions' terms and is best summarize by graphing farm production under various input levels.

Figure 4.3 shows the farm production for input levels covered by the data and for a full-time operator ($Y=0$) and a part-time operator ($Y=\$16,500$). All models imply only small differences between part-time and full-time operators when the level of inputs is low. However, when input levels increase above the KFBM data mean (e.g. 1500 acres for land input), the unconstrained model would imply that part-time farmers can produce more farm output than full-time operators, which is counter intuitive. Imposing regularity constraints generate a production pattern much more sensible as part-time operators become less efficient in farm production at high input levels.

As will be discussed later, the main difference between model 2 and 3 is the presence of significant economies of scale, even for very large farms. But results from both constrained models imply that part-time operators may hold a very slight farm production advantage when operating on less than 1000 acres, but find themselves at a disadvantage on larger farms.

Linear input terms ($\tilde{\beta}$) and cross input and output terms (γ) also indicate some differences in input productivity under full and part-time operations. This is reflected in figure 4.4 which displays the marginal product of each input under the two regimes. In particular, capital and hired labor appear more productive under part-time operations as their input share and marginal products are expected to be higher under part-time operations. On the other hand, variable inputs and land appear more productive for full-time operators.

Most interaction terms among inputs $\beta_{i,j}$ are not significant with the exception of inputs' own quadratic terms (e.g. $\beta_{H,H}$) which suggest some modest diminishing returns and the interaction between variable inputs and hired labor $\beta_{H,VC}$ which indicates some degree of substitution between these two inputs. Finally, interaction terms between inputs and farm output (γ_f) suggest that, as farm output increases, land productivity tends to decrease more rapidly than other inputs.

Figure 4.3: Farm production

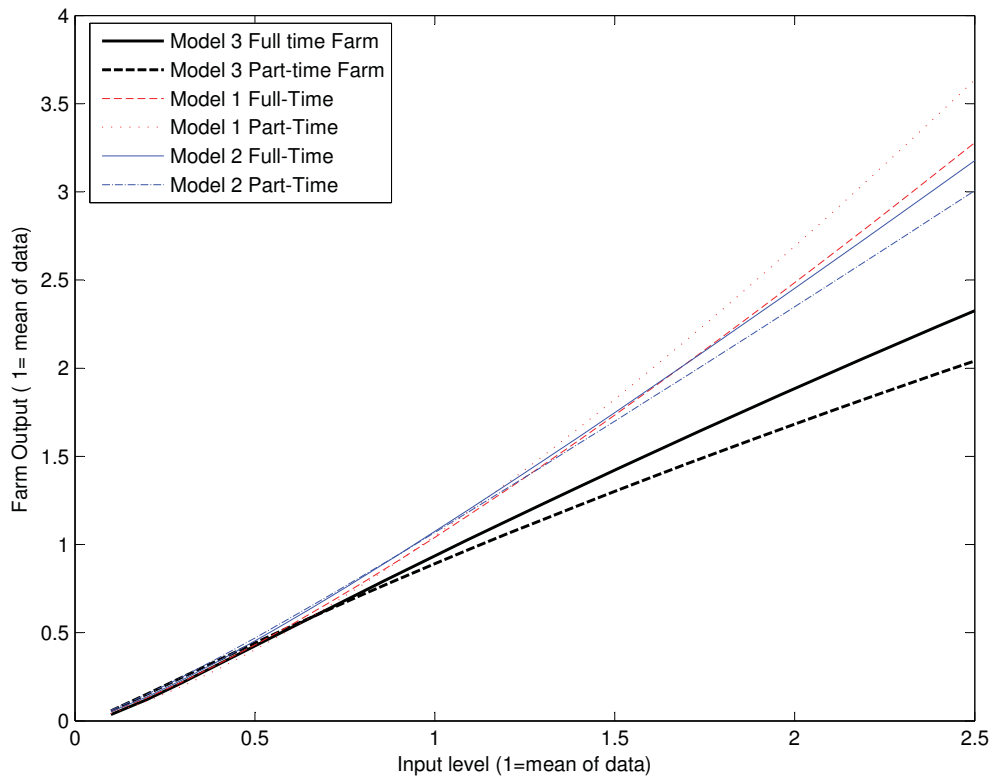
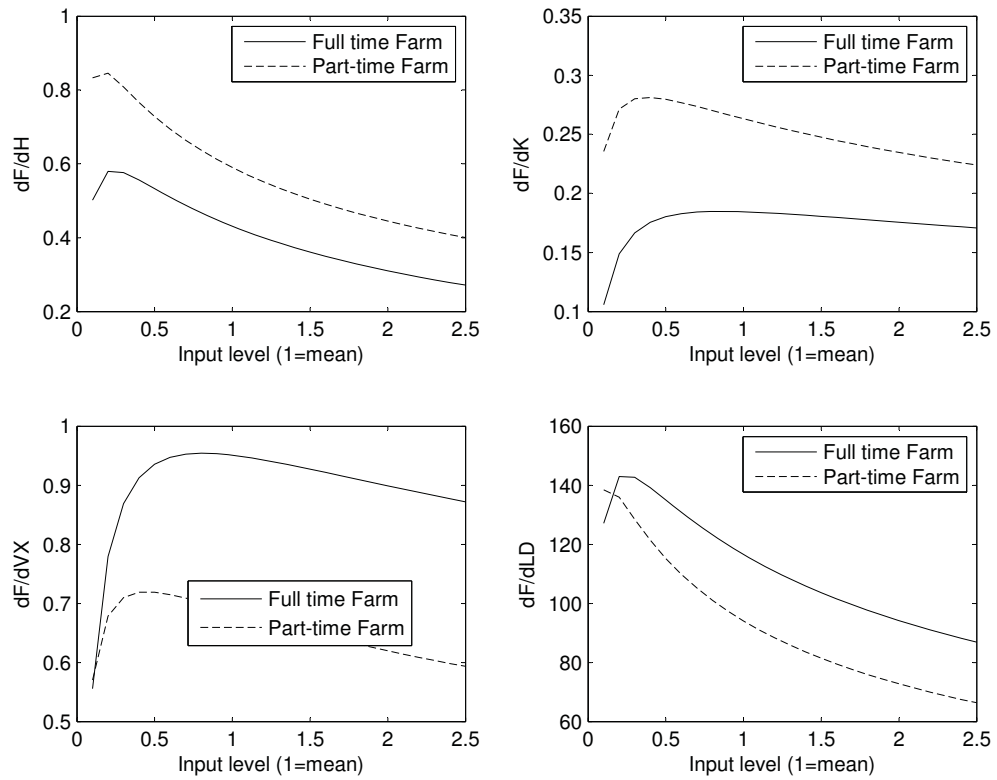


Figure 4.4: Marginal Farm product of Inputs (Model 3)



Economies of scale

Figure 4.5 indicates that, among this sample of Western Kentucky commercial crop farms, many farms experience economies of scale. Model 2⁶ implies fairly important economies of scale, which persist as farm size increases. Imposing the second-order condition linked to an assumption of profit maximization reduces the extent of economies of scale, such that the model estimates diminishing returns for farms with more than \$1.5 million in farm sales.

A few reasons can cast doubts on the high level of economies of scale estimated in model 2. First it must be noted that input distances have been reported to overestimate economies of scale compared to an output distance measure (Paul et al., 2004).⁷ Second, the conventional wisdom is that economies of scale are mostly attributed to the livestock sector while they remain much more limited in the crop sector (e.g. Chavas, Chambers, and Pope, 2010; MacDonald, O'Donoghue, and Hoppe, 2010; Schnitkey, 2012). Finally, as will be discussed later, for the input distance function the estimated economies of scale appear to be closely related to the implied level of efficiency for operators of larger farms. High estimates of economies of scale seem to imply low levels of technical efficiency for larger farms and vice versa.

Further investigation reveals that the extent of economies of scale also depends in part on the input and output mix of any given farm. In particular, more intensive use of variable costs would appear to increase the level of economies of scale, while more intensive use of land would reduce it⁸. Also, part-time operators experience lower economies of scale. According to Figure 4.6, most operators working off the farm are facing lower degrees of economies of scale. This might be explained by the greater constraint imposed on operator's labor and management induced by higher levels of off-farm work. It thus implies significant trade-off between farm expansion and off-farm work.

In fact, there appears to be a clear negative relationship between farm and off-farm operation. Both the constrained and unconstrained models suggest that some degree of diseconomies of scope exist between farm and off-farm activities, as indicated by the negative sign of the estimated parameter $\alpha_{Y,F}$. This result is at odd with previous results of Paul and Nehring (2005). A few hypotheses can be put forward to explain the discrepancy with their results. On the one hand, this may be due to violation of regularity conditions in Paul and Nehring (2005) results since they neither checked nor imposed those conditions. Alternatively, this may be due to the difference in the data. Paul and Nehring (2005) used pseudo-panel data from the

⁶Model 1 is not shown in figure 4.5 but implies even greater levels of economies of scale compared to Model 2 and 3

⁷As reported in Appendix B, an output distance function estimated using the KFBM data yields a pattern of estimated returns to scale that follows closely the pattern of Model 3 with high economies of scale for smaller farms and decreasing economies of scale for larger ones.

⁸The impact of input x_i on the elasticity of scale can be computed as $\eta_i^{scale} = \frac{\partial \eta^{scale}}{\partial x_i} = \sum_j \gamma_{i,j}$.

ARMS dataset which covers the entire U.S. and includes a large number of smaller "non-commercial" farms. The lack of economies of scope in the KFBM data estimates may reflect greater difficulties in accessing suitable off-farm employment among Kentucky operators compared to the rest of the country, or it may be that the results of Paul and Nehring (2005) were driven in large part by non-commercial and smaller farm operators which are not represented in the KFBM data.

Figure 4.7 reports the shadow output cost calculated using equation 4.6, which measures the change in gross farm revenues induced by an increase in off-farm income while holding input and distance (efficiency) constant. The upper panel of Figure 4.7 shows that the opportunity cost of off-farm income is quite low for smaller farms, making it profitable to diversify off the farm. The shadow output cost of off-farm work increases with the size of the farm operations, although most of the larger farms still display a shadow cost close to one. This would suggest that operators of larger grain farms are effectively paying a diversification premium to work off the farm. The lower panel shows that lower shadow output cost coincide with higher levels of off-farm income.

Efficiency

The technical efficiency obtained from the output distance function are presented in figure 4.8. It seems that most farms are relatively efficient with more variation found among operators of smaller farms. The decision to work off the farm does not seem to affect efficiency as some part-time operators are found among the most efficient of the entire sample. And larger farms do not appear to be systematically more efficient than their smaller counterparts. In fact, model 2 estimates suggest that operators of very large farms are among the most inefficient. Considering the stark contrast between model 2 and 3 in terms of economies of scale, it seems that for larger farms models either estimate large economies of scale with coefficient of technical efficiency that decrease with farm size, or constant return to scale and comparable efficiency between operators of small and large farms.

4.6 Implications and Conclusions

Using farm level panel data from Western Kentucky grain farms, the impact of off-farm diversification on production and efficiency was estimated using an input distance function on which different theoretical restrictions are imposed. Overall, the results are in line with the findings reported in the literature in various ways. First, estimated efficiency coefficient and elasticities differ substantially between constrained and unconstrained models, much like the results reported by Sauer (2006). The unconstrained model implies that as farm size increases, part-time operators becomes more efficient than full-time operators. This is a rather counterintuitive result that is

Figure 4.5: Economies of Scale (Model 2 and 3)

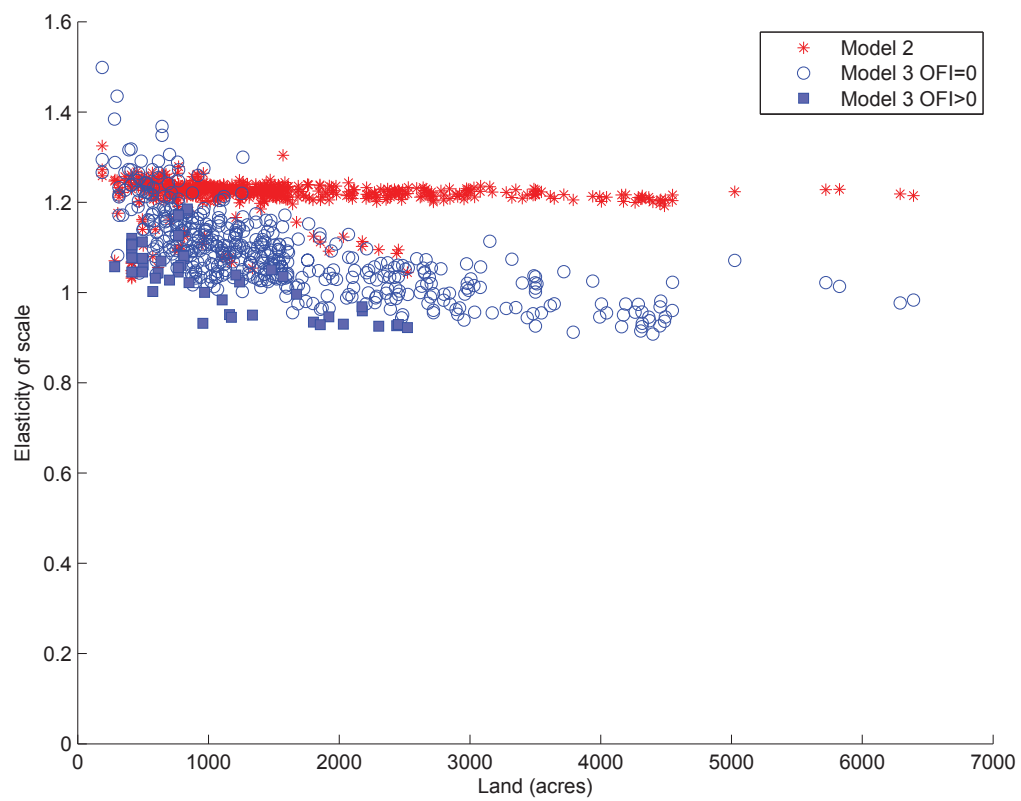


Figure 4.6: Economies of Scale (Model 2 and 3)

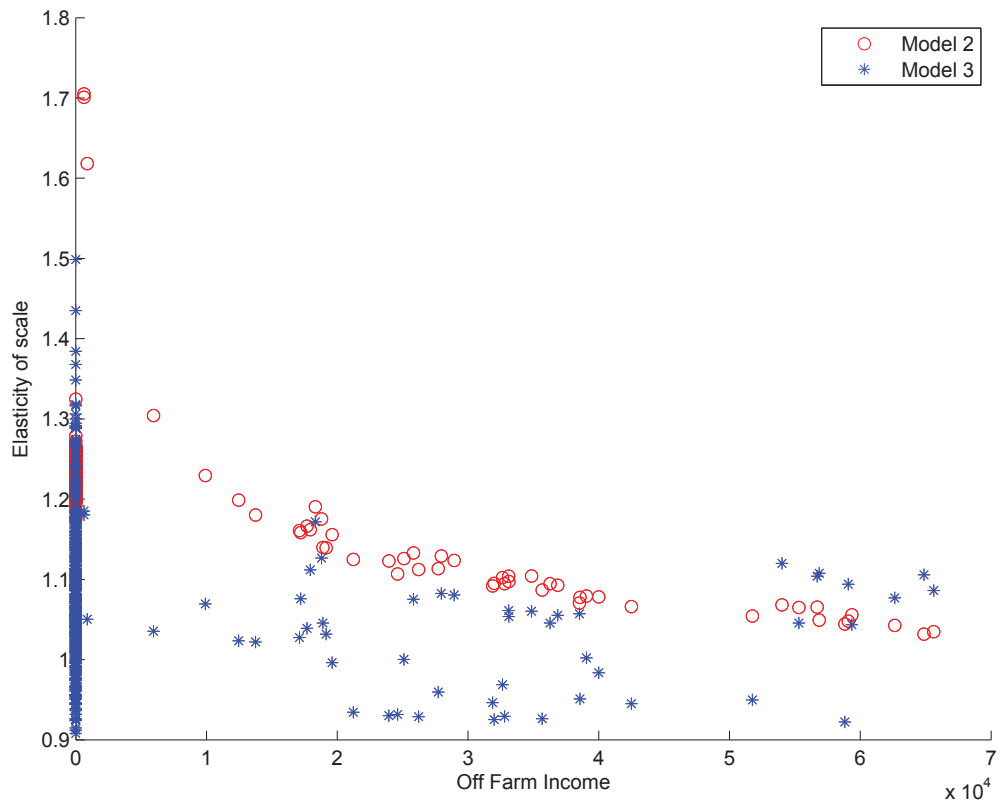


Figure 4.7: Shadow output cost $\left(\frac{dF}{dY}\right)$ (Model 3)

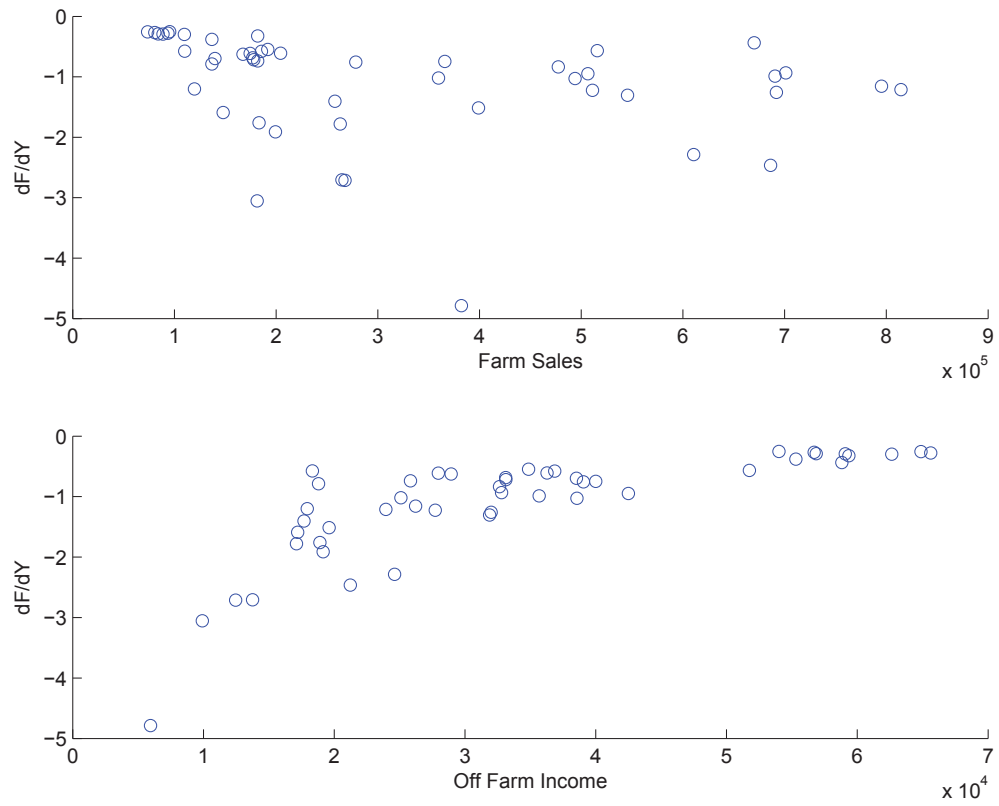
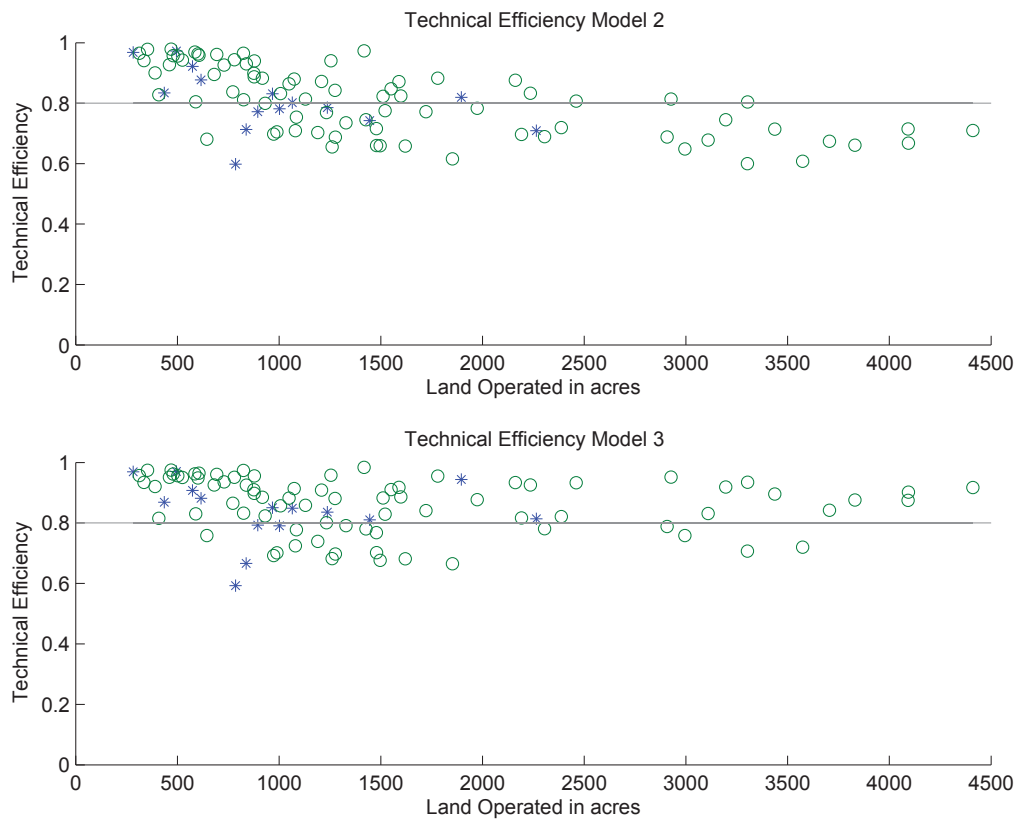


Figure 4.8: Efficiency (Model 2 and 3)



reversed once regularity conditions are imposed. Hence, the results presented above reiterate the importance of obtaining theoretically consistent estimates.

For farm operators of smaller commercial farms, the constrained models imply that off-farm diversification has little to no negative impact on farm production efficiency. In fact, these model estimated a slightly positive impact for smaller farms. However, for larger farms off-farm work has a clear negative impact on farm production efficiency. These results are in line with previous literature(Lien, Kumbhakar, and Hardaker, 2010; Paul et al., 2004; Paul and Nehring, 2005; Fernandez-Cornejo, Nehring, and Erickson, 2007), although the focus on commercial farms implied by the nature of the sample used in this study differs markedly from previous studies which included a large share of non-commercial. Hence, the results presented here imply that economies of scale extend beyond the smaller non-commercial farms and up to the smaller commercial farms.

Besides the impact on farm production efficiency, the estimates also suggest that hired labor and capital inputs have a greater importance for part-time operators. The implied marginal product of these inputs is higher for part-time operators, suggesting that they may act as substitutes for operators labor. On the other hand, variable inputs and land appear less productive under part-time operation.

In the end, the estimated models indicate that part-time operators experience lower levels of economies of scale, while full-time operators enjoy economies of scale at least until they reach 1500 acres in size. This suggest a certain trade-off between off-farm work and on-farm expansion. Overall, the diversification premium related to off-farm work appears to be relatively small for Kentucky grain farms with less 1500 acres. Beyond that, the diversification premium would increase significantly although more detailed information about the impact of off-farm employment on larger farms is scarce given that no part-time operators in the KFBM data operated on more than 2000 acres.

An interesting contrast between model 2 and 3 is the degree of economies of scale faced by full-time operators which differs markedly between the two models. The high degrees of economies of scale in model 2 are compensated by low technical efficiencies, while the reverse is true for model 3. Hence, it appears that assumptions about the data-generating process may have important implication for the results. Similar conclusions were reached by Kumbhakar (2011) when exploring the potential for endogeneity issues in the estimation of distance function. It is a possibility that the apparent bias in the economies of scale estimates based on input distance function, which was also reported by Paul et al. (2004), would find its origin in some of the potential endogeneity issues highlighted by Kumbhakar (2011).

Finally, other limitations inherent to the data must be kept in mind when generalizing those results. The KFBM data are said to be representative of Kentucky commercial farms, and thus do not represent the entire farm population. In addition,

the subsample selected consists only of grain farms operated by a single operator. The impact of off-farm work on farm with multiple operators and other farms types such cattle or dairy farms may be different.

Chapter 5

Numerical Analysis

To assess the impact of off-farm income on farm decisions and welfare, and its potential in mitigating the adverse effect of farm income risk, the dynamic model presented in section 3 is solved numerically under different scenarios. The model can be used to explore the interactions between farm revenue insurance programs and off-farm diversification and their impact on operators' welfare as well as their farm production decisions.

Within the model, the availability and coverage of farm revenue insurance programs is defined by the parameters $\bar{\Phi}$. The parameters defining accessibility and level of off-farm income for farm operators and households is defined by: 1) the presence of adjustment costs \mathbf{SC} if operators choose to exit farming, 2) the diversification of operators' own labor through part-time operation $E = 1$, and 3) the presence of a spouse working off the farm $\vartheta = 1$. In this section, the impact of each of these components on the adverse effect of farm income risk is explored.

Because policy concerns may vary from distortions in farm production to lower operators' welfare, the impact of off-farm diversification on these different variables is explored. More specifically, the impact of diversification and insurance programs on farm production is defined by the impact on the risk premium on farm inputs (eq. 3.17). This premium represents the distortion induced by risk on resource allocation. Naturally, the welfare of operators is capture by the value function (eq. 3.23).

The chapter starts by presenting the calibration of the model. It is followed by the introduction of the model solution under certainty and a comparison of the optimal solution with farm statistics from Kentucky. The analysis under uncertainty follows and is conducted in three steps. First, the impact of adjustment cost on optimal behavior is presented to assess the value and impact of labor mobility and improved access to off-farm labor markets. Then an analysis of the impact of operators' labor diversification on farm revenue insurance effect is presented. Finally, the impact of spouse income sharing is addressed.

5.1 Model Calibration

For the purpose of the simulation, farm production parameter values are derived from the KFBM data for the most part. First, the estimates from model 3 are selected to parameterize the distance function presented earlier, which defines the relationships between farm inputs, off-farm work and farm production. Despite the lower fit of

the model as indicated by the DIC in table 5.1, model 3 has the advantage of being theoretically consistent with the framework defined by the dynamic model. In fact, the choice between model 2 and 3 can be seen as a choice between two potential explanations of the KFBM data. The first one, represented by model 2, is based on the presence of substantial economies of scale which only decrease mildly over the range of farm sizes included in the data. However, operators of larger farms are found to have substantially lower coefficients of technical efficiency compared to most small farm operators. On the other hand, model 3 implies that operators of the largest farms display a similar level of efficiency compared to operators of smaller farms, but are facing modest diseconomies of scale.

Parameterization of the dynamic model using model 2 estimates would have to be accompanied by strict acreage or credit constraints. Absent of any constraint, model 2 would imply that an efficient farm operator could take advantage of substantial economies of scale and would then have incentives to grow his farm without limits to take advantage of the increasing returns to farm inputs. If either tight credit constraints or limits on available acreage is imposed to avoid unabated farm expansion, the solution is then defined primarily by these constraints while risk considerations only have a marginal impact. On the other hand, model 3 implies increasing return to scale only over a limited range of smaller farms. Larger farms face decreasing return to scale such that the solution of the dynamic model becomes much less dependent on exogenous constraints. It also allows comparisons of part-time and full-time operators with the same level of technical efficiency, letting the interactions between off-farm work and farm production implied by the parameters define the solution in each case.

Farm revenue variability is set at $\sigma = 0.125$ based on the variance of the residual of the estimated distance function. Land rent is set at \$85 per acre based on information from Halich, Pulliam, and Lovett (2010), USDA (2009), and the KFBM data. Depreciation on farm capital is set at 10%, which is also in line with the 1998-2009 KFBM data.

The risk free interest rate (\tilde{r}) is set at 1% based on the average real rate for the U.S. one-year treasury bills between 1997 and 2009 ¹. The interest rate profile for borrowed funds defined in equation 3.3 and figure 3.1 is based on an unsecured debt rate of 20%, an average debt-to-asset ratio slightly above 10% (Harris, 2010), and an average nominal cost of capital of 9% and 7% within the 1997 and 2006 ARMS data (Shleifer and Vishny, 2012).

Farm revenue insurance is introduced as a fair premium insurance covering gross farm revenues losses, and is similar in nature to programs in place in the U.S. and Canada. For this analysis, the parameters defining government payments (Φ) are set

¹The nominal interest rate was deflated using the annual percentage change in CPI index. Interest data taken from The Federal Reserve and CPI data from Bureau of Labor Statistics

to approximate the USDA ACRE program ² using the simplifying assumptions that the farm and state benchmark yields are the same and the state and farm ACRE guarantees are also equal. More specifically, government payments are defined as:

$$gov_t = \begin{cases} \Phi_1 \cdot \min[-\epsilon_t, 0.25] & \text{if } \epsilon_t < -0.1 \\ 0 & \text{otherwise} \end{cases} \quad (5.1)$$

where Φ_1 is the maximum insurance coverage available. In the following section results are presented for coverage levels varying from 0% to 80% of the revenue loss.

Following previous literature (e.g. Gomes and Michaelides, 2005; Willen and Kubler, 2006) the expected return to stocks is set at 5% with a standard deviation of 15%. Finally, the utility parameter is hypothetically set at $\omega = 4.25$, with a discount rate of 0.925 implying a rate of time preference of 8.11%. The transaction cost incurred when exiting the farm sector or choosing part-time farming are set in function of the utility parameters. Under baseline parameter values, low adjustment costs are set to 1/2 and high adjustment cost are set at 1.

Table 5.1: Parameters

Parameter	Description	Value/range
ω	utility parameter	4.25
ρ	time preference	0.93
θ_y	off-farm labor share	0.5
\tilde{r}	risk free interest rate	0.01
\bar{r}	interest rate on unsecured debt	0.20
κ_1, κ_2	parameter of interest function	{5,1.5}
σ_ϵ	volatility of farm gross revenues	0.125
σ_ν	volatility of stock returns	0.15
r_s	expected return on stocks (r_s)	0.05
N	number of retirement periods	25
T	number of production periods	25
ϕ	government programs parameters	see equation 5.1
ψ	regime switching adjustment costs	1/2,1
β, α, γ, D	distance function parameters	see Table 5.1
rent	land rent per acre	\$85 per acre
δ	depreciation rate	0.1

Finally, the model is solved by backward recursion using an approximant for the value function (equation 3.23) which is defined over the state space \mathbf{S} using cubic splines. The value function in period T is defined by the retirement value (equation

²See Paulson (2009), and Farm Service Agency for references.

3.10) and a solution for the value function at time T-1, (V_{T-1}) is found by finding the optimal policy at each node of the states space grid using the optimization routine *fmincon* in Matlab®. The operation is repeated until t=1. The distribution of shocks ν and ϵ are approximated using Gaussian quadrature as defined within the Compecon toolbox (See Miranda and Fackler, 2004).

Part-time and full-time operators under certainty

The first analysis is performed under certainty to provide a comparison of the optimal solution defined by the calibrated model with the KFBM data. It also provides a comparison of part-time and full-time operators with respect to their production efficiency and optimal production choices. The scenarios defining full-time and part-time enterprises are presented first, followed by their comparison.

Full-time operation Under this scenario, off-farm employment is available only if the operator exits the farm sector. Hence, part-time operation is not accessible for the operator and it is assumed that there is no spouse, or that the spouse is not working on or off the farm. This could represent a case where suitable off-farm employment is unavailable within the vicinity of the farm, such that exiting the farm operation and relocating elsewhere to find an off-farm job is the only employment alternative to the farm operator. Under this scenario, the adjustment costs related to farm exit would be relatively high. The impact of these adjustment costs is explored later in this section by solving the dynamic model under two different levels of transaction costs.

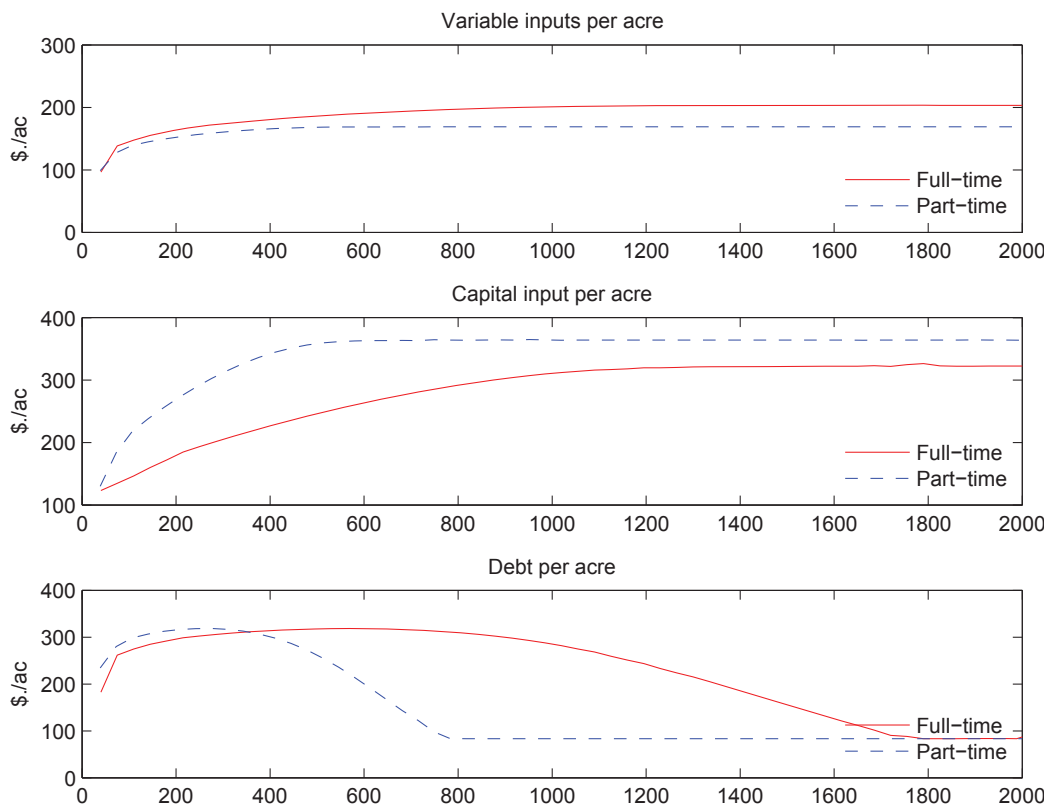
Part-time operation In this scenario, full-time farming is precluded, leaving the operators to choose between part-time farming or exiting the farm sector to find off-farm employment. The model is calibrated using the same parameter values as before. However, in this case the parameters of the distance function which define the relationship between off-farm work and farm production will be of importance. They will in fact define the potential efficiency cost of working off the farm, and the optimal changes in the input mix. Parameters of the distance function implies that economies of scale are more limited for part-time operators. In addition, part-time operators face large differences in the production share of inputs. In particular, parameters indicate that part-time operators will favor a more intensive use of capital ($\tilde{\beta}_K = 0.10$) and will get less productivity out of land ($\tilde{\beta}_K = -0.11$).

Comparing production and efficiency

The optimal production decisions of part-time operators reflect an input mix biased towards more intensive capital use (Figure 5.1) suggesting substitution of capital for

labor. The model generates capital input levels slightly above the average of the KFBM data (\$333/ac.), while the levels of variable inputs are below the average of the KFBM data (\$265/ac.).³ The maximum level of debt per acre is similar between the two types of operations, but it decreases much more rapidly for part-time operators as equity increases. This is a reflection of the limit on the optimal farm size imposed by the diversification of labor off the farm. The lower panel of Figure 5.2 shows the optimal acreage. With an equity of about \$500,000, the maximum optimal acreage for part-time operators is achieved at about 1,400 acres. By contrast, for full-time operators the optimal acreage reaches 3,100 acres. This difference reflects the lower economies of scale under the part-time regime, which curtail farm expansion possibilities. Another implication is that investment in stocks also occurs at lower levels of equity for part-time operators, leading to lower levels of financial risk.

Figure 5.1: Optimal Production under certainty



The calibration of the model also implies that overall part-time operators will choose a less intensive production approach, as reflected by the lower farm inputs

³University of Kentucky Cooperative Extension (2005) estimate variable costs between \$140/ac. to \$250/ac. depending on crops, and depreciation charges between \$30/ac. to \$40/ac.

and output per acre (Figure 5.2). Only when operators' equity is below \$500,000 does the intensity of production of full-time operators decrease to a level similar to part-time operators. This is mainly due to the presence of economies of scale and credit constraints.

Figure 5.2: Optimal Farm Production under certainty

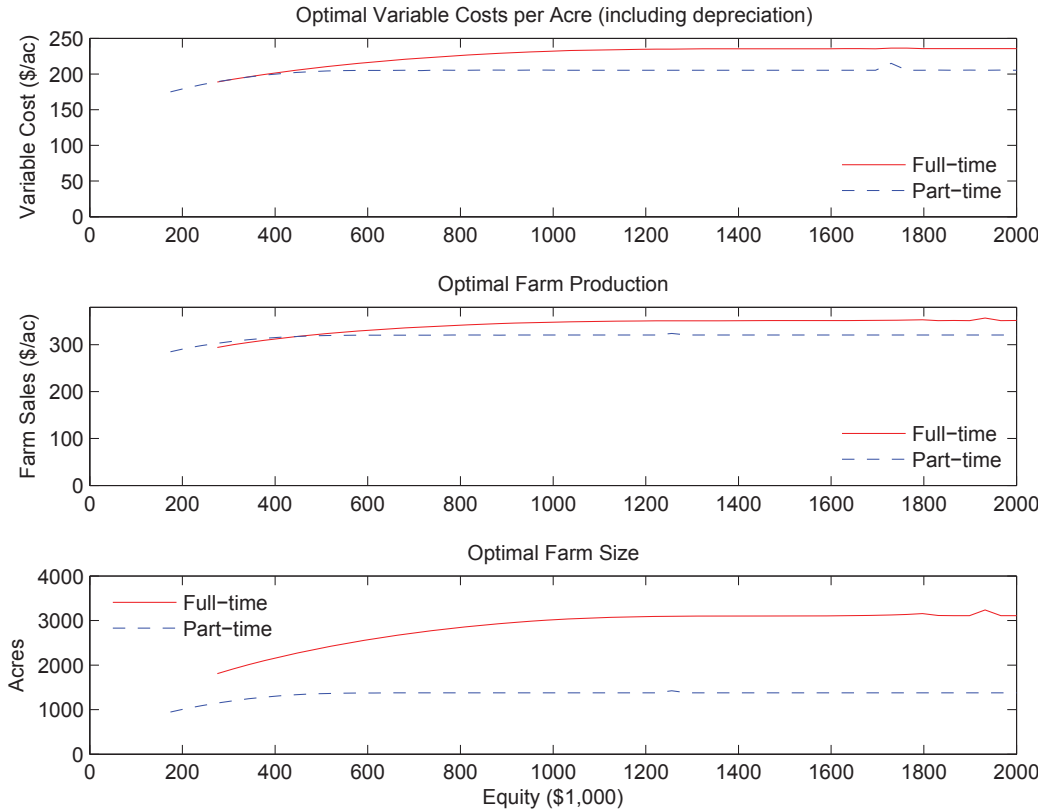


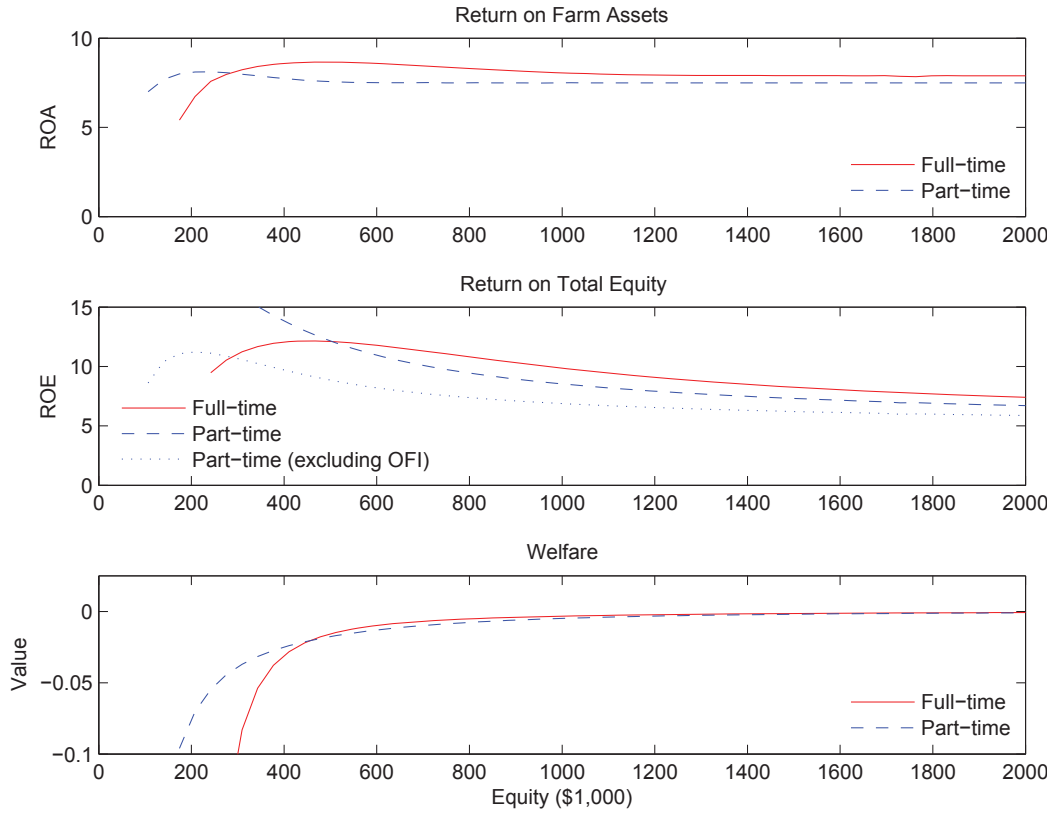
Figure 5.3 compares different measures of profitability and welfare for part and full-time operators. The top panel shows that farm return on assets (ROA)⁴ is slightly higher for full-time operators, which is consistent with the KFBM data (see Table 4.1).

The second panel reports the return on equity (ROE)⁵ with and without off-farm income. This measure of profitability also tends to be slightly higher for full-time

⁴ The return on assets is computed as the net farm income plus interest on borrowed funds divide by farm assets. In this case, farm assets include capital (K), hired labor (H) and variable costs (VC). Net farm income plus interest is defined as: $(F \cdot (Pg - \pi) - VC - H - \delta K - LD \cdot \text{rent})$

⁵The return on equity is computed as the net income divide by operators equity (W). Net income is defined as $((Pg - \pi) - VC - H - \delta K - LD \cdot \text{rent} - r_b B + r_s S + \theta_y Y)$. This measure reflects the return on farm operators equity including human capital.

Figure 5.3: Profitability of Farm level under certainty



operators. When including off-farm income, part-time operators have a higher ROE than full-time operators at levels of equity below \$500,000. Within the KFBM sample of grain operators presented in Chapter 4, about one third had less than \$500,000 in equity.

The apparent advantage of part-time operation at lower equity levels is also reflected in the welfare of operators under certainty. At equity levels below \$400,000, the welfare of part-time operators is higher but, abstracting from farm income variability, it becomes advantageous to switch to a full-time operation as equity increases. The optimal switching point depends on the profitability of the farm operation relative to other investment opportunities and off-farm wage. For example, results presented in Appendix D shows that operators with lower levels of efficiency may never find it optimal to switch to a full-time operation. Also, the decision to move to a full-time operation may depend on the presence of adjustment costs. These may include the loss of pension and health care benefits for example. Hence, the benefits of each regime may be affected by a number of factors not reflected in standard measures of profitability like ROE.

Obviously, risk and uncertainty will affect the production and diversification choices of operators and households. This will be explored below. Yet, this comparison under certainty suggests that, when focusing on farm production of commercial size enterprises, full-time farm operations are more profitable and produce more intensively, generating higher demand for farm inputs per acre and higher outputs. These implications of the calibrated model are inherited from the KFBM data which display similar trends. Naturally, increases in farm income risk will negatively affect welfare as well as farm production and profitability. And this negative impact will presumably be larger for full-time operators than for those working off the farm. Then, the policy question is whether the negative impact of risk on farm decisions and welfare of full-time farm operators is larger than the cost imposed by the diversification premium.

5.2 Full-time Operation and Adjustment Costs

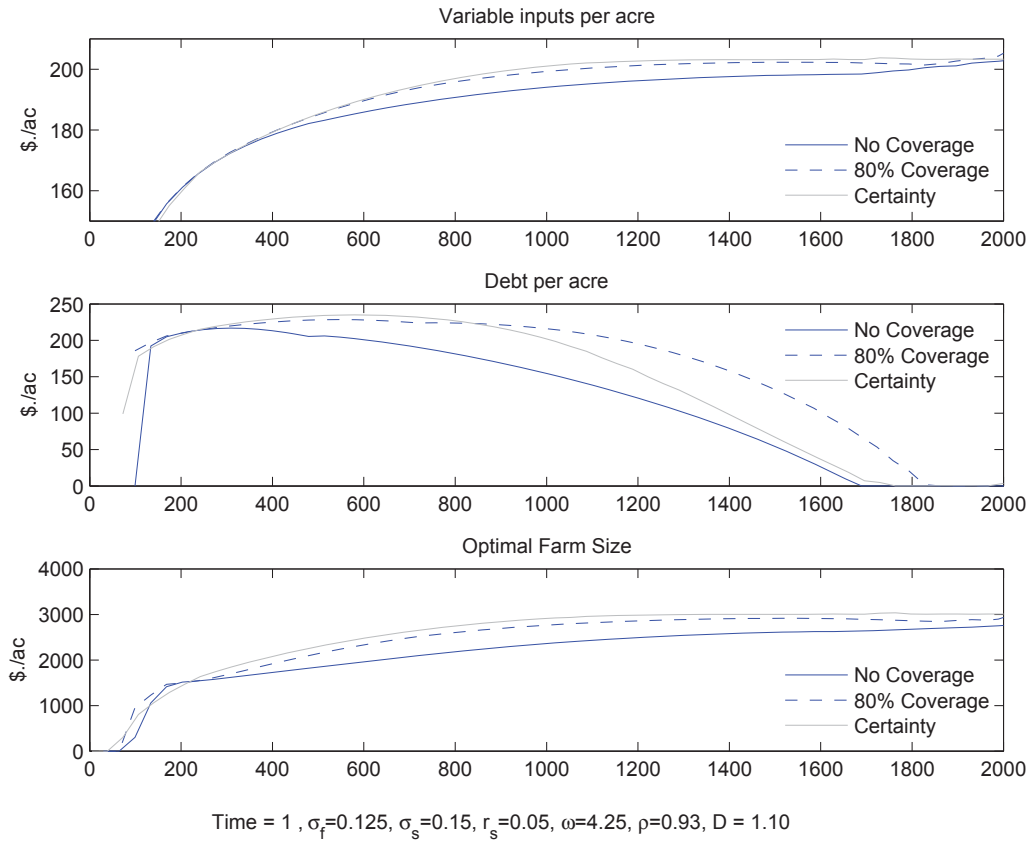
Under full-time operation, the introduction of farm income risk generally leads to the typical risk responses. Welfare decreases, the expected rates of return on asset and equity decrease, and the presence of a positive risk premium on farm inputs leads to a reduction in input demand and farm output. Figure 5.4 shows the impact of introducing farm income risk on farm production decisions while Figure 5.5 shows the impact on profitability and welfare.

However, the introduction of capital and labor market imperfections and the presence of economies of scale induce a change in response around the farm exit point. The smooth pasting and value matching conditions (equation 3.18 and 3.19) ensure that at the switching points the value and marginal value will be the same under each regime. However, the shape and curvature of the value function are altered, leading to a reduction in the degree of risk aversion, and potentially to risk neutral or even risk loving behavior near the switching point. This occurs despite the risk aversion implied by the utility function. For example, in the bottom panel of figure 5.5, the value function for the low adjustment costs scenario is no longer concave at values of equity near \$200,000.

This change in curvature implies that the marginal value of equity may increase at an increasing rate when approaching the switching point. This is because additional equity will allow an operator to maintain the farm operation and avoid the adjustment costs associated with farm exit. Hence, the marginal value of equity is a lot higher at, or near, the switching point than it is at other points sufficiently far above, or below, it.

This behavior is induced in part by imperfections in the capital market. If capital markets were perfect, even operators with little or no equity may be able to obtain the necessary funds (presumably through equity financing) to maintain the farm in operation at reasonable costs, and thus the prospect of having to face farm exit

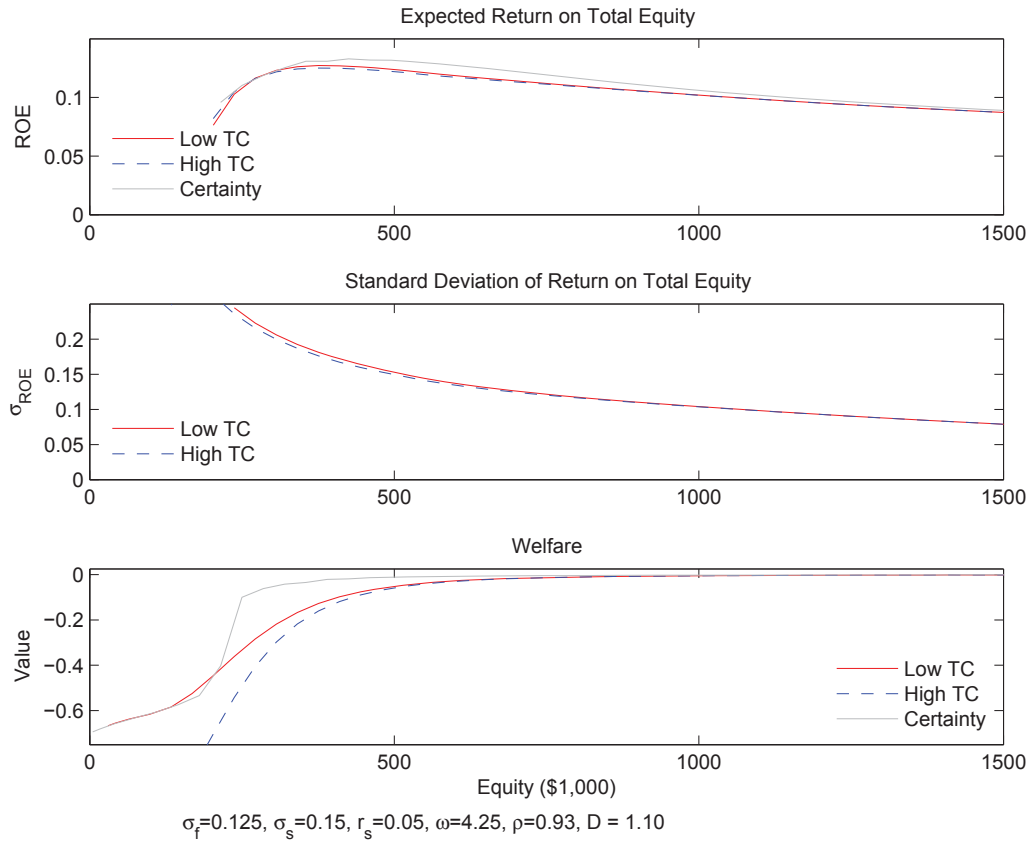
Figure 5.4: Optimal Production Decisions under Uncertainty



and adjustment costs, or to have to operate at an inefficient scale would be heavily discounted. This behavior is also induced by the presence of economies of scale over a range for smaller commercial farms, and the potential costs and difficulties involved in diversifying labor off the farm. If farming involved constant or decreasing returns to scale even for these smaller farms, and if operators had perfect flexibility in their labor allocation decisions, i.e. they could freely adjust the number of hours of off-farm work, then instead of exiting the farm sector and facing adjustment costs operators would simply downsize the operation and diversify their labor off the farm as needed. As a result, the presence of economies of scale in combination with imperfect capital and labor markets can have profound effects on the optimal risk response implied by the model.

The impact of this behavior is best exemplified by looking at the risk premium on farm inputs over a range of equity. Figure 5.6 shows the optimal expected marginal value product (MVP) of variable farm inputs. The dark line shows the optimal MVP under certainty, reflecting the impact of credit market imperfections on the cost of debt. As equity increases, the excess return on input converges to its opportunity cost

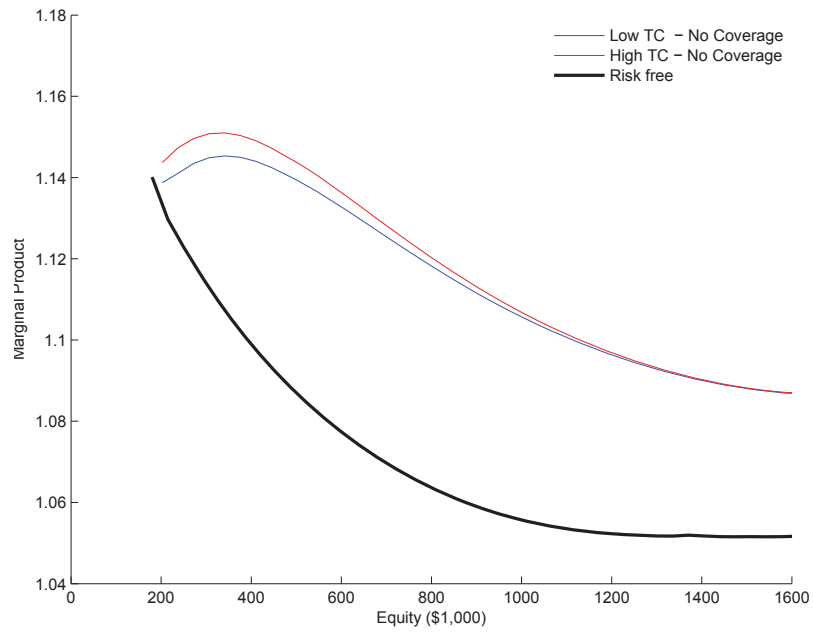
Figure 5.5: Profit and Welfare under Uncertainty



of 5%, determined by the expected return on stocks. The figure also shows the optimal expected MVP under uncertainty and two different levels of adjustment costs. As defined by equation 3.17, the difference between the cost of debt and expected MVP is the risk premium⁶. The risk premium is depicted in figure 5.7, including the effect of farm income insurance. It clearly shows the non-monotonic relation between the risk premium and equity. Below the switching point, there is no demand for farm inputs and the premium is not defined. As equity increases above the switching point, the premium actually increases as the behavior of operators is less and less driven by the downside risk imposed by credit constraints and, potential costs of farm exit. As equity further increases, the value function becomes concave and we find the traditional risk return trade-offs, implying a decreasing premium as equity increases.

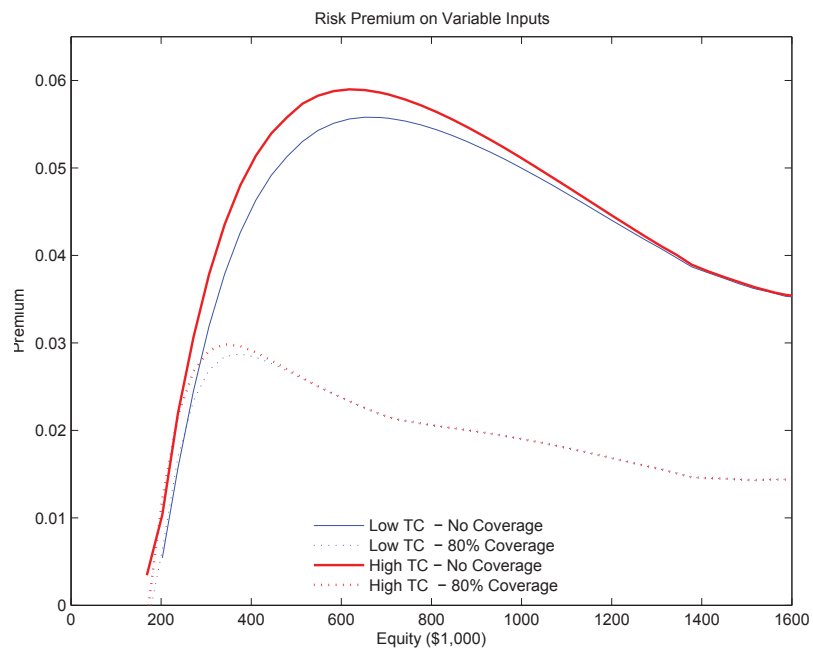
⁶ See Appendix C for more details about the nature of the risk premium and its relation with risk aversion and precautionary saving motives.

Figure 5.6: Marginal Value Product of Variable Input



$$\sigma_f = 0.15, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1, TC = 1$$

Figure 5.7: Risk Premium on Farm Variable Inputs



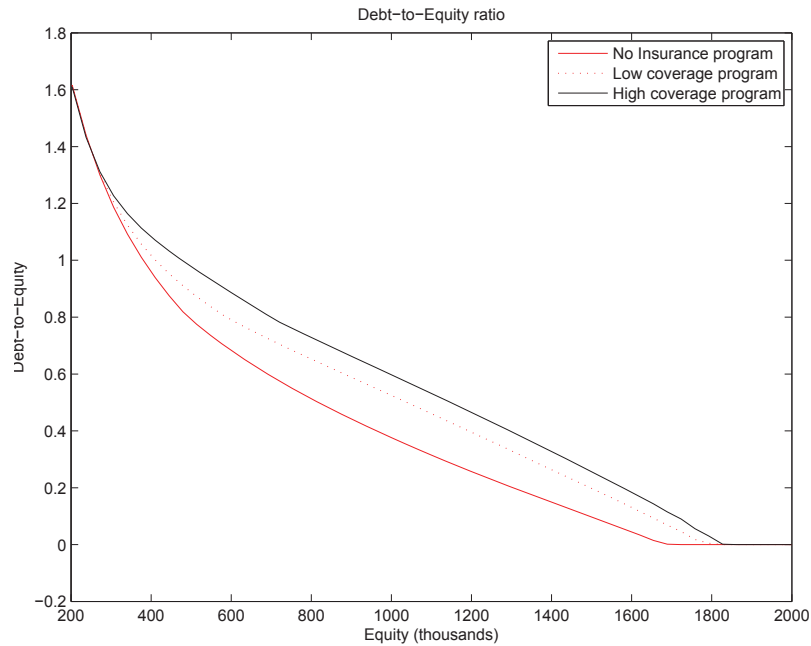
$$\sigma_f = 0.15, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1, TC = 1$$

Farm revenue insurance

An important policy implication of imperfect markets and economies of scale is that changes in insurance benefits will also be non-monotonic with respect to operators' equity. As shown in figure 5.7, the introduction of farm income insurance induces a substantial decrease in the risk premium. This effect is most pronounced for operators with \$500,000 to \$1,000,000 in equity. But operators with less equity will have little incentive to increase their demand for farm inputs and expand production. In the limit, because fairly priced insurance also reduces the upside risk, it could even lead credit constrained operators to reduce their demand for farm inputs.

Other farm inputs behave in a similar fashion to variable inputs, although the magnitude of the risk premium is lower for capital inputs since their return is amortized over a number of years. Since farm income risk is modeled as a short-term shock without persistence, returns to capital becomes less volatile. Introducing shock persistence would increase the risk premium on capital inputs. Also, the impact on debt-to equity is presented in figure 5.8. In low equity states, insurance programs have very little effect on optimal levels of financial risk as measured by the debt-to-equity ratio. However, as equity increases the insurance does reduce the precautionary motive of operators leading to higher optimal levels of farm inputs and financial risk.

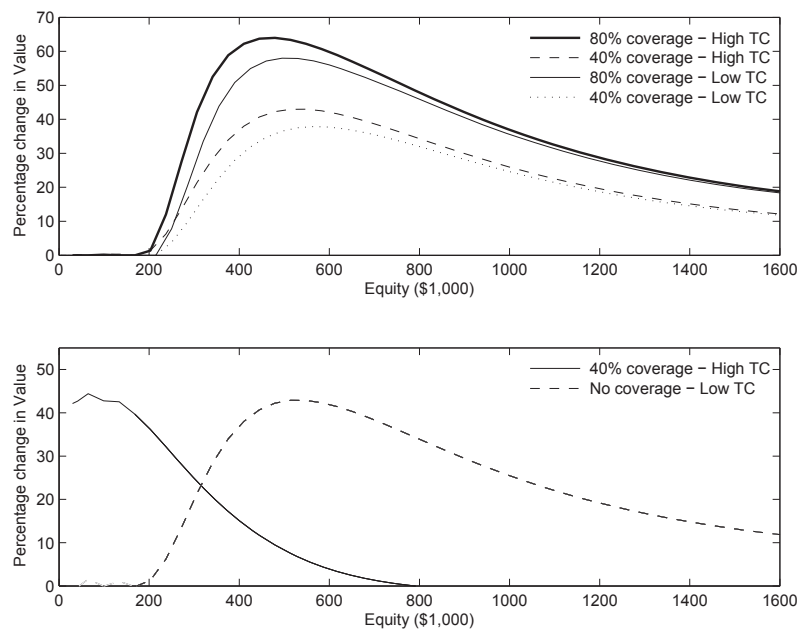
Figure 5.8: Debt-to-Equity ratio under different levels of insurance coverage



$$\sigma_f = 0.125, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1, TC = 1$$

While the risk premium is a key indicator for policy aiming at reducing the negative affect of risk on farm input demand and production, it does not directly reflect the changes in welfare. The welfare benefits of insurance programs are summarized by changes in the value function. Figure 5.9 shows that at equity levels below the exit point there is no insurance benefit since it is optimal to leave farming altogether. Immediately above the critical equity level, insurance benefits start to increase with equity. For those with barely more than \$200,000 in equity, insurance is simply not enough to reduce the probability of farm exit significantly. As equity grows, farm revenue insurance becomes an increasingly efficient tool in reducing the potential of farm exit, thus making it more valuable. Naturally, at some point insurance becomes less valuable for wealthier farmers as they accumulate enough wealth to reduce their level of financial risk significantly.

Figure 5.9: Welfare under different levels of insurance coverage



$$\sigma_f = 0.125, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1, TC = 1$$

Farm exit/adjustment costs

The possibility to leave the farm can be viewed as a switching option where the cost of exercising this option is the farm exit cost. Naturally, the benefits of easier access – or the value of the option – depends on the probability of exit in future periods and the cost of exercising the option. Hence, the value of easier access to labor market

is highest for states where farm exit is higher and nearer in the future. As a result, the impact of changes in adjustment costs on operators welfare remains bounded to lower equity levels and only overlaps with farm revenue insurance over a limited range. The bottom panel of Figure 5.9 shows that reducing adjustment costs as an effect of similar magnitude compare to 40% insurance coverage, but the effect is distributed towards very low equity operators. Hence, access to off-farm income acts more like catastrophic insurance.

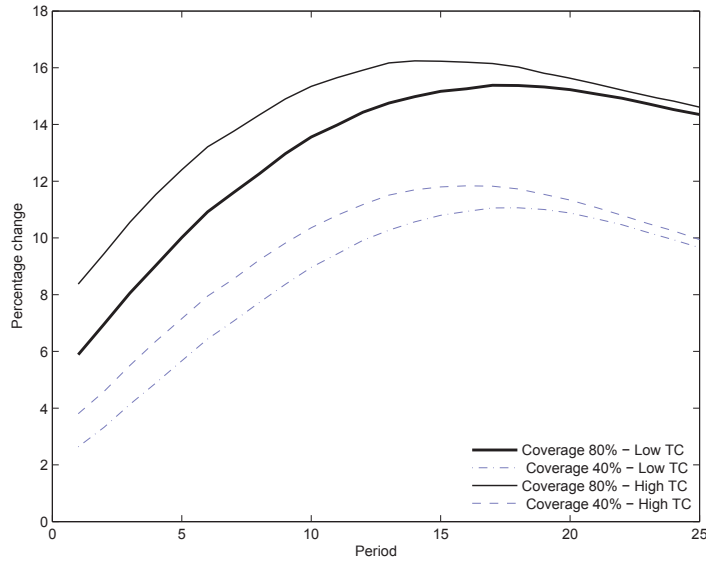
As such, easier access to off-farm employment would appear more as a complement to farm revenue insurance programs, especially when payments are capped to a maximum amount, as is the case with ACRE. Nevertheless, reducing the adjustment cost associated with off-farm employment does affect farm decisions. Figure 5.7 shows that by reducing the downside risk, the lower adjustment cost also reduces the risk premium on farm inputs.

Like other options, the value of the option provided by off-farm employment opportunities depends on time to maturity, i.e. time before retirement, and the probability of it being exercised which depends on the level of equity and the profitability of switching to off-farm employment. This option lessens the downside risk faced by operators, effectively making them less responsive to farm income risk and decreasing the benefit they derive from insurance. Because the option is most valuable for younger and less wealthy operators, their behavior is most affected by easier access to off-farm labor markets.

Because the value function in period one represent the discounted sum of utility, changes in value in period 1 summarize the total change in welfare induced by insurance and adjustment costs. The impact of a change in adjustment cost on farm production decisions through the operators life-cycle can be illustrated with simulation results. Figure 5.10 shows that under low farm exit costs, the average change in variable input induced by maximum coverage insurance is around 2% less for the first 10 years. This gap lessens as operators approach retirement. This is in part because the probability of leaving the farm decreases with time since the precautionary motive has led operators to accumulate equity. In some instances where adverse shocks prevented them from building savings, operators exited the sector. Lower adjustment costs lead to higher exit rates, but those that remain in operation derive less benefit from farm insurance.

Hence, access to an off-farm labor market can provide a valuable option to farm operators, especially when young and/or less wealthy. This could lend support to the long held view that off-farm income serves as a transition tool allowing young farmers to enter the farm sector and facilitating farm transfers. Not only does working off the farm facilitate farm entry but the mere possibility of transferring to an off-farm occupation at a later date helps younger operators shoulder the business risk associated with farm entry.

Figure 5.10: Changes in Expected Variable Inputs



All percentage changes are computed based on a baseline scenario that includes no insurance coverage.

$$\sigma_f = 0.15, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1$$

Also, the results presented here are based on changes in the cost of farm exit, which may represent monetary costs involved in job search, training, or relocation, and non monetary costs. But changes in the off-farm wage would have a similar effect on the value of the off-farm option. Hence, factors affecting either farm exit costs or off-farm wages, such as age, education and location, may all play an important role in defining the downside risk facing farm operators and in turn affect their farm decisions.

Under increasing labor market integration, the probability of farm exit increases. But it should also lead younger and/or less wealthy operators to 1) have a lower demand for insurance, 2) have more incentives to intensify or expand farm production and 3) have the capacity to accept greater financial risk. To the extent that access to off-farm labor market depends on distance from important urban agglomerations, one could conclude that insurance programs are therefore of lesser importance for beginning farmers with higher education and who are established in peri-urban areas, and are of greater importance for those in remote areas.

Lower adjustment costs increase labor mobility thus providing a valuable option to operators in case of farm failure, but also ensuring an efficient use of resources and contributing to the diversification of rural economy. This increased mobility that

has erased inequality between farm and nonfarm households also contribute to rural development and reduces the adverse effect of farm income risk on producers' welfare and farm income decisions.

5.3 Part-time Farming Under Uncertainty

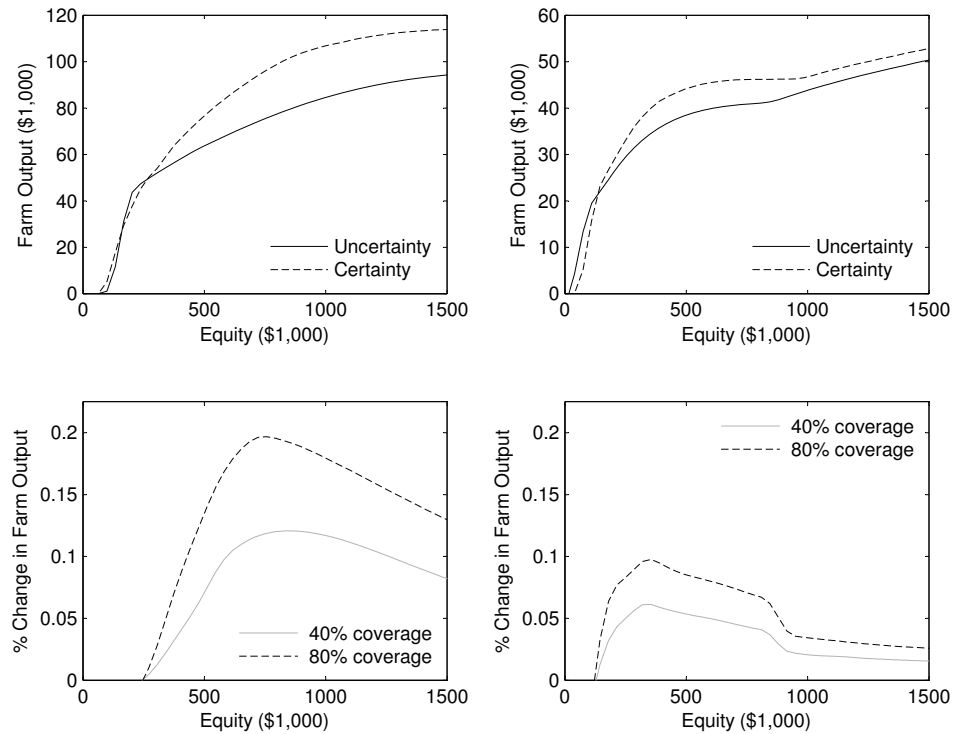
Given reported results in the literature stating that diversified labor income reduces the role of insurance (e.g. Gollier, 2003), it is easy to surmise that off-farm employment will lessen the impact of insurance programs on farm production decisions and operators' welfare. At the same time, results under certainty presented above have exposed some of the downside of part-time operation in terms of lower farm efficiency and production intensity. While the adverse effects of risk is expected to be lower, the question is whether the benefits of diversification can offset its downside so as to make it an effective risk management tool. This will depend largely on the risk-return trade-off between the diversification benefits, and the adverse impacts in terms of the level farm production and welfare.

For the part-time farmers the introduction of uncertainty leads to responses similar to full-time operators, but of lesser magnitude. While farm production is reduced by the presence of risk, the impact on part-time operators is significantly less (see Figure 5.11). The impact of government farm revenue insurance programs also have a much smaller impact on the farm production incentives of part-time operators. For full-time operators, a revenue insurance program offering 80% coverage can increase production by up to 20% compared to a scenario without insurance. But production would not increase by more than 10% for part-time operators.

This is because farm income risk has a much smaller impact on consumption and welfare of part-time operators. The lower covariance between future marginal value and current farm income shocks is reflected in the lower premium on farm inputs (see figure 5.13). Because the consumption and welfare of part-time operators is defined in large part by off-farm income, farm income risk and farm insurance have little impact on their decisions. This is a direct outcome of the non-separability between consumption and production induced by imperfect capital and labor markets. Under these assumptions the farm decisions are driven by the consumption and welfare of the operators and farm household, which in turn are influenced by their portfolio of income sources.

A lower premium on farm inputs, in turn, implies that investment in agriculture will be closer to its optimal level under certainty. Because of this, the return on equity for part-time operators will also be little affected by farm income risk and changes in farm insurance programs. In contrast, farm income risk decreases the ROE for full-time operations much more significantly, and as a result the range of equity over which part-time farm operation may be more profitable than full-time operation will increase under uncertainty. But the model suggests that this effect, no matter what

Figure 5.11: Production under Uncertainty

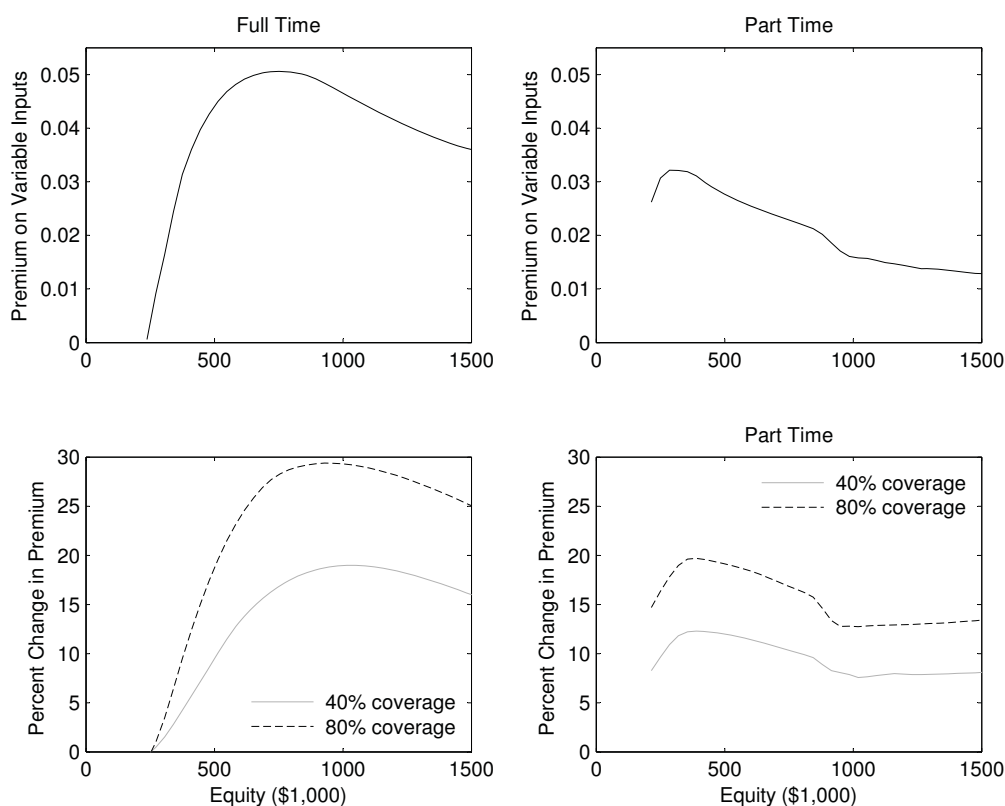


level of insurance is available, remains small. Hence, when focusing on farm production and competitiveness, the calibrated model indicates that the financial benefits of part-time operations are not enough to overcome its negative impact on farm profitability.

However, a much more sizable effect of risk is reflected in the relative change in welfare between full-time and part-time operators. Not only is it the variable that is most affected by risk, it is also the one that drives the decision making process of agents. The top panel of Figure 5.14 shows that under uncertainty, part-time operation becomes optimal for a much larger range of equity levels. Under certainty part-time operation was optimal when equity was less than \$400,000. Under uncertainty this range increases up to \$1,000,000. This would suggest that the presence of subsidized insurance has a large role to play in shifting the choice toward full-time operation, and that without it the number of part-time operators may increase substantially.

Also, the previous analysis was based on the optimal choices at period 1 of the model, i.e. when operators are 25 years away from retirement. When moving closer to retirement the diversification value of labor decreases because its discounted present value shrinks with the number of working periods remaining. As a result, operators

Figure 5.12: Risk Premium of Part-time Operators



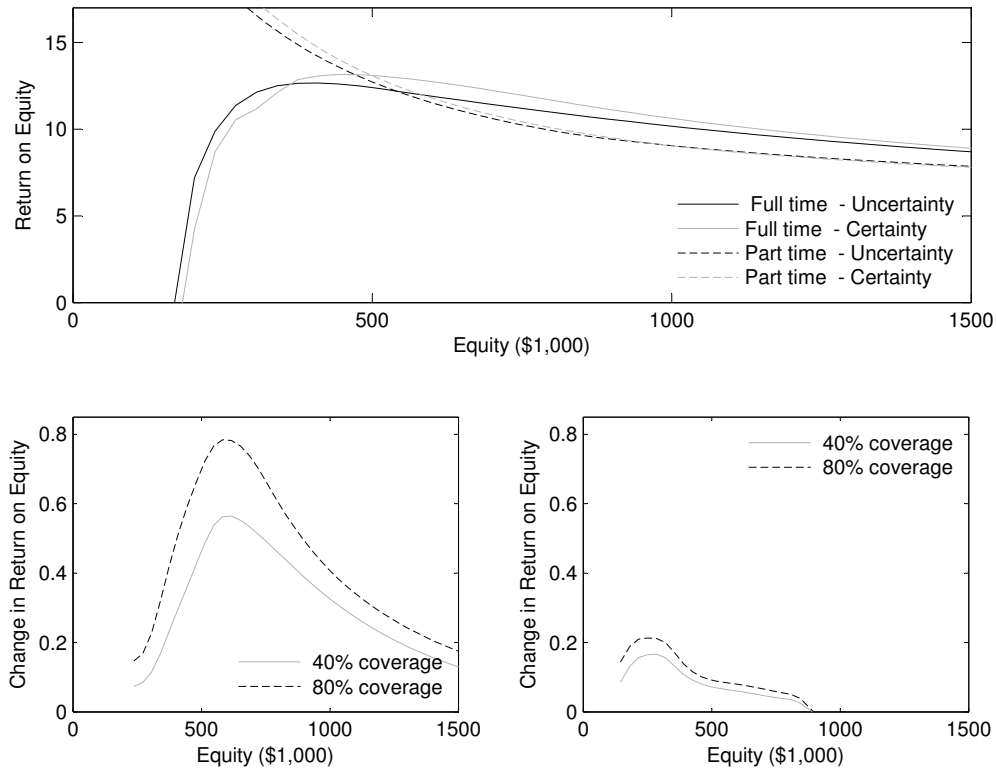
tend to become slightly more conservative and the welfare of part-time operators dominates that of full-time operators over an increasingly larger range of equity.

Summary

Overall, this scenario shows that part-time operators are less affected by insurance programs, which may suggest that their increasing number would undermine the policy rationale based on farm income risk and its adverse effects on operators' decisions and welfare. First, in this model part-time operators are less responsive to risk policies not because they have different farm objectives but rather because they benefit from diversified income sources and do not need to leverage their equity as much as full-time operators.

However, the cost of diversification in terms of lower farm profitability and intensity of production remains relatively high. Hence, despite the fact that full-time operators may be induced to reduce the intensity and profitability of their operation

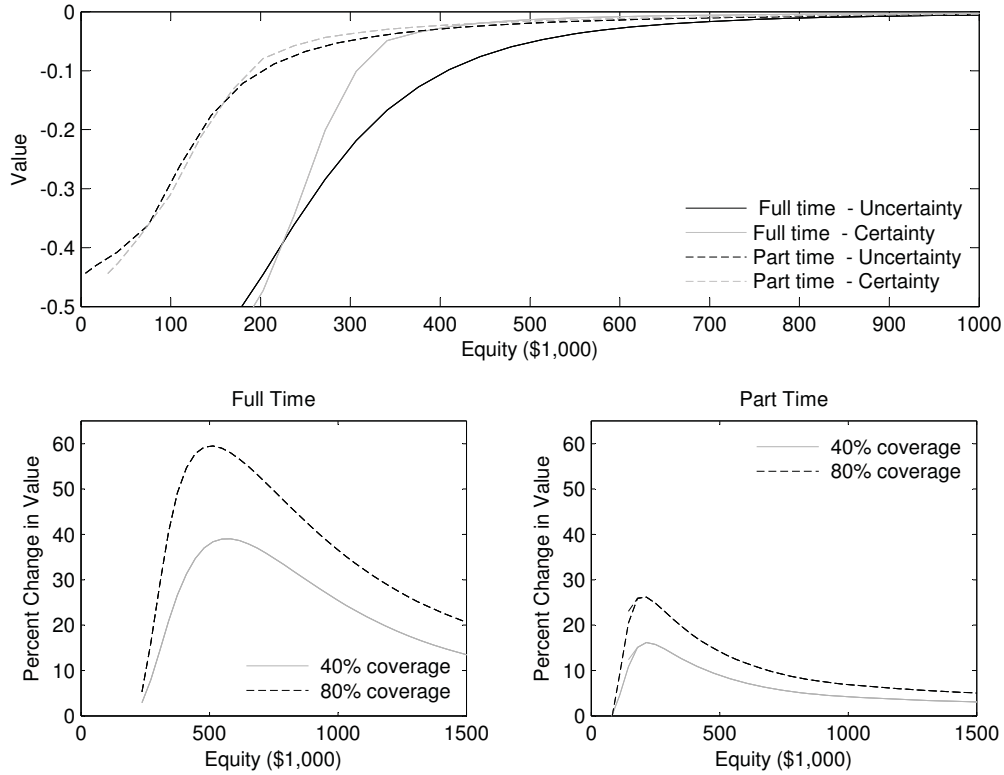
Figure 5.13: Return on Equity of Part-time Operators



under uncertainty, they remain more profitable than part-time operators with similar characteristics. As a result, while operators labor diversification reduces the impact of risk on farm input demand and production decisions, it also appears as a undesirable outcome of risky farm income if fostering farm production and investment is the main policy objective.

Even so, the income earned from off-farm employment may compensate for lower farm returns, thus making the overall profitability of the operators financial and human capital comparable to full-time operators, at least at lower levels of equity. Moreover, the higher level of diversification leads to higher welfare for part-time operators compared to full-time operators over a fairly large range of equity. Hence, the model suggests that the desirability of part-time operation as a risk management tool depends highly on policy and social objectives.

Figure 5.14: Welfare of Part-time Operators



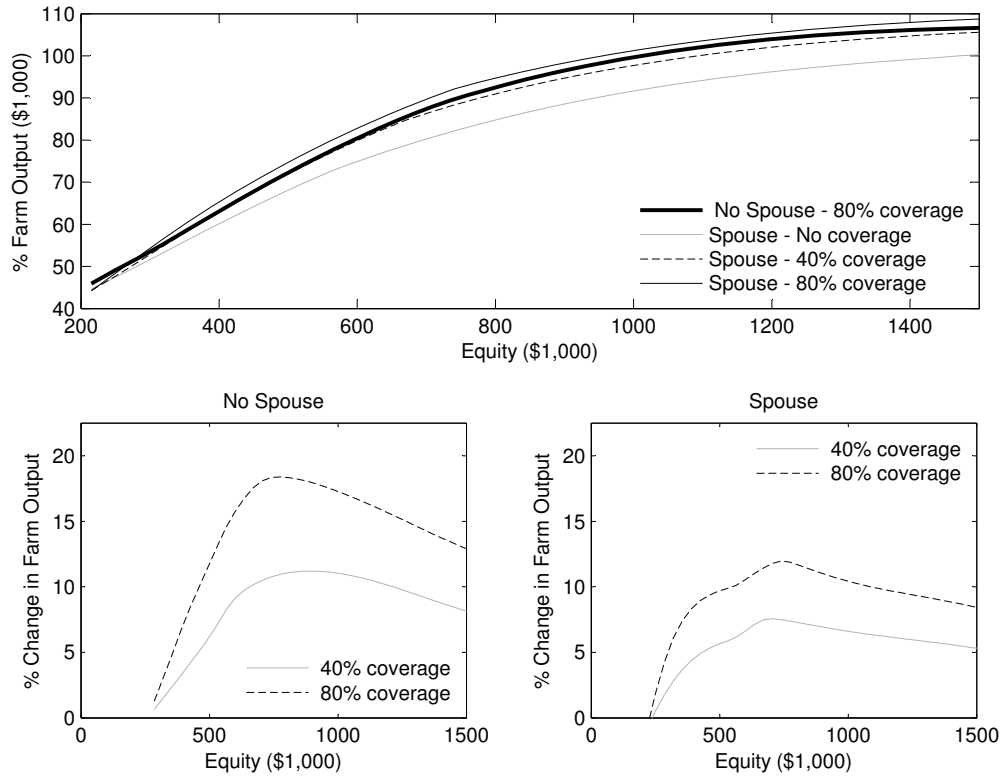
$$\sigma_f = 0.125, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1, TC = 0.5$$

5.4 Spousal Income

This scenario includes the presence of a spouse working off the farm and sharing income as per the sharing rule defined by the budget constraint in 3.9. In such a case diversification takes place at the household level and while the operator is allowed to seek part or full-time employment off the farm, his/her incentives to do so are likely to be reduced by the presence of a spouse. This scenario makes the implicit assumption that spousal labor allocation decisions are mostly independent of the farm labor and managerial constraint. It thus eliminates the negative impact of off-farm labor diversification on the farm enterprise. Such a scenario represents a fairly common case, based on U.S. ARMS data Ahearn (February 23, 2012) reports that in 2010, 82 percent of principal operators reported being married and about half of their spouses worked off the farm.

The presence of a spouse working off the farm implies not only a diversification of income sources but also a flow of liquidity that will relax the credit and liquidity con-

Figure 5.15: Impact of Spousal Income on Farm Production

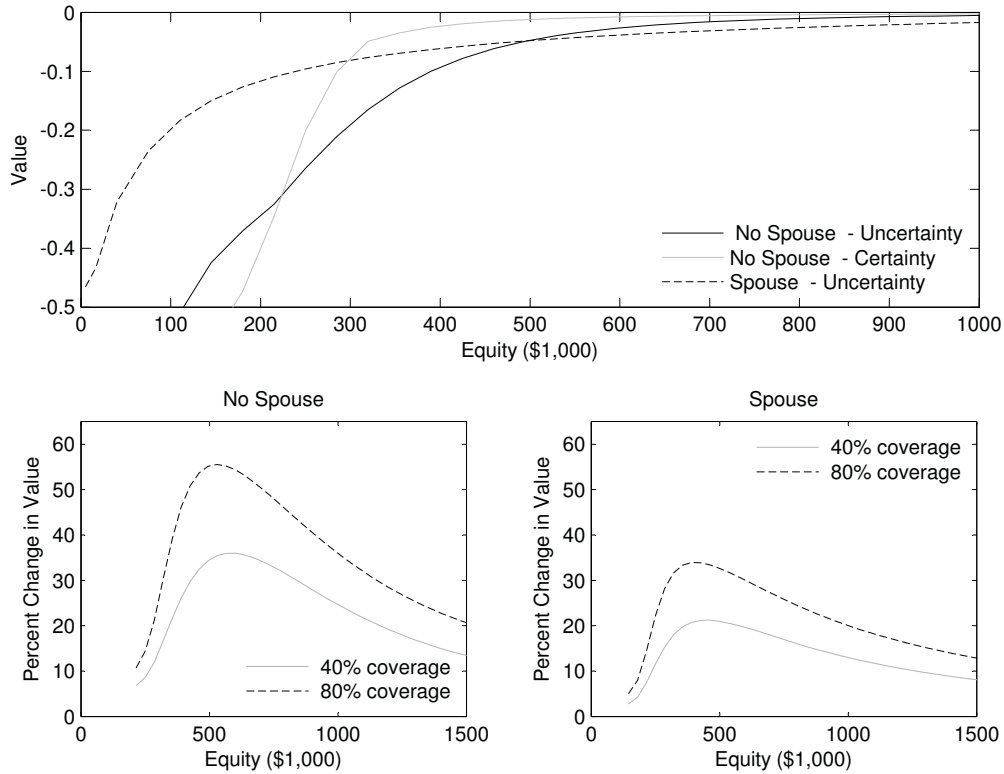


$$, \sigma_f = 0.125, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1, TC = 1$$

straints. The impact of spousal labor diversification on farm production decisions is shown in Figure 5.15. The top panel compares the optimal expected level of production with and without a spouse. It shows that the level of production in the presence of a spouse working off the farm and with farm revenue insurance with 40% coverage is comparable to the level of production with 80% coverage and no spousal income. The diversification benefits of spousal income are also reflected in the lower panels which compares the responsiveness of farm production to changes in farm revenues insurance coverage.

Besides the diversification in income, the other difference implied by the presence of a spouse is equity sharing, which result in lower welfare of the operator. Because it is assumed that equity is shared between spouses upon retirement, it leads to lower operator welfare but also to a higher saving and investment motive. Figure 5.16 shows that the welfare of single operators is higher for equity levels above \$500,000. However, changes in farm revenue insurance have a much smaller impact on operator welfare in the presence of spousal income.

Figure 5.16: Impact of Spousal Income on Welfare



$$, \sigma_f = 0.125, \sigma_s = 0.15, \omega = 4.25, \rho = 0.93, D = 1.1, TC = 1$$

Overall, the presence of a spouse working off the farm provides an efficient risk management alternative. It does reduce the adverse effect of farm income risk on farm production decisions and farm profitability. It thus limits the potential for resource misallocations due to farm income risk. While it may lead to a decrease in operator's welfare, this is the result of a personal choice, that of sharing his/her life and equity with a spouse.⁷ Clearly, the choice of having a spouse is not defined by farm income risk and farm policies. However, the model suggests that the presence of a spouse may well affect the effectiveness and need for farm income stabilization policies. This model indicates that spousal income provides a risk management alternative that is consistent with policy rationale defined either in terms of farm production and investment, farm competitiveness, or operator's and household's welfare. Consequently,

⁷ The model abstracts from the possibility of prenuptial agreements that would separate initial operator's equity from the common pool of equity acquired by the spouses during their common life.

these results suggest that the value of farm programs crucially depends on whether the unit of analysis is the household or the farm enterprise.

5.5 Implications and Conclusions

Once calibrated on the KFBM data, numerical solutions of the dynamic model developed in Chapter 3 were derived to assess the role of off-farm diversification in mitigating the adverse effect of farm income risk. The model includes capital market imperfections, economies of scale in farm production, and the presence of adjustment costs in labor allocation decisions. The model provides a more thorough and realistic characterization of the environment defining income and financial risks faced by farm operators, as well as the risk management alternatives available to them.

As a first step, the analysis focused on the role of off-farm income in defining the downside risk faced by operators of commercial size farms. In the case of catastrophic risk, if farmers are forced to abandon farming, adjusting to off-farm employment is the most likely alternative. Hence, accessibility to off-farm labor markets defines the downside risk of farm operators. The solutions and simulation of the model calibrated on KFBM data show that this option to exit can affect the farm decision of full-time operators and mitigate the impact of farm income risk on operators' farm decisions and welfare. The value of the option to exit farming is amplified by the presence of credit constraints combined with economies of scale over a range of smaller commercial farm sizes. It also depends in part on adjustment costs reflecting the degree of labor mobility and access to dynamic labor markets. The value of this option is greater for younger operators, which would imply that, for similar levels of equity and farming skills, younger operators would be willing to shoulder more risk to enter or remain in farming. This is in line with the findings of Bodie, Merton, and Samuelson (1992).

In fact, even in the case of part-time farm operation or spousal off-farm income, the value of off-farm labor diversification as a risk management tool is found to decline as operators get closer to retirement. This is in line with the adjusted portfolio rule presented in equation 3.1, which shows that as the discounted value of future labor income declines, it becomes optimal to diversify a greater portion of wealth into risk-free assets. Hence, the model predicts that, *ceteris paribus*, older operators will be more conservative and less inclined to invest in risky farm assets. This implication from the model also suggests that the role of off-farm diversification as a risk management tool would be more limited for older operators. However, the typical life cycle also implies a build-up of equity and savings which can compensate for the reduction in the value of human capital.

An interesting consequence of this exit option is the non-monotonic relation between risk responsiveness and equity. It is usually assumed that increasing wealth and equity will decrease the magnitude of risk responses. However, the model implies

that as operators get closer to the switching point their behavior will move gradually towards more risk neutral or even risk loving behavior, such that operators with low levels of equity will tend to be less responsive to risk. Whether this prediction of the model is corroborated by the data is unknown and represents an interesting implication to test in further research. It also raises the question of whether this switching regime behavior may contribute to explain the low interest of farmers in insurance products.

The actual diversification of labor off the farm is also found to mitigate the impact of normal risk on farm operation decisions and welfare. It allows the smoothing of consumption and reduces the financial risk faced by operators and households. However, the impact on farm production can be ambiguous. The diversification of labor by the main operator seems to impose labor and managerial constraints that can reduce the intensity and technical efficiency of the farm enterprise. Even so, the income and benefits earned from off-farm employment may compensate for lower farm returns, thus making the overall profitability of the operator's financial and human capital comparable to full-time operators with similar characteristics. Given the higher level of diversification, the welfare of part-time operators may even be higher than full-time operators. But the farm production intensity and effectiveness is likely to remain below that of full-time operators. Hence, the desirability of part-time operation as a risk management tool is found to depend highly on policy and social objectives.

Alternatively, diversification at the household level through the allocation of spousal labor off the farm provides benefits in mitigating the adverse effects of farm income risk on farm production and efficiency, and on operators' and households' welfare. It thus provides an efficient risk management alternative that is consistent with most rationales that can be invoked to justify farm policies.

Finally, the model also displays some shortcomings and limitations. One omission of the model is land ownership. Ownership remains the preferred method among operators to gain control over land. It also implies opportunities for capital gains which are often key in defining financial wealth of operators and in turn their borrowing capacity. Hence, it may be that to capture the full breath of financial risk and decisions facing operators, the choice between ownership and rental agreement should be included. Also, for simplicity the model assumes that shocks are purely transitory in nature. However, there may well be some degree of persistence in farm income shocks and the response to permanent and transitory shocks may differ. The buffer stock model literature suggests that, compare to temporary shocks, permanent shocks have a much larger impact on agents consumption and investment decisions (Haliassos and Michaelides, 2003). Thus, the introduction of degree of persistence in farm income shocks may have large impacts on the risk of bankruptcy and the optimal financial structure, and, as a result, it may imply in a much larger role for off-farm income as a risk management tool. If other risk management alternatives such as future and forward contracts, and on farm diversification were also introduced, it could also re-

veal some degree of complementarity between short-term risk management tools and off-farm employment.

Chapter 6

Conclusions

The increasing influence of nonfarm economic sectors and general economic growth on the welfare, structure and performance of the farm sector has long been recognized. In particular, the development and diversification of most rural economies created new opportunities for off-farm employment and played a key role in raising the average income of farm households, thus dissipating most of the policy concerns related to chronically depressed farm income. As a result, farm policies are now focusing on farm income risk and much of the policy debates center on the efficiency of subsidized crop and farm revenues insurance programs. While acknowledging the incompleteness of capital and risk markets, many economists argue that subsidized programs are inefficient because they tend to crowd out private initiatives, including off-farm income. Hence, the role of off-farm income as a private risk management tool has generated some interest and a number of empirical studies suggest the existence of a positive relationship between farm income risk and off-farm income.

While it is usually presumed that the use of off-farm income as a risk management tool is limited to smaller farms, this research suggests that off-farm diversification is a potent risk management tool for large and even very large crop farms. Based on current policy concerns and the growing importance of off-farm income as a component of farm households total income, this dissertation set out to formally examine the extent to which off-farm diversification can mitigate the adverse effect of farm income risk on resource allocation and welfare among commercial farm operators and households. The interactions between farm income stabilization policies and households' labor allocation decisions are analyzed using a dynamic optimization model calibrated on a sample of commercial grain farms and much of the effort has been directed towards defining a realistic model of the diversification premium and financial benefits provided by the steady flow of liquid income generated by off-farm employment.

The study provides a theoretical argument justifying the focus on the farm household as the relevant decision making unit, and presents some of the implications of doing so in assessing the impact of farm income risk. It is suggested that off-farm income can be advantageous not only in addressing distributional and equity issues but also the resource allocation and efficiency issues that are presumed to underlie current risk management policies. By adding to the list of private risk management tools available to farm households, off-farm diversification reduces the potential benefits of farm income insurance programs and strengthens the argument that the social cost of these programs is greater than the cost of relying only on incomplete private risk management tools.

By highlighting the potential of off-farm labor diversification in addressing farm income risk issues, the results also raise questions on the nature of interactions and the potential complementarity between farm policies and rural development efforts. Over the last decades most rural economies have grown and diversified away from agricultural commodity production, providing arguments to shift resources away from farm policies towards more broad-based rural development efforts. The complementarity between rural development and farm policies may be region specific, depending on the importance of commodity production and the diversity of the local economies in different rural areas. But, while it has been argued elsewhere that broader economic policies had a large influence in closing the income gap between farm and urban households, it may also be that policies other than conventional farm policies have a role to play in addressing farm income risk issues and, in some cases, may represent more sustainable and efficient policy alternatives.

Modeling off-farm diversification benefits

To explore the financial benefits of off-farm diversification a dynamic stochastic model was chosen based on theoretical and empirical considerations. In developing the model, the farm households' consumption decisions and production decisions are assumed to be non-separable due to some degree of incompleteness in the labor and capital markets, as supported by the empirical literature. The use of a household model where consumption is taken as the ultimate objective of the decision makers was thus justified by this non-separability of consumption and production.

Also, risk aversion is unlikely to be the sole cause of risk responses by farmers. In fact, the empirical literature indicated that the dynamic implications of labor allocation decisions, including labor mobility and the potential role of off-farm employment in providing liquidity and smoothing consumption, could be of importance. This suggested that a dynamic model including financial and labor mobility constraints may be more appropriate than a static expected utility model to explore the effects of off-farm employment on farm households' welfare and production decisions.

Consequently, the model presented in this dissertation integrates credit constraints and labor flexibility within a farm household life-cycle model. The model borrows from the buffer-stock saving models developed in the consumption and finance literature, and successfully endogenizes the trade-offs between farm business risk and financial risk. Such models have been used to explore the impact of labor income risk and credit constraints on consumption and investment choices. In this type of model, labor income acts as a risk free asset allowing for consumption smoothing, and inducing more aggressive investment in risky assets as well as a reduction in the demand for insurance.

While standard expected utility models focus solely on the diversification effect associated with off-farm employment, the proposed model also accounts for the liq-

uidity and the flexibility provided by human capital. Hence, the financial benefits of off-farm employment embedded in the model can be summarize in three parts: 1) the flexibility in human capital allocation providing a farm exit option in case of catastrophic risk, 2) the diversification of income, 3) the value of the liquidity provided by off-farm employment. All of these effects may alter operators' and households' welfare as well as their investment and production decisions. While some attempts at valuing the diversification benefits of off-farm employment are provided in the literature, none accounted for labor and capital market imperfections, thus leaving income liquidity and labor flexibility aspects largely unexplored.

Empirical findings - diversification premium

The existence and magnitude of the diversification premium was investigated empirically in Chapter 4 by estimating a distance function that includes farm and off-farm outputs. A Bayesian estimation approach was followed in order to impose theoretical regularity conditions during the estimation. The results show that failing to satisfy those theoretical constraints yields counterintuitive results implying a negative diversification premium. However, when the theoretical constraints are imposed the estimates suggest the presence of an off-farm diversification premium. These results illustrate the impact of theoretical constraints on estimates and reiterate the importance of testing and, if necessary, imposing theoretical consistency.

The off-farm diversification premium implied by theoretically consistent models is relatively small for commercial Kentucky grain farms operating less than 1500 acres but increases significantly on larger farms. This tend to confirm the conventional wisdom that, as a risk management tool, off-farm income is somewhat limited by the size of farm operations. However, farms of 1500 acres were well above the U.S. national average farm size over the period 1998-2010, and it represents the average size for Kentucky commercial grain farms. Overall, this suggests that while diversification of operators' labor may not be accessible to the largest of commercial farms, it does remain accessible at a low premium even for farms much larger than the small hobby or limited resource farms, making it of potential relevance for farm stabilization policies.

In addition, the limitations of the data must be kept in mind in interpreting these estimates. The sample used in this dissertation only included farms with a single operator and the estimated premium is based on the diversification of the labor from the main operator. The premium would likely be lower when considering diversification of spousal labor or for farms with multiple operators. Hence, the estimated premium may be seen as an upper bound estimate, in which case the range of farms for which off-farm diversification is a potent risk management strategy would expand to cover most commercial farms.

In the context of an evolving farm structure and technology, the diversification premium may change over time. While increases in factors like the managerial capac-

ity of operators and the access to labor market may reduce the premium, the evolution of the diversification premium will likely hinge in large part on future technological developments. If new technologies are labor-saving, the premium may actually be reduced, depending on whether significant economies of scale are also induced by these technological changes. The empirical evidence from the last 30 years suggest that while farm size has kept increasing, the range over which economies of scale prevail in the crop sector may have increased in absolute terms but remains limited to small and medium sized farms. One can only speculate about the direction of future technological changes, but if the past is any indication we may not see large increases in the off-farm diversification premium among commercial grain farmers.

Implications for risk management policies

The last part of the dissertation is based on a numerical analysis of the calibrated dynamic model and puts in relation the diversification premium previously estimated with the financial benefits of diversification embedded in the dynamic model. The results suggest that part-time farming maybe of greater interest with respect to distributional and welfare policy objectives. First, the presence of economies of scale in combination with imperfect capital and labor markets generate a non-monotonic risk response among full-time operators. There is a critical level of equity beyond which the risk response decreases as liquidity and credit constraints are relaxed. But, if equity falls below that critical level of equity, the risk response becomes constrained on the one hand by the need to achieve economies of scale while facing binding credit constraints, and on the other hand by the presence of transaction costs if he/she chooses to diversify some or all of its labor off the farm. This implies that as the financial position of operators becomes more precarious, insurance becomes of little use for them and has little to no effect on their behavior, while access to off-farm employment and part-time operation becomes more beneficial.

Second, a potential reduction in farm revenue insurance coverage would have a much larger impact on full-time operators' welfare and farm production decisions compared to those working off the farm. Such reduction would also lead to a significant drop in production and profitability of full-time operators, some of which would find it optimal to switch to part-time operation. Higher labor mobility between farm and non-farm sector would facilitate the transition to part-time operation, would increase the number of operators adopting this strategy, and would also contribute in limiting the welfare cost of reducing insurance coverage. However, the diversification premium does impose a cost in term of farm production and profitability. The calibrated model indicates that farm production and profitability of part-time operators remain below that of full-time farmers despite the fact that risk represents a smaller cost to them. As a result, to the extent that farm policy is intended to reduce the adverse effect of farm income risk on farm production and profitability, part-time operation would not be consistent with such policy objectives, but it would be consistent with other welfare and distributional policy objectives.

At the same time, national data and anecdotal evidence suggest that spousal off-farm income has become a common occurrence among farms of all sizes. And there is some historical evidence of it being used to address farm income risk. The results from the calibrated model show that the household's welfare and farm production decisions in the presence of a spouse working off the farm and with farm revenue insurance with 40% coverage are comparable to those with 80% coverage and no spousal income. It thus supports the idea that spousal income could reduce significantly the adverse impact of farm income risk on the welfare and production decisions of households operating large commercial farms. It suggests that subsidized farm revenue insurance may crowd out the use of household labor diversification, a private risk management strategy that appears perfectly consistent with welfare and efficiency objectives presumed to underlie farm policies.

Also, off-farm income may be advantageous in helping farm households to cope with permanent or persistent farm income shocks. Current farm revenue insurance programs such as ACRE and the Canadian Agri-Stability programs are based on multi-year averages, thus offering some protection even when shocks are persistent. On the other hand, most private risk management tools such as futures and forward contracts provide insurance only against short-term intra-year shocks. The capacity of off-farm employment in addressing long term and persistent shocks may thus be a useful complement to other private risk management tools. The analysis provided in this dissertation is limited to temporary shocks, but it may be of interest to extend it to explore the impact of off-farm diversification when farm income shocks are persistent and other risk management tools such as futures contracts are introduced in the model.

Another interesting aspect of off-farm diversification is its natural targeting characteristics. Over time, numerous attempts have been made to improve the targeting of commodity programs, mainly by imposing payment limits. This indicates a desire to improve the distributional impact of those policies. For off-farm income, the numerical analysis presented in this dissertation shows that the financial benefits of diversification are more important for younger and low equity operators facing more substantial financial and liquidity risk. This is driven by the natural balance between the discounted value of future labor earnings, and the accumulated equity. For young operators, the higher value of labor earning potential provides a hedge against future farm income shocks, while operators closer to retirement will tend to face lower financial risk due to accumulated equity.

Limitations and potential extensions

From a methodological point of view, this dissertation extends the conventional risk analysis models by integrating intertemporal behavior into the analysis. While our understanding of risk responses and our capacity to identify the underlying cause

of risk responses remain limited, the empirical literature strongly suggests that intertemporal trade-offs and credit constraints play a significant role in defining farm household allocation decisions. And understanding these decisions is crucial in improving our capacity to formulate policy recommendations. Thus, by modeling various dynamic aspects of the decision making of farm households, the objective is to provide a better understanding of the complex allocation problems that farmers face, to improve our ability to understand an increasingly complex farm structure, and to formulate stronger policy recommendations.

For risk analysis purposes, the ideal analytical framework should encompass all relevant sources of risk, and all risk management tools available to the decision makers. By adopting a dynamic framework, the approach presented in this dissertation broadens the scope of risk management instruments by including some degree of labor mobility and the capacity of households to save and smooth consumption over time. Hence, the buffer stock dynamic model used in this dissertation provides a more thorough and realistic characterization of the level of risk faced by farm operators by focusing on household consumption and by endogenizing financial risk decisions in the framework. New hypotheses could be derive from such framework and help us understand the financial implications of farm household decisions. For example, the model revealed that market imperfections could imply a non-monotonic risk response. Whether the non-linear relationship implied by this dynamic model can contribute to explain the historically low participation of farmer in insurance markets is unknown, but it might represent an interesting hypothesis to test empirically.

Yet, while the modeling approach presented here may represent a useful analytical tool, the calibration of the model could be improved in a number of ways. First of all, household risk and intertemporal preferences should ideally be identified independently and empirically. From a modeling point of view, alternatives exist to separate risk and intertemporal preferences within the context of a buffer stock model (e.g. Epstein-Zin utility function). However, identification of preference parameters would require behavioral data in addition to production and consumption data. At the same time, even if only production data are available they could be used to estimate the risk implications of changes in farm input mix, and thus add farm input choices as another potential risk management tool. This could be done, for example, by estimating a state-contingent distance function, although such estimation still faces a number of challenges.

And, as was already mentioned, it would be of interest to investigate the impact of persistence in the stochastic process followed by farm income shocks. The buffer stock model literature suggests that, compare to temporary socks, permanent shocks have a much larger impact on agents consumption and investment decisions .Thus, the introduction of some degree of persistence in farm income shocks may have large impacts on the optimal financial structure, and it may imply a more important role for off-farm income as a risk management tool. If other risk management alternatives such as future and forward contracts were also introduced, this type of model exten-

sion could be used to explore the degree of complementarity between short-term risk management tools and off-farm employment.

Another key determinant of financial risk is farmland investment. Ownership is still the preferred method among operators to gain control over land which remains the primary asset of most farm households. Returns on land assets are largely determined by capital gains which are key in defining financial wealth of operators and in turn their borrowing capacity. Hence, it may be that to capture the full breath of financial risks and decisions that farm operators are facing, the choice between ownership and rental agreement should be included. This would also provide the opportunity to consider equity financing as part of the array of private risk management tools.

In general, risk analysis remains fraught with difficulties, most importantly understanding and identifying sources of risk responses is still a challenging task. However, the policy focus on risk management issues demands that we keep improving our capacity to derive meaningful policy recommendations. It is hoped that by providing a more complete representation of the microeconomic environment of farm households, including the market imperfections that are presumed to underly policy rationales, the type of model presented in this dissertation can help in developing further understanding of farm households choices and policy responses.

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Appendix A: Profit Maximization and the Input Distance Function

The input distance can be related to a profit maximizing problem of the type:

$$\max_{y,x} p \cdot y - w \cdot x \quad \text{s.t.} \quad D(x, y) \geq 1$$

Following Simon and Blume (1994, p.467), the second order condition for such a problem requires checking the sign of the leading principal minors of the bordered Hessian¹:

$$BH = \begin{bmatrix} \mathbf{O} & -\mathbf{D}_y & -\mathbf{D}_x \\ -\mathbf{D}'_y & \lambda_L \mathbf{D}_{yy} & \lambda_L \mathbf{D}'_{yx} \\ -\mathbf{D}'_x & \lambda_L \mathbf{D}_{yx} & \lambda_L \mathbf{D}_{xx} \end{bmatrix}$$

In case of single output and input, the condition can be expressed as:

$$\begin{aligned} \det(\text{BH}) &= \lambda_L D_x [-D_x D_{y,y} + D_y D_{x,y}] - \lambda_L D_y [-D_x D_{x,y} + D_y D_{x,x}] \\ &= \lambda \left(-D_x^2 D_{x,y} + 2D_x D_y D_{x,y} - D_y^2 D_{x,x} \right) \end{aligned}$$

Where $D_x = \frac{sD}{x}$ and $D_y = \frac{rD}{y}$ with s and r being defined by equation 4.3 and 4.4. Other expressions are defined as follows:

$$\begin{aligned} D_{x,x} &= \frac{(\beta_{x,x} + s^2 - s) \cdot D}{x^2} \\ D_{x,y} &= \frac{(\gamma_{x,y} + s \cdot r) \cdot D}{x \cdot y} \\ D_{y,y} &= \frac{(\alpha_{y,y} + r^2 - r) \cdot D}{y^2} \end{aligned}$$

Given homogeneity in input of the input distance we know that $s = 1$. And the determinant of the bordered Hessian can be expressed as:

$$\det(\text{BH}) = \frac{\lambda D^3}{x^2 y^2} \left(-\alpha_{y,y} + r + r^2 + 2r\gamma_{x,y} - r^2\beta_{x,x} \right)$$

In this simple case, the condition would require that the determinant is positive. Under constant return to scale, $r = -1$ and satisfying this condition would require that $(-\alpha_{y,y} - 2\gamma_{x,y} - \beta_{x,x}) > 0$. But the condition can be met even if there is increasing returns to scale, i.e. $r > -1$. It would simply require that some of the second order coefficients, β, γ, α , be negative and their magnitude to be large enough to offset

¹The largest principal leading minor should be of the same sign as $(-1)^{n-k}$ where n is the size of BH and k is the number of constraints (1 in this case)

the effect of increasing return to scale. In fact, this condition can be verified to be equivalent to the slope of the marginal product of input x while keeping the distance (D) constant:

$$\begin{aligned}\frac{\partial y}{\partial x} &= \frac{-s \cdot y}{r \cdot x} \\ \frac{\partial^2 y}{\partial x \partial x} &= \frac{y}{r^3 x^2} \left(-\alpha_{y,y} + r + r^2 + 2r\gamma_{x,y} - r^2\beta_{x,x} \right)\end{aligned}$$

Under standard production economics assumptions, the marginal product becomes negative at some point during stage I of production, while economies of scale are exhausted at some point in stage II of production. For an illustration of the relationships between marginal product, economies of scale, and stages of production see Doll and Orazem (1984, p.48). As a result, imposing the second order condition of a profit maximization problem on the estimation of an input distance function does not preclude the presence and estimation of economies of scale. It does, however, impose the assumption that operators are facing decreasing marginal return to farm inputs.

Appendix B: Output Distance Function

The *output* distance function can be expressed as:

$$D_{it}^o(\mathbf{x}_{it}, \mathbf{y}_{it}, \mathbf{z}_{it}) = \inf_{\theta} \left\{ \theta > 0 : \left(\mathbf{x}_{it}, \frac{\mathbf{y}_{it}}{\theta} \right) \in T(\mathbf{z}_{it}) \right\} \leq 1$$

where $\mathbf{x}_{it}, \mathbf{y}_{it}$ are the set of inputs and outputs, respectively, for farm household i in year t . Where T is a technology set defining the possible combination of outputs \mathbf{y}_{it} , inputs \mathbf{x}_{it} , given the set of socioeconomic, demographic, and agro-climatic characteristics \mathbf{z}_{it} . Hence, an output distance functions estimates by how much the output set could be expanded while maintaining the same input set.

Translog output distance function

The translog functional output distance function takes the same form as the input distance function in equation 4.2:

$$\begin{aligned} \ln D_{it}^o = & \beta_0 + \sum_j^J \beta_j \ln x_{j,it} + \sum_n^N \alpha_n \ln y_{n,it} + 0.5 \cdot \sum_j^J \sum_k^K \beta_{jk} \ln x_{j,it} \ln x_{k,it} \\ & + 0.5 \cdot \sum_n^N \sum_j^J \gamma_{nj} \ln x_{j,it} \ln y_{n,it} + 0.5 \cdot \sum_n^N \sum_m^M \alpha_{nm} \ln y_{n,it} \ln y_{m,it} \\ & \sum_l^L \phi_l \ln z_{l,it} + v_it \end{aligned}$$

As a result the elasticity measures from both specifications have the same functional form. Following equation 4.5, homogeneity in output implies that $\sum r_n = 1$ so that $\eta^{scale} = (\sum s_i)$.

Regularity Conditions

Production theory suggest that the distance function should satisfy a number of regularity conditions (Fare and Primont, 1995; Coelli et al., 2005). An output distance function should be:

1. homogeneous of degree one in output;
2. monotonically increasing in output;
3. monotonically decreasing in inputs;
4. quasi-convex in inputs;
5. convex in outputs.

Estimation

Since distance D is unknown, for estimation we can rearrange the output distance function D^o as follow

$$\begin{aligned}
-\ln F_{it} &= \beta_0 + \sum_j^J \beta_j \ln x_{j,it} + \frac{1}{2} \sum_j^J \sum_k^K \beta_{jk} \ln x_{j,it} \ln x_{k,it} + \sum_l^L \phi_l \ln z_{l,it} \\
&\quad + \lambda_{it} \left(\beta_y + \sum_j^J \tilde{\beta}_j \ln x_{j,it} + \alpha_y \ln y_{it}^* \right. \\
&\quad \left. + \sum_j^J \gamma_{yj} \ln x_{j,it} \ln y_{it}^* + \frac{\alpha_{yy}}{2} (\ln y_{it}^*)^2 \right) + v_{it} - \ln D_i^o \\
\ln F_{it} &= -\beta \mathbf{X}_{it} - \gamma \mathbf{X} \mathbf{Y}_{it} - \alpha \mathbf{Y}_{it} - \phi \mathbf{Z}_{it} - v_{it} + u_i
\end{aligned}$$

where * indicates outputs that are normalized by the numeraire output F . This transformation is possible given the homogeneity of the distance function in output, which implies that $\theta D(y, x) = D(\theta y, x)$. Equation 6.1 is obtained by letting $\theta = \frac{1}{F}$ and transferring the efficiency term to the right hand side. The last line represents a more compact formulation where v_{it} is a standard error term while $\ln D_i = -u_i \geq 0$ provides a measure of the distance and technical efficiency, $D_o = TE_i = e^{-u_i}$.

The model is estimated as a random effect model following the Bayesian approach developed by O'Donnell and Coelli (2005) and presented in Chapter 4. In this framework, the random variable u_i is assumed to follow an exponential distribution with parameter λ . The standard error term v_i is assumed to follow a normal distribution centered at zero and with variance h^{-1} .

Estimation results

The coefficient estimates of the output distance function for the unconstrained and constrained (imposing all regularity conditions) models are presented in Table B.1. As mentioned in Chapter 4, the main disadvantage of the output distance function are the constraints it imposes on the relationship between off-farm output and other variables. In particular, homogeneity in output adds a number of restrictions on the coefficients defining the relation between inputs and outputs (γ), and the relation among outputs ($\alpha_{i,j}$). With only two outputs, imposing convexity requires that $-\alpha_{y,f} = \alpha_{f,f} = \alpha_{y,y} \geq 0.25$ which directly implies some degree of economies of scope for the entire range of output.

Figure B.1 and Figure B.2 show the estimated elasticity of scale for the constrained and unconstrained models. When compare to Figure 4.5, it is clear that the unconstrained input distance yields much higher estimates of economies of scale compared to the unconstrained output model. The regularity constraints of either

the input or output distance function do not appear to affect this result. Only when conditions related to profit maximization are imposed on the input distance (model 3) does the pattern of economies of scale becomes closer to the ones estimated by the output distance function.

This result is similar to what Paul et al. (2004) obtained and would suggest that either the orientation of the distance function or some bias due to endogenous variables would lead to an overestimation of economies of scale by the input distance function or an underestimation by the output distance function. Nevertheless, given the lack of flexibility inherent to the output orientation, at least in the 2 outputs case, it appears more advantageous to use an input orientation even if profit maximization conditions must be imposed to obtain a function that is well-behaved and suitable to calibrate the simulation model.

Table B.1: Parameter Estimates

Parameters	Unconstrained	Constrained	
β_0	-0.001	-0.110	*
β_{dy1}	0.068	-0.030	
α_Y	0.161	0.270	**
α_F^\dagger	0.839	0.730	**
$\tilde{\alpha}_F$	-	-	
β_H	-0.0656	-0.030	**
β_{VC}	-0.545	-0.592	**
β_K	-0.145	-0.116	**
$\tilde{\beta}_H$	-0.057	-0.023	**
$\tilde{\beta}_{VC}$	0.259	0.128	*
$\tilde{\beta}_K$	-0.057	-0.031	
$\beta_{H,H}$	-0.018	-0.002	**
$\beta_{H,VC}$	-0.040	-0.008	**
$\beta_{H,K}$	0.002	-0.003	
$\gamma_{H,Y}$	0.022	-0.005	
$\gamma_{H,F}^\dagger$	-0.022	0.005	
$\beta_{VC,VC}$	0.128	-0.007	*
$\beta_{VC,K}$	-0.004	-0.038	
$\gamma_{VC,Y}$	-0.196	0.140	**
$\gamma_{VC,F}^\dagger$	-0.196	-0.140	**
$\beta_{K,K}$	-0.099	-0.015	**
$\gamma_{K,Y}$	0.067	-0.066	**
$\gamma_{K,F}^\dagger$	-0.067	0.066	**
$\alpha_{Y,Y}$	0.064	0.255	**
$\alpha_{Y,F}^\dagger$	-0.064	-0.255	**
$\alpha_{F,F}^\dagger$	0.064	0.255	**
β_{LD}	-0.261	-0.278	**
$\tilde{\beta}_{LD}$	-0.066	0.041	
$\beta_{H,LD}$	0.039	0.003	**
$\beta_{VC,LD}$	-0.155	0.026	*
$\beta_{K,LD}$	0.039	0.013	
$\beta_{LD,LD}$	0.280	0.108	**
$\gamma_{LD,Y}$	0.288	0.156	**
$\gamma_{LD,F}^\dagger$	-0.288	-0.156	**
ϕ_{age}	0.004	0.005	**
$\phi_{famsize}$	-0.008	0.001	
$\phi_{curr.ratio}$	-0.006	-0.005	**
ϕ_{ROADA}	-0.027	-0.028	**
ϕ_{year}	-0.032	-0.033	**

[†] Indicate the parameters derived from the homogeneity property of the distance function.

** Indicate that $\Pr(\beta < 0 | y) < 0.05$ for positive estimates and $\Pr(\beta > 0 | y) < 0.05$ for negative estimates.

* Indicate that $\Pr(\beta < 0 | y) < 0.1$ for positive estimates and $\Pr(\beta > 0 | y) < 0.1$ for negative estimates.

Figure B.1: Economies of Scale

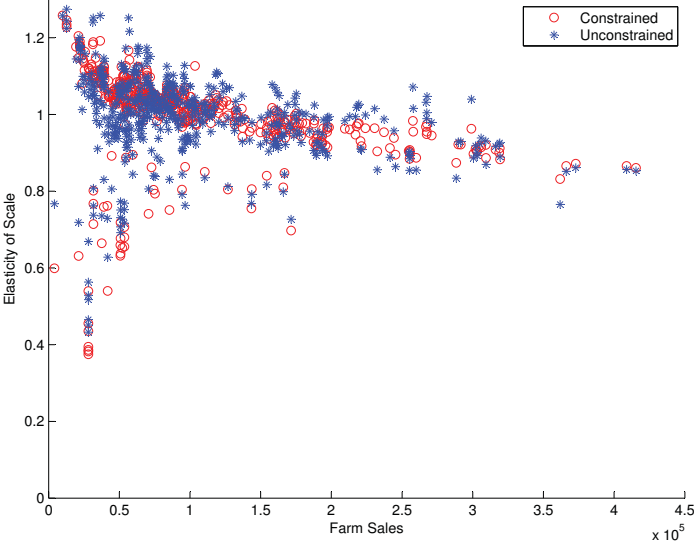
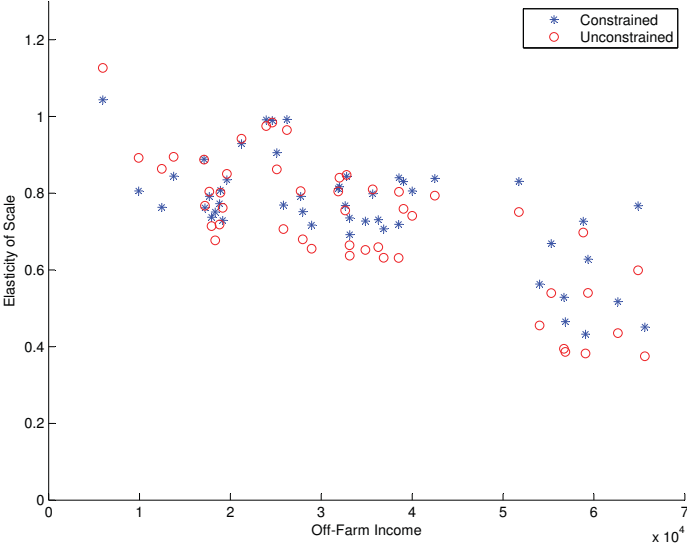


Figure B.2: Economies of Scale



Appendix C: Approximation of Risk Premium

If one takes a second order expansion of the covariance factor in equation 3.17, then we can decompose this covariance into 2 factors.

$$r_b(W, \mathbf{A}) = E[e^\epsilon \cdot F'] - 1 + \frac{\text{Cov}(e^\epsilon \cdot F', V'_W(W_{t+1}, R_{t+1}))}{E[V']}$$

Let $\epsilon \sim N(0, \sigma)$, $\pi = E[e^\epsilon]$ and V is a value function with argument $W = g(A) + Fe^\epsilon$ then taking a second order Taylor expansion of V' :

$$\begin{aligned} V'|_{e^\epsilon} &\approx V'|_0 + \epsilon V''|_0 F + \frac{\epsilon^2}{2} V'''|_0 F \\ E[V'] &\approx V'|_0 + \frac{\sigma^2}{2} V'''|_0 F \end{aligned}$$

The last term on the LHS is known as the precautionary saving motive (Romer, 2001). The distributional assumption on ϵ also implies :

$$\begin{aligned} eV' &\approx \epsilon V'|_0 + \sigma^2 V''|_0 F + \frac{\epsilon^3}{2} V'''|_0 F \\ E[eV'] &\approx \sigma^2 V''|_0 F \end{aligned}$$

Using these approximations and $e^\epsilon - E[e^\epsilon] \approx \epsilon$, we get

$$\begin{aligned} \text{Cov}(\epsilon \cdot F', V'_W(W_{t+1}, R_{t+1})) &= F' E[(e^\epsilon - E[e^\epsilon]) (V' - E[V'])] \\ &\approx F' E[(\epsilon) (V' - E[V'])] \\ &\approx F' E[(\epsilon) V'] \\ &\approx F' \sigma^2 V''|_0 F \end{aligned}$$

and

$$\begin{aligned} \frac{\text{Cov}(Pg_t \cdot F'_{VC}, V'_W(W_{t+1}, R_{t+1}))}{E[V']} &\approx F' \frac{\sigma^2 V''|_0 F}{V'|_0 + \frac{\sigma^2}{2} V'''|_0 F} \\ &\approx F' \frac{\sigma^2 \phi F}{\lambda(\sigma^2)} \end{aligned}$$

where ϕ is defined by the second derivative of the value function and is thus akin to a coefficient of risk aversion while $\lambda(\sigma^2)$ encapsulate the precautionary saving as a

function of income variability. The coefficient of risk aversion is usually presumed to be negative, implying that the marginal value of additional equity is increasing at a decreasing rate. And precautionary saving depends on the third derivative which is presumed to be negative in most cases, implying that the marginal value falls more slowly as equity increases.

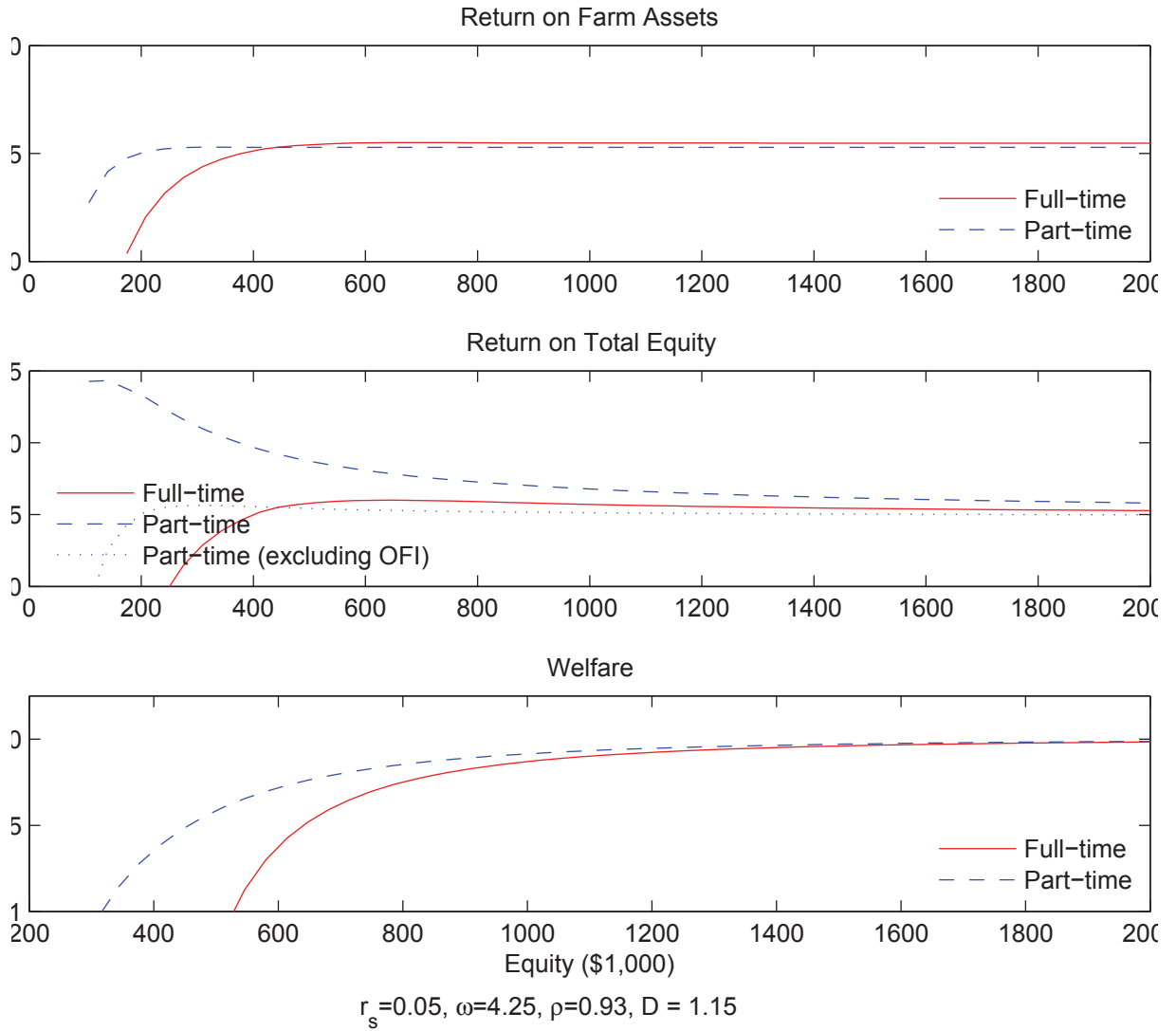
As a result, the premium on farm inputs represents a combination of precautionary saving motive and risk aversion. A larger risk aversion coefficient will lead to higher premiums while increasing the precautionary saving motive will lead to higher incentives to invest and thus lower premiums.

$$\begin{aligned}
 r_b(W, \mathbf{A}) &\approx \text{E} \left[e^\epsilon \cdot F' \right] - 1 + F' \frac{\sigma^2 \phi F}{\lambda(\sigma^2)} \\
 &\approx F' \left(1 + \frac{\sigma^2}{2} + \frac{\sigma^2 \phi F}{\lambda(\sigma^2)} \right) - 1
 \end{aligned}$$

The direct effect of credit constraints is to make r_b a function of equity W and of positions in different assets defined by action variables \mathbf{A} . At lower equity levels the optimal marginal product will be higher as the interest rate on debt increases. However, credit constraints and other non-linearities in the model, including economies of scale and adjustment costs, will also affect the curvature of the value function thus affecting the covariance term in the last equation.

Appendix D: Numerical Analysis: Further Results

Profitability at lower farm efficiency level



Vita

Simon Jetté-Nantel

Education

- M.Sc.** Agricultural Economics (Dean's Honour List - GPA 3.88/4.0) 2006
McGill University, Montreal, Qc, Canada
Title: "*Impact of a carbon market on afforestation incentives: A real option approach*"
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Publications

- Y. Liu, W. Hu, and S. Jetté-Nantel. (2013) "The Influence of Labor Price Change on Agricultural Machinery Usage in Chinese Agriculture". Accepted for publication in *Canadian Journal of Agricultural Economics*.
- Jetté-Nantel, S., D. Freshwater, M. Beaulieu, and A. Katchova.(2011) "Farm Income Variability and Off-Farm Diversification in Canadian Agriculture". Agriculture and Rural Working Paper Series, Catalogue no. 21-601-M No. 93, Statistics Canada, Ontario, Canada.
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- S. Agrawala, F. Crick, S. Jetté-Nantel and A. Tepes. (2008), "Empirical Estimates of Adaptation Costs and Benefits: A Critical Assessment". In "Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments", (S. Agrawala and S. Fankhauser ed.), ISBN 978-92-64-04603-0, OECD, Paris, France.
- Contributing Author to Chapter 17, IPCC Working Group II: "Assessment of Adaptation Practices, Options, Constraints and Capacity". In: Impacts, Adaptation and Vulnerability [M. Parry et al. eds.]. Intergovernmental Panel on Climate Change Fourth Assessment Report (April 2007).
- S. Jetté-Nantel and S. Agrawala. (2007), "Climate change adaptation and natural hazards management". In "Climate Change in the European Alps: Adapting Winter Tourism and Natural Hazards Management", (S. Agrawala ed.), ISBN - 978-92-64-03169-2, OECD, Paris, France.
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Working Papers

- S. Jetté-Nantel, Y. Liu, and W. Hu. "Corn and Wheat production technology in Chinese Agriculture."
- S. Jetté-Nantel. "The impact of off-farm income on farm decisions and farm household welfare: A farm life-cycle model approach."
- S. Jetté-Nantel. "Estimation of interactions between farm and off-farm activities among Western Kentucky grain farms."
- D. Freshwater and S. Jetté-Nantel. "Risk Management and The Role of Off-Farm Income."
-

Presentations

- D. Freshwater and Jetté-Nantel, S. "Risk Management from a Household Perspective" Presentation given at the OECD Risk Management Workshop, Paris, France, November 22-23, 2010
- Jetté-Nantel, S., D. Freshwater, M. Beaulieu, and A. Katchova. "Farm Income Instability and Off-Farm Diversification in Canadian Agriculture" Presentation given at the Southern Agricultural Economics Association Annual Meeting, Orlando, FL, February 6-9, 2010
- Jetté-Nantel, S., D. Freshwater, M. Beaulieu, and A. Katchova. "Farm Income Instability and Off-Farm Diversification in Canadian Agriculture" Presentation given at Statistics Canada 2009 Socio-Economic Conference, Ottawa, Canada, May 4, 2009.
- D. Freshwater and S. Jetté-Nantel. "Agricultural Risk Management Through Household Portfolio Choice". Presentation given at the 2008 NARAE Agricultural Policy Workshop, Quebec City, Canada, June 29, 2008.
- S. Agrawala and S. Jetté-Nantel. "Adaptation to Climate Change in the European Alps: Focus on Winter Tourism and Natural Hazards Management". Presentation given at the 11th Meeting of the Working Group on Global and Structural Policies, Organisation for Economic Cooperation and Development, Paris, France, November 20-21, 2006.
- Jetté-Nantel, S. "Climate Change and Natural Hazards in the Alpine Arc: a cross country analysis". Presentation given at the OECD-Wengen 2006 Workshop, Wengen, Switzerland, October 4-6, 2006.
- Jetté-Nantel, S. "Option Modeling and Carbon Markets". Presentation given at CAES Workshop/AIEA2 International Conference, Laval University, Quebec, August 23-24, 2004
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Work Experience

Agriculture and Agri-food Canada Research Analyst Ottawa, Ontario, Canada	Summer 2009
Statistics Canada Research Analyst Ottawa, Ontario, Canada	Spring 2009
McGill University Lecturer Ste-Anne-De-Bellevue, Qc, Canada	Spring 2007
Organisation for Economic Cooperation and Development Consultant Paris, France	2006
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Teaching Experience

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Computer Skills

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STATA	Excel	Access

Service

- President - Graduate Student Organization, UK Ag. Econ Department 2009-2010.
 - Co-organizer of the seminar series, UK Ag. Econ Department 2009-2010.
 - President - University of Kentucky Badminton Club 2010-2011.
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