Acreage Response to Government Support Programs: Are Supposedly Decoupled Payments Really Decoupled?

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ABSTRACT

The primary objective of this dissertation is to investigate whether Canadian whole farm programs with both income-supporting and income-stabilizing attributes, which are considered as decoupled based on the WTO criterion, are actually decoupled from production. The dissertation began with the review of the existing theoretical and empirical literature on the impact of programs designed to be decoupled payments on acreage response including studies related to the wealth and insurance effects. The review revealed that previous studies lack a detailed theoretical model of how acreage decisions will be affected by stabilizing the farm profit (insurance effect) as well as the higher expected profit (wealth effect). Given the nature of Canadian whole farm programs which attempt to smooth income, to examine the whole farm programs, a model is needed to capture the insurance effect arising from these programs as well as the wealth effect.

To address this gap, the theoretical framework developed by Chavas and Holt (1990) was extended, in this dissertation, to incorporate the insurance effect into the farmers' acreage decisions under uncertainty. In particular, by developing theoretical restrictions, which consider the relationship between income stabilization compensated and uncompensated acreage decision functions, the insurance effect emphasized in the literature was explicitly derived within the theoretical model. The acreage allocated to each crop was derived as a function of expected crop profits, elements of the variance-covariance matrix of crop profits, expected total wealth (initial wealth plus market profit), and variance of total wealth. The government payments were incorporated into the model through truncation of the probability distribution of profits. Specifically, the whole-farm programs truncated the total (farm) profit distribution which affected the expected total wealth and variance of total wealth.

The theoretical model was then used to develop an empirical model. The econometric model was applied to acreage data in the Canadian Prairies from 1970 to 2006 in order to statistically test if the whole farm programs were really decoupled. The results revealed that coefficients of expected total wealth (wealth effect) and variance of total wealth (insurance effect) were statistically significant in the whole system, which implied the whole-farm programs were production and therefore trade distorting and were not actually decoupled, even if they satisfied the WTO criteria. The statistically significant coefficients for expected total wealth and variance of total wealth variables were then used to simulate the impact of recent whole-farm programs—the Western Grain Stabilization Act (WGSA), the Net Income Stabilization Account (NISA) and the Canadian Agricultural Income Stabilization (CAIS)—on crop choices.

The results suggested that the WGSA, NISA and CAIS programs have increased the acreage allocated to spring wheat and peas (through both wealth and insurance effects, although the insurance effect appears to dominate) while they have decreased the acreage for barley (through the wealth effect), canola and hay (through the insurance effect) in the prairie provinces. In general, the size of the wealth effect was quite small, while the insurance effect was always significant. Specifically, the acreage allocated to wheat increased by 7.79 percent on average across Prairies while canola acreage decreased by 8.86 percent under the CAIS. Thus, the empirical results revealed that for Canadian whole-farm programs the impact of the effects related to risk is important. Particularly, the results showed the inherent difficulty in divorcing the stabilization effect received by Canadian whole-farm programs from farmers' production decisions.

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List of Acronyms

AIDA	Agricultural Income Disaster Assistance
AMTA	Agricultural Market Transition Act
ASA	Agricultural Stabilization Act
CAIS	Canadian Agricultural Income Stabilization
CAP	Common Agricultural Policy
CCPs	counter cyclical payments
CFIP	Canadian Farm Income Program
GATT	General Agreement on Tariffs and Trade
GRIP	Gross Revenue Insurance Program
LDPs	Loan Deficiency Payment Program
MLA	Market Loss Assistance
MTR	Mid-Term Review
NISA	Net Income Stabilization Account
PFC	Production Flexibility Contract
SFP	Single Farm Payments
URAA	Uruguay Round Agreement on Agriculture
WGSA	Western Grain Stabilization Act
WTO	World Trade Organization

Chapter 1

Introduction

1.1 Problem Statement

In the Uruguay Round of the General Agreement on Tariffs and Trade (GATT), the distortionary effects of domestic farm programs figured high on the negotiating agenda. Along with the export subsidies and market access, domestic farm policies were targeted for reductions in support. Under the Uruguay Round Agreement on Agriculture (URAA), domestic support is classified into three categories or boxes according to their supposed impact on international trade. According to URAA conventions, the Amber-Box contains the most distorting subsidies, and, hence, limits to their use have been agreed. Blue-Box payments also cause some distortion but are required to be production limiting. The Green-Box contains subsidies that are classified as being minimally trade distorting. The subsidies in the Blue- and Green-Boxes are excluded from all World Trade Organization (WTO) disciplines and are expected to have no, or at most minimal, trade-distorting effects on production. Decoupled support policies which are defined as payments that are financed by taxpayers and are not related to current production, factor use, or prices, and for which eligibility criteria are defined by a fixed, historical base period, are categorized as Green-Box payments. Since they are exempt from WTO disciplines, payments considered to be decoupled have been providing a growing and important share of the total support to agriculture provided by governments, especially in industrialized countries.

The extent to which exempted policies really are production and trade neutral has, however, recently come under increasing scrutiny. It is hypothesized that there are various mechanisms by which decoupled payments may affect production decisions. The literature addresses six major channels through which decoupled payments could affect production.

They could ease credit constraints faced by farmers (when capital market are imperfect); they could affect the labour allocation decisions of farm households (when labour market are imperfect); they could alter land values, rents and land prices or influence the entry and exit decisions of farmers; they could influence farmers decisions through expectations about future payments; and they may affect the risk faced by farmers. In the latter case, Hennessy (1998) developed a theoretical framework for the analysis of agricultural income support policies under uncertainty. He showed that for decoupled payments which tend to increase expected profit as well as to contract the variability of profit, decreasing absolute risk aversion is sufficient to ensure an increase in production. He introduced two effects of decoupled payments that would not arise in a certain world: the wealth effect and the insurance effect. The former means that the higher average income arising from the support policy may affect producer decisions. The latter refers to the income-stabilizing attribute that may affect optimizing decision.

In Canada, over the past 50 years, governments have redistributed considerable amounts of money to the grain sector which have taken different forms due to the combined effects of government budget constraints, international trade negotiations, and economic and social objectives and pressures. The result has been a move from commodity specific and price based programs towards programs that are intended to stabilize farm gross margin or net income. Figure 1.1 shows the total receipts from direct payments in Manitoba, Saskatchewan and Alberta from 1971 to 2006. As can be seen, direct government payments to the Canadian agricultural sector in the Prairie Provinces have significantly increased from \$10,352,000 to \$626,087,000 in Manitoba, from \$9,912,000 to \$1,267,192,000 in Saskatchewan from \$15,782,000 to \$945,115,000 in Alberta over the period 1971-2006. With the increasing

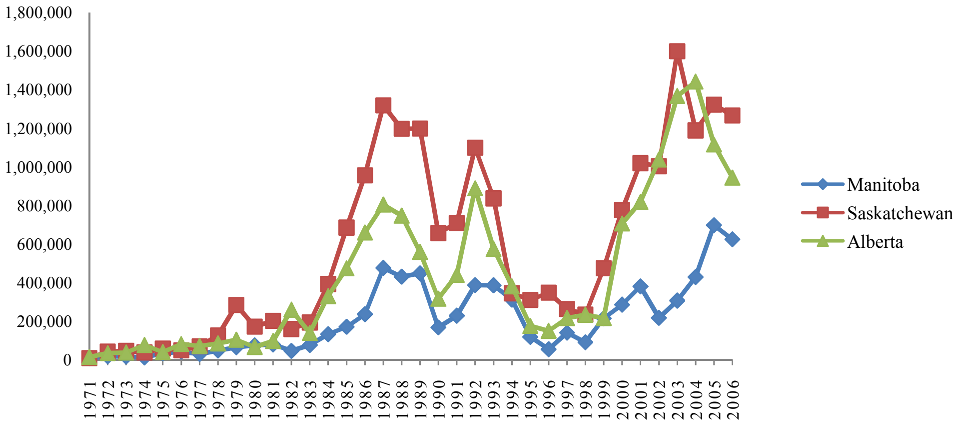

Figure 1.1: Total Receipts from Direct Payments (,000 dollars)

use of government payments for farm income protection, an important question, then, concerns their economic implications. Examining this issue is important. Because finding that payments have large effects on production would bring into question the underlying rationale for the WTO non-actionable (Green Box category) supports in addition to the environmental consequences arising from increased crop production. More importantly, if the payments have the effect of increasing crop production, then the payments are less effective in increasing crop producer income, as increased production leads to lower market prices and returns, transferring some of the benefits of the payments to consumers.

Since Canadian farm income stabilization and support policy has moved toward a whole farm approach that targets net income and uses a moving average mechanism to temporally smooth income, it possesses income-supporting (wealth effect) and income-stabilizing (insurance effect) attributes. The existing literature controls for the wealth effect through changes in average total income arising from government supports, however the insurance effect is captured only through an ad hoc measure (Goodwin and Mishra, 2005, 2006; Sckokai and Moro, 2006; Coyle, Wei and Rude, 2008). Given the nature of Canadian whole farm programs which attempt to stabilize producers' income, to examine empirically the whole farm programs, a model is needed to capture the insurance effect arising from these programs. A measure is derived, in this dissertation, inside the theoretical framework to capture the insurance effect of whole farm programs as well as the wealth effect.

1.2 Objective of the Study

The primary objective of this study is to investigate whether Canadian whole farm programs, which are considered as decoupled based on the WTO definition, are actually decoupled.

To accomplish this goal, we follow the following steps which are, in fact, our secondary objectives. First, we explore the existing theoretical and empirical literature on the impact of programs designed to be decoupled payments on acreage response. Our review shows that these studies lack a detailed theoretical model of how acreage decisions will be affected by stabilizing the farm profit (insurance effect) as well as the higher expected profit (wealth effect).

Second, to fill this gap, we extend the existing theoretical framework to incorporate the insurance effect into the farmers' acreage decisions under uncertainty. In particular, we derive a measure inside the theoretical framework to capture the insurance effect of government policies as well as the wealth effect.

Third, based on the theoretical model, an empirical model is presented in which a system of equations is specified for crop acreage as a function of variables derived in the theoretical framework.

Finally, we apply the econometric model to acreage data in the Canadian Prairies to statistically test if the whole farm programs are really decoupled. By considering a system of all major crops acreage, this model is also able to show the impact of government programs on cropping patterns.

Meeting these objectives should result in a richer framework for examining whether and how much government payments have had role on acreage response. Policy makers can use this information as an input to the design of subsidies.

1.3 Methodology

Chavas and Holt (1990), by considering a farm household producing n crops and having preferences represented by a von Neumann-Morgenstern utility function, assume that the household maximizes expected utility of total wealth subject to budget and acreage constraints. By solving the optimization problem, initial wealth, expected profits and second moments of the distributions of profits are identified as factors affecting the optimal acreage decision. Then using the relationship between wealth compensated and uncompensated acreage decision and by substituting the wealth compensated slopes with respect to profit, the acreage equations are specified as a function of expected total wealth (initial wealth plus expected total profit), expected (own and cross) profits and the variance-covariance matrix of profits. The influence of government programs on the subjective probability distribution of profits was considered by truncation method. Hennessy (1998), however, analytically showed that the stabilization of total income (insurance effect) increases production as well as the higher expected total income (wealth effect) arising from the support policy. Although studies after Hennessy's work used an ad hoc measure for the insurance effect in their empirical model (Goodwin and Mishra, 2005, 2006; Sckokai and Moro, 2006; Coyle, Wei and Rude, 2008), there is no study in which the insurance effect is derived inside a theoretical framework.

By developing theoretical restrictions (i.e. by considering the relationship between income stabilization compensated and uncompensated acreage decision functions), in this dissertation we thus contribute to the literature on supply response by explicitly deriving the insurance effect (income stabilization) emphasized in the literature (Hennessy, 1998), which was ignored by Chavas and Holt model (1990), within our theoretical model. The acreage response equation is derived as a function of expected crop profits, elements of the variance-covariance matrix of profits, expected total wealth (initial wealth plus market profit), and variance of total wealth. The government payments are also incorporated into the model through truncation of the probability distribution of profits. Specifically, the whole-farm programs truncate the total (farm) profit distribution which affect the expected total wealth and variance of total wealth.

We specify a system of acreage equations as a function of variables derived in the theoretical model as well as lagged dependent variable to control for the cost of adjustment in switching from one crop to another. Within this model, we discuss the expected sign for the explanatory variables and the theoretical restrictions that should be imposed on the coefficients.

To examine the effects of Canadian support programs on acreage decisions for major crops in the prairie provinces over 1970-2006, the econometric model provided is applied to a system of nine crop equations and all the relevant elasticities of acreage allocation with respect to the exogenous variables are estimated. If the coefficient of expected total wealth and variance of total wealth variables are statistically significant (insignificant) in the whole system, the whole-farm programs are (are not) production and therefore trade distorting and are not (are) decoupled. The statistically significant coefficients are then used to simulate the impact of recent whole-farm programs—the Western Grain Stabilization Act (WGSA), the Net Income Stabilization Account (NISA) and the Canadian Agricultural Income Stabilization (CAIS)—on crop choices.

1.4 Organization of the Study

This thesis is organized into six chapters. The concept of decoupling and a history of decoupling in agricultural policies in the U.S., the EU and Canada, in particular, is presented in chapter two. After reviewing the literature pertaining to modeling farmers' acreage decisions under uncertainty, chapter three presents a literature review pertaining to the impact of decoupled payments on production decisions. Chapter four develops the theoretical framework used to derive the acreage response equation determinants which captures the insurance and the wealth effects. Incorporating the government payments into the theoretical model through the truncation method and developing an analytical framework to derive the expected signs for variables in acreage function are also presented in this chapter. Chapter five provides data description and the empirical model, then it discusses the estimated results and reports simulations for the Canadian whole-farm programs. Chapter six contains concluding comments and lessons learned.

Chapter 2

Decoupling: The Concept and Direct Government Payments in Canada

The distortionary effects of domestic farm programs figured high on the negotiating agenda in the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). Along with the conventional focus on export subsidies and market access, domestic farm policies were targeted for reductions in support. Under the Uruguay Round Agreement on Agriculture (URAA), domestic policies were classified based on the extent to which they were considered to be trade-distorting. Domestic policies that were considered to be minimally trade distorting were classified as non-actionable (Green Box) policies and not subject to reduction. Decoupled support policies, defined as payments that are financed by taxpayers and are not related to current production, factor use, or prices, and for which eligibility criteria are defined by a fixed, historical base period, are categorized as non-actionable (Green-Box) payments. Since they are exempt from WTO disciplines, payments considered to be decoupled have been providing a growing and important share of the total support to agriculture provided by governments as domestic agricultural policies are revised in light of Green Box criteria. The extent to which exempted policies really are production and trade neutral has, however, recently come under increasing scrutiny. It is hypothesized that there are various mechanisms by which decoupled payments may affect production decisions.

This chapter first describes the ambiguity surrounding the definition of decoupling, then presents the various channels through which decoupled payments could affect production and finally outlines the Canadian agricultural stabilization and support programs after briefly describing some practical experiences with decoupling of agricultural support in the U.S. and the EU.

2.1 The Concept of Decoupling

Agricultural production has a long tradition of being supported financially by governments. There are at least two sets of motivating factors behind domestic subsidies to agriculture. Economists argue that if prices are highly variable and producers are risk averse, then output will be less than the social optimum. Under price uncertainty, producers make fewer long-term investments that reduce production (Just, 1974). Therefore, reducing price uncertainty can be Pareto improving and can increase overall economic welfare. Stabilization programs can reduce price uncertainty, if they are designed with that objective. There are also political reasons for introducing stabilization programs. Support to agriculture is often legitimized by the argument that small family farms need income support in order to secure a fair standard of living. The provision of agricultural products at reasonable prices to consumers is also used as a supportive argument. Furthermore, as a consequence of existing agricultural policies, farmers have been led to invest in certain areas, and it may be problematic to suddenly remove agricultural support that could lead to bankruptcies in the agricultural sector.

The Uruguay Round Agreement on Agriculture (URAA) of the World Trade Organization (WTO) provided formal recognition that domestic subsidies to agriculture could adversely affect trade and, for the first time in 1994, domestic subsidies to agriculture were brought under the discipline of global trade rules. Member countries of the WTO decided to reduce the distortions that were caused by current levels of domestic farm subsidies. Under the URAA, domestic support is classified into three categories or boxes according to their supposed impact on international trade. According to URAA conventions, the Amber-Box contains the most distorting—actionable—subsidies, and, hence, limits to their use have been agreed. Blue-Box payments also cause some distortion but are required to be production limiting. The Green-Box contains non-actionable subsidies that are classified as being minimally trade distorting. The subsidies in the Blue- and Green-Boxes are excluded from all WTO disciplines—are excluded from the Aggregate Measure of Support—and are expected to have no, or at most minimal, trade-distorting effects through their influence on production. Decoupled support policies are categorized as Green-Box payments.

2.1.1 Definition of Decoupled Policies

A policy (or a package of policies) is said to be decoupled if it has no, or small effect on the level of production and trade. In theory, the decoupled policy has no effect on output, while the coupled policy will affect the level of production (Andersson, 2004). The World Trade Organization (WTO) and the Organization for Economic Cooperation and Development (OECD) have provided two prominent operational definitions of decoupled payments. A fundamental difference between the two definitions is whether a policy is defined as decoupled ex ante, as in the legal definition in the URAA, or ex post as adopted by the OECD (2001).

The ex ante definitions are criteria based, and the Uruguay Round Agreement on Agriculture (URAA) of the WTO in Article 6 of Annex II provides a list, presented below, of five criteria that payments should meet to be defined as decoupled. (a) Eligibility for such payments shall be determined by clearly defined criteria such as income, status as a producer or landowner, factor use or production level in a defined and fixed base period. (b) The amount of such payments in any given year shall not be related to, or based on, the type or volume of production (including livestock units) undertaken by the producer in any year after the base period. (c) The amount of such payments in any given year shall not be related to, or based on, the prices, domestic or international, applying to any production undertaken in any year after the base period. (d) The amount of such payments in any given year shall not be related to, or based on, the factors of production employed in any year after the base period. (e) No production shall be required in order to receive such payments. Based on the above criteria for decoupled payments, Canadian whole-farm programs, discussed later, for which eligibility criteria are defined by a fixed, historical base period, can be considered as decoupled.

Figure 2.1 illustrates why the WTO considers farm programs satisfying the above criteria as decoupled, i.e. those that do not distort production and trade. In this figure, the domestic supply and demand are given by S and D, and P^0 and Q^0 indicate the free trade prices and output, respectively. If world price falls to P^1 for some reasons (including the use of production subsidies by competitors), there is a welfare loss of area b. If the government provides a price support of P^0 given a world price of P^1, the level of production increases to Q^0. Moreover, the welfare loss is given by area c. Now suppose that a farm program which satisfies the WTO definition, instead of a price support program, is introduced (such as payments based on the previous years' average net income). Since in the absence of government intervention producers lose the entire area $a + b$, governments must provide a payment equal to area $a + b$. Under this program, output will remain unchanged at Q^1 and thus trade will not be affected. Therefore, this kind of program is categorized as decoupled.

Moreover, there are no welfare costs associated with decoupled programs, and therefore these programs are more efficient than price support policies (Schmitz, Furtan and Baylis, 2002).

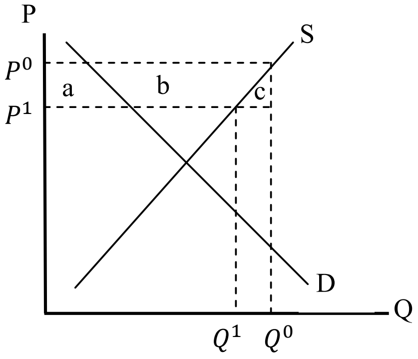

Figure 2.1: Trade and the Decoupling of Farm Programs

Another definition for decoupled policies is provided by the OECD, the ex post definition. This definition is based on the outcome of the policy. A policy is fully decoupled if it does not influence production decisions of farmers receiving payments. Under this definition, the demand and supply functions remain unchanged when a package of policy measures is introduced. The OECD (2001) discusses, however, the government payments (even those that are considered as decoupled by the WTO) can affect the production decisions through some indirect channels. Thus, it is obviously difficult to imagine a fully decoupled agricultural policy in the real world. Rather than defining a fully decoupled policy, the OECD introduces a more operational definition which is a degree of decoupling given by Cahill (1997)[1]. Defining a degree of decoupling requires two references for comparison: full decoupling[2] and full coupling. If a policy package results in production that equals the level of production under a policy package based on the level of production of the planted crop, the package is fully coupled. The degree of decoupling would be a measure of the production and trade effects of a package relative to those of a fully coupled policy.

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[1] Cahill (1997) explores the concept of decoupling and measures a rate of decoupling achieved by the compensatory payments package provided under the European Union's Common Agricultural Policy (CAP) reform. In the analytical model, compensatory payments affect the revenue per hectare and whereby affect acreage and therefore production. In particular, the author develops an expression for the change in output as a function of price and compensatory payments changes, and acreage and yield elasticities. The model is calibrated on 1991-1992 and rates of decoupling of CAP payments for five crops (rapeseed, soybeans, sunflower, wheat, coarse grains) are obtained.

[2] A less restrictive concept is effectively fully decoupled. If a policy package results in production that does not exceed the level that would exist without the policy, the package is effectively fully decoupled. Production decisions by farmers could be affected through the effectively fully decoupled package, but in a way that does not result in larger production. This means that equilibrium levels of production and trade are unchanged but that the shape of the demand and supply curves can change.

In this dissertation, decoupled payments refer to the WTO ex ante definition which are defined by a fixed, historical base period.

2.2 Potential Impacts of Decoupled Payments on Production

Although there has been a positive development, a move towards decoupled support away from coupled support, consistent with the 1994 URAA, a number of potential links between decoupled payments and farmers' decisions have been identified in the literature. In an attempt to decouple the agricultural policy, direct effects (which arise as a consequence of changes in incentive prices or by quantitative restrictions) can be removed by e.g. providing support through lump-sum transfers. However, indirect effects (arise broadly as a consequence of, or expectations of, changes in income and wealth) may remain after the reform, as agricultural support may induce indirect effects by the pure existence of the support. The economics profession has recently addressed and delineated many of these potential links, both with analytical conceptualizations and empirical investigations (OECD, 2001).

If credit markets are imperfect (for example the existence of a significant gap between borrowing and lending rates and/or the presence of binding debt constraints for the farmer willing to invest), decoupled payments have the potential to increase the liquidity of credit constrained farmers and so will affect investment decisions. The payments may also increase land values and rents, which also improves the credit worthiness of credit-constrained farmers and lead to keeping land in agricultural production. Decoupled payments affect farmer expectations by linking current decisions to future payments. Support programs that are directly based on previous production, e.g. output last year, have a built-in dynamic aspect, since the farmer can directly affect next year's payments with today's production decision. If labour markets are imperfect (for example a wage gap between on-farm and off-farm returns), decoupled payments can affect labour markets by influencing the on- and off-farm labor supply decisions and so will affect agricultural production.

In the presence of uncertainty, decoupled payments can affect the total wealth of the farmer and this change in wealth can affect the farmers' attitude to risk (risk aversion). The way in which wealth affects risk aversion depends on assumptions concerning the utility function. Hennessy (1998) shows that if absolute risk aversion is reduced by the wealth effect (decreasing absolute risk aversion assumption), farmers will be willing to assume more risk and therefore will produce more. Decoupled payments may affect the degree of risk faced by the farmer. The idea is that a policy reducing the risk faced by the farmer will have a positive effect on production. It can be proved that a government scheme that increases payments when prices fall and reduces payments when prices rise will increase production if there is partial income compensation for the price movements.

In general, decoupled payments may indirectly influence farmers' decisions. Therefore, the implementation of decoupled programs calls into question the current definition of the non-actionable (Green-Box) payments in the WTO.

2.3 Experiences of Decoupling in Agricultural Policies

Numerous reforms of agricultural support have been made over the years. This section presents some experiences with decoupling of the agricultural policies and reforms in the EU, the U.S. and Canada.

2.3.1 The EU

The EU's Common Agricultural Policy (CAP) came into force in 1962. Since the policy was developed in the years after the Second World War, it was constructed to secure the availability of supplies of agricultural products for consumers. The official objectives were to ensure a fair standard of living for the agricultural community, increase agricultural productivity, to stabilize the markets, and to maintain and increase food production. Recent reforms emphasised rural development, protection of the environment and competitiveness. The initial CAP's major policy avenue was to increase farm prices.

The MacSharry reform of the CAP in 1992 reduced price support for arable crops (cereals, oilseeds and protein crops), and for beef and veal, and farmers were compensated for the resulting loss of income by direct payments. The reductions in price supports were compensated by a per hectare payments (which were based on historical yields and historical acreage) in the case of cereals, and increased premium payments for beef cows and cattle. The 1992 reform introduced a set-aside scheme in the arable sector which allowed the Commission to curtail the quantity of arable land in production and curtail the growth of surpluses in that sector.

In 1999, the second major reform of the CAP was adapted as part of the Agenda 2000.

The reform was a deepening of the MacSharry reform and focused on increasing the competitiveness of agricultural products. Price support to crops was further reduced and the direct payments were increased and realigned across crops. The reference year for payments was also changed in some countries. In this reform rural development was given a higher priority.

In 2003, the Mid-Term Review (MTR) of the CAP was agreed upon. This reform requires at least 75 percent of payments to be decoupled in the arable sector. Single Farm Payments (SFP) will be based on historic entitlements and linked to land rather than production. Under the MTR reform, a single farm payment will replace the existing crop-specific area payments. Eligibility for payments is subject to cross-compliance with a variety of EU environmental, animal welfare and food safety standards (European Commission, 2003).

2.3.2 The U.S.

The New Deal farm program in the 1930s attempted to control farm prices by offering producers payments in return for voluntarily reducing the acreage devoted to crops and taking surplus production off the market. The total payment was equal to the yield per acre multiplied by a farm's eligible payment acreage. In 1954, the flexible price support program provided for direct payments to farmers in return for reducing their acreage of major supported crops and required that they leave fallow the land removed from production. This portfolio of policy instruments were the primary means of price support for the major field crops for decades up to the 1980s.

The 1985 Food Security Act set a new trend for the major field crop sector by dropping the price supports and reducing the role of acreage set-asides and public stock holding, which had the purpose to decouple payments from current yields and link them to historical yields. Coupled direct payments on fixed quantities of products were based on average yields between 1981 and 1985.

The Federal Agricultural Improvement and Reform Act (FAIR) of 1996 signaled a transition toward a new policy environment characterized by diminished government involvement in agricultural markets. Under the FAIR Act, agricultural subsidies (market price support and deficiency payments) were replaced with fixed payments to farmers based on historical production, which has been called a Production Flexibility Contract (PFC) or Agricultural Market Transition Act (AMTA) payments, and with a loan deficiency payment program (LDP) with the aim to establish minimum support prices for program crops. AMTA payments were intended to decline each year until the FAIR Act expired in 2002. However, as prices fell sharply in the 1990s, the government intervened to avoid farm bankruptcies and Congress passed supplemental, ad hoc payments to farmers. These payments, known as Market Loss Assistance (MLA), were also decoupled since they were paid on the basis of historical base acreage and thus carried no current production requirements. However, these payments were tied to market prices since they were a response to poor market conditions.

In the 2002 Farm Bill, the Food Security and Rural Improvement Act (FSRIA), the PFC payment were replaced with direct payments for crops (DPC) which also are higher than the PFC payments. The DPC was also set at a constant level over 2002-2007 while the PFC, as stated above, were scheduled to decline. The disaster payments that were paid on an ad hoc basis since 1998 are also formally brought into farm legislation in the 2002 Farm Bill in the form of counter cyclical payments (CCPs). The farmers are also allowed to update their base acres and yield, which determine the payments (Baffes, 2004).

2.3.3 Canadian Agricultural Stabilization and Support Programs

Canadian agriculture has a long history of government involvement in programs designed to stabilize prices and incomes. From the time of Confederation in 1867 until the 1930s, identifying and attracting quality immigrants was a significant feature of national policy for agriculture. The Great Depression of the 1930s and the simultaneous droughts and insect damage throughout the North American Great Plains led to action by the federal government. In January 1935, the Canada government announced reforms which implied government intervention (as control and regulation) and, in turn the development of a policy for agriculture in Canada. From 1950s, government activities were transformed from simply control and regulation to direct provision of subsidies (Hedley, 2007). During the period 1955-1970, a major program was the Temporary Wheat Reserve Act. This program resulted in a major income transfer to Prairie farmers. During that period, Canada accumulated large grain stocks. Under the Temporary Wheat reserve Act, farmers were partly compensated for on-farm storage charges by payments to elevator companies. In what follows, we will review agricultural stabilization and support programs in Canada starting in 1950.

After the Agricultural Products Board Act 1951, which stated that government should have a role to play in supporting agricultural prices and incomes, the federal government put into effect the Agricultural Stabilization Act (ASA) in 1958. The ASA was the first Act in

Canada which allocated direct payments to farmers that were fully funded by the Canadian government based on a specific formula to stabilize the low prices of a predetermined set of farm commodities. Under this Act, the federal government provided direct subsidies for nine commodities (cattle, hogs, sheep, butter, cheese, eggs, wheat, oats and barley) when the annual average price for them dropped below 90 percent of the average price over the three preceding years[1]. The amount of money paid under the ASA to farmers was initially small but started to grow during a period of inflation in Canada starting in 1975. Since western farmers felt that price stabilization under ASA was not sufficient (in many years, the Canadian Wheat Board quotas for wheat, barley and durum were constraining, thus farmers could not deliver and get stabilization payments for all of their production), the WGSA was put in place to help prairie farmers stabilize their crop income. After the introduction of the Western Grain Stabilization Act in 1976, western grains were removed from the Agriculture Stabilization Act.

A second important policy was put in place through the Crop Insurance Act, 1959. Based on this Act, the Federal Government provided funds to the provinces to operate subsidized crop insurance programs within each province. The Crop Insurance Act was the first agricultural support program which introduced the concept of cost sharing between the federal and provincial governments. Protection offered under the crop insurance program only insured 60 percent of long-term yields. In 1966, the Federal Crop Insurance Act was amended in an attempt to increase farmer participation in the program. Since 1966, the insurance yield coverage level available to farmers had been increased from 60 percent of the long-term, average-area yield to 80 percent of the long-term, average-area yield. Also, the federal contribution to farmer premiums increased from 20 percent to 25 percent. In 1973, participation in the crop insurance program increased dramatically, with the federal and provincial governments increasing their combined share of the premiums from 25 percent to 50 percent and expanded coverage to include hail spot-losses [2]. Since all crop insurance contracts guarantee a price, in 1996 governments began to offer insurance to farmers that was based on a futures

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[1] Later, the support price for industrial milk and cream was based on 190% of the five-year average market price while for the beef sector was 95% (Rosaasen and Schmitz, 1984).

[2] The next amendment to the Act, in 1973, provided two options for the federal-provincial-producer cost-sharing arrangements. In one option, the federal and provincial governments each contributed 25 percent of total premiums and 50 percent of administrative costs. In the other option, the federal government contributed a total of 50 percent of premiums and the provinces paid all administrative costs. In the 1990 amendment, the maximum coverage was increased to 90 percent for low risk crops. Furthermore, the single cost-sharing formula was adopted, where the federal government and provinces each pay 25 percent of total premiums and 50 percent of administration costs (Giraldez et al., 1998). In recent years, federal and provincial governments combined share of premiums has increased to about 60 percent.

price.

In 1976, the Western Grain Stabilization Act (WGSA) was passed to provide crop income stability for western grains and oilseeds. Under the WGSA, the total value of payout to all farmers in a given year was based on the aggregate net cash flow of prairie grain producers[1]. Payment were made when aggregate net cash flow (cash receipts minus cash variable costs) from eligible grain (wheat, oats, barley, rye, flaxseed, canola and mustard seed; from 1988 nine crops are added to the seven previously covered triticale, mixed grains, sunflower, safflower, buckwheat, peas, lentils, fababeans, canary seed) sales were less than the average net cash flow over the previous five years. Individual farmers voluntarily entered into the program, which was funded through both farmer levies and federal government contributions. Participating farmers contributed a percentage of their gross sales to the stabilization fund (the farmer levy ranged between one and four percent of gross sale depending on the balance of the stabilization fund), an amount that was matched by the federal government in addition to a further contribution equivalent to two percent of gross sales (Fulton, Rosaasen and Schmitz, 1989). The individual farmer's share of this payout was then determined by comparing the farmer's contributions to the program (levies) in the current and the previous two years with total levies of all farmers over the same period. The WGSA was the first support program with fixed producer-federal government shares, and a composite of commodities; not support for each specific commodity. Under the WGSA the payouts were not large until after the grain trade wars of 1985. The program built up a large surplus in the early 1980s. In 1984, the payout triggers were changed to allow greater payouts to producers. However, the large payouts in the late 1980s led to a deficit in the WGSA fund. It was subsequently replaced with a new program called the Farm Income Protection Act (which had three components, the Gross Revenue Insurance Program, the Net Income Stabilization Account, and Crop Insurance).

As a result of the low grain prices in 1986, the government of Canada announced a new program called the Special Canadian Grains Program. Under this program, payments of $1 billion in 1986 and $1 billion in 1987 were made to producers. With several years of ad hoc programming experience and little improvement foreseen by governments, the federal and provincial governments began a major policy review in 1989. The economic difficulty felt

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[1] In response to criticism directed at the program, Bill C-33 was passed to amend the WGSA in June 1984. The amendment was intended to make the program more responsive to crop production volume changes. Therefore, the new trigger was based on a per-unit of net cash flow. Under the new mechanism, payouts were triggered whenever the per-ton net cash flow fell below its simple average over the preceding five years.

by governments was that farmers in the crops sector were increasingly making planting and crop choice decisions based on governmental programming rather than market signals. The product of these debates was the Gross Revenue Insurance Program (GRIP) in 1991.

The Gross Revenue Insurance Program (GRIP) was the first program introduced under the Farm Income Protection Act. In GRIP, farmers were guaranteed a per acre gross return on whatever crop they grew[1]. A farmer would pay a premium to insure the gross revenues of a crop at a certain level, and he/she would receive an indemnity when area revenues fell below the coverage level. Premiums were subsidized (typically producers would pay 1/3 of the insurance premium). There were two payouts that compromised GRIP: (1) revenue insurance and (2) crop insurance. The program guaranteed producers their long-term average yield. The guaranteed price was set by an indexed moving average price. This index was an average of prices from the previous fifteen years, lagged by two years, indexed by a farm input price index which was used to index the grain price by a cost of production formula. As shown in figure 2.2, revenue insurance provided revenue protection between the level offered by crop insurance and the target revenue set by GRIP. Crop insurance provided a production guarantee equal to 70 percent of the producer's normal production times the price listed in the crop insurance contract. To collect the revenue insurance, the market revenue had to be below the target revenue.

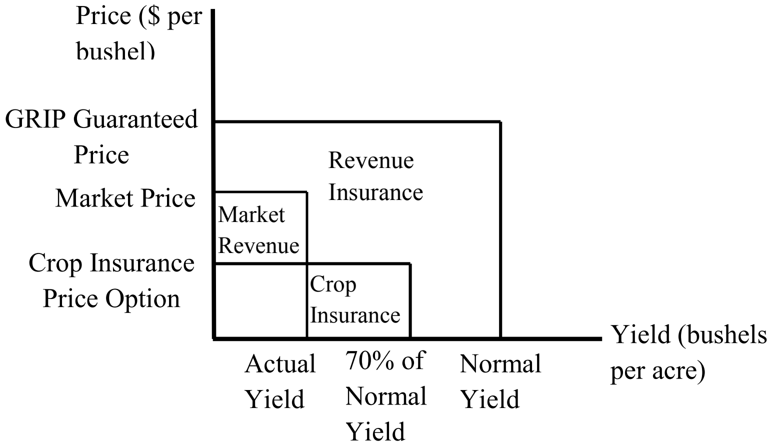

Figure 2.2: The Mechanics of the GRIP (Schmitz, Furtan and Baylis, 2002)

Saskatchewan withdrew from the program just eighteen months after it was implemented, because it was considered too expensive for the province and it was poorly designed. By 1999, the only province still participating in GRIP was Ontario.

The Net Income Stabilization Account (NISA), which had tripartite (federal, provincial

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[1] Note that the rules for administration of GRIP differed across provinces.

and farmer) funding, was the second program introduced in the Farm Income Protection Act. The stated purpose of the NISA program of 1991-2002 was to encourage farmers to save more funds in high income years for use in low income years, so as to smooth incomes over time (this is similar to the objective of the WGSA. Unlike WGSA, each participant had an individual NISA account). NISA was a voluntary farm income safety net scheme, where farmers could set aside money (after tax) in individual accounts which is then matched by federal and provincial government. A farmer could contribute up to three percent of eligible net sales as savings to a Fund "one" NISA account and the federal and provincial governments generally make a matching contribution to a Fund "two" NISA account for the individual (two percent from the federal government and one percent from the provincial government). Matching funds would earn a competitive interest rate, but the farmer's own deposits received a three percent interest bonus paid by government. The maximum net sales for the qualifying matching government contribution was set at Cdn $250,000 per farm. In addition, a farmer could contribute up to an additional 20 percent of eligible net sales to his Fund one NISA account. These additional farmer contributions were not matched by government, but they would earn the three percent interest bonus from government. Farmer contributions were not tax deductible. All interest from both accounts was accumulated in Fund two which is taxable upon withdrawal.

In years of declining income, farmers could withdraw funds from their NISA accounts in amounts determined by either one of two trigger mechanisms. Under the stabilization trigger, if, in the tax year, farm income fell below 70 percent of the previous three-year average, a farmer could withdraw money from his NISA account. Under the second trigger, if the farmer's net farm income fell below Cdn $10,000, the farmer could choose to withdraw his money from his NISA account. In all cases, a farmer's NISA account could not be in deficit. This trigger was increased in 1999 to Cdn $20,000 per farm or Cdn $30,000 for cases in which the NISA account was held as a partnership.

In response to the drop in grains and oilseed prices, in 1998, the federal government introduced a temporary farm income support program called Agricultural Income Disaster Assistance (AIDA). This program was designed to meet the criteria of the WTO Annex for Green Box. When farmers' net income fell below 70 percent of their three-year, moving-average net income they become eligible for a pay-out (net income below zero is not included in the averaging process)[1]. The cost share on this program was 60 percent from the federal

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[1] Note that the rules for administration of AIDA differed across provinces.

government and 40 percent from the provincial government. Since AIDA was costly in terms of the number of accountants and government employees needed to manage the individual farmers' AIDA application (which result in farmers receiving less than the full benefits of the program), the Canadian government in 2001 announced the Canadian Farm Income Program (CFIP). Even though CFIP replaced AIDA, it was similar to it.

The Canadian Agricultural Income Stabilization (CAIS), which is now Canada's single safety net program, was approved in late 2003 in place of the Net Income Stabilization Account (NISA), Canadian Farm Income Plan (CFIP) and related provincial programs. A production margin is intended to reflect revenues and expenses that are directly related to production for the firm and is calculated by subtracting farmer's total allowable expenses from his total allowable income. A reference production margin is an average of the five previous production margins for the farmer, excluding the high and low margins. A CAIS payment is triggered when a farmer's program year production margin declines below his reference margin (CAIS payouts are based on farm specific losses relative to reference margin rather than on a regional measure of loss as in the Western Grain Stabilization Act). The greater the decline in the margin, the greater the payment. Payments are financed from farmer deposits and government contributions, and shares vary with the difference relative to the reference margin, the amount of government funds the farmer will receive is determined by the extent of his margin decline.

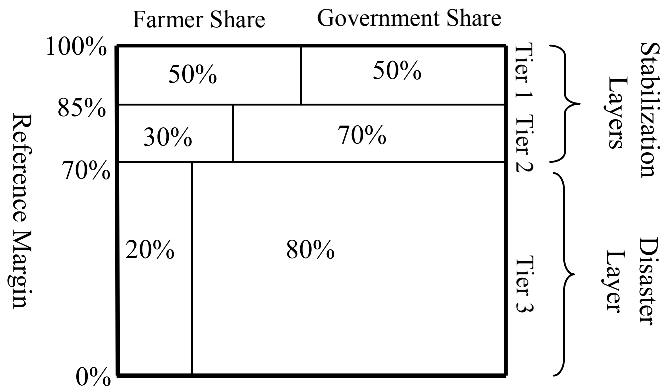

Figure 2.3: The Mechanics of the CAIS (CAIS Program Handbook)

As shown in figure 2.3, the program measures the extent of farmer decline using three tiers, with Tier 1 representing the smallest decline and Tier 3 representing the largest decline. If the program year margin is between 85-100 percent of the reference margin, government pays fifty percent of the decline (Tier 1). If the program year margin is between 70-85 percent of the reference margin, government pays seventy percent of the decline (Tier 2) in addition to the Tier 1. If the program year margin is between 0-70 percent of the reference margin, government pays eighty percent of the decline (Tier 3) in addition to the Tier 1 and Tier 2. In an unlikely case when production margin is negative, the government pays sixty percent of loss. The share of a farmer is inversely proportional to loss. Farmer deposits must be a minimum of 14 percent of the current reference production margin; these deposits are not a premium and the farmer gets the money back.

Growing Forward is a new commitment to Canada's agriculture sector (AAFC, 2007). AgriInvest, AgriStability, AgriRecovery, and AgriInsurance are the first programs available under Growing Forward and form a new suite of business risk management programs for farmers. AgriInvest has replaced the coverage under the Canadian Agricultural Income Stabilization (CAIS) program for margin losses of 15 per cent or less. Through government and farmer contributions to producer accounts, it will provide producers with flexible coverage for small income declines as well as support for investments to mitigate risks or improve market income. Under this program, producers who make a deposit to their AgriInvest account will receive a matching government contribution based on a percentage of allowable net sales of eligible commodities. AgriStability is a margin-based program that will provide farmers with assistance for larger income declines. It replaces the coverage previously available under CAIS, compensating producers for larger declines relative to the reference margin (a decline of greater than 15 percent). AgriRecovery provides disaster relief for smaller natural disasters that are regional in scope and have a relatively small impact on the Canadian industry. These types of disasters jointly fund on a 60/40 federal/provincial-territorial basis.

In general, numerous reforms of agricultural support have been made over the years across countries. This chapter presented some experiences with decoupling of the agricultural policies and reforms in the EU, the U.S. and Canada. The extent to which decoupled payments are truly decoupled from production decisions has recently come under debate. Various mechanisms by which decoupled payments may affect production decisions have been identified in the literature. The next chapter reviews the studies concerning measurement of the effects of decoupled payments on acreage decisions.

Chapter 3

Literature Review

This chapter provides a literature review pertaining to the impact of government direct payments on acreage decisions and agricultural production. The review is organized as follows: the first section presents a review of the literature pertaining to modeling farmers' acreage decisions. This section focuses on studies that attempt to estimate the acreage decision determinants (which are essential to farm policy decision makers) under uncertainty. The procedures for calculating expected net returns and variance of net returns as the two main factors affecting acreage decisions have been extended after Nerlove's seminal paper in 1958. Future prices or adaptive expectations, and the weighted three-year moving average of variances are primarily used as proxies for expected prices and expected variance-covariance of prices, respectively. Then, since single commodity studies, which do not consider all alternative uses of land and theoretical constraints, are potentially incomplete, studies that try to estimate a system of acreage decision equations are presented.

Coupled payments affecting prices and net returns (and therefore agricultural production, and acreage) have been examined, and price elasticities estimated, for use in forecasting under government intervention. Furthermore, in the wake of domestic subsidies to agriculture being brought under the discipline of global trade rules of the World Trade Organization (WTO) in 1994 (because of their trade-distorting effects), many farm programs are shifting towards policies that fit the WTO definition for non-actionable subsidies. Although programs fitting the non-actionable criteria are expected to have no direct effect on production decisions, it is argued that there are some possible ways that these payments indirectly affect agricultural production (Westcott and Young, 2002). In other words these supposedly decoupled payments do, indeed, affect production albeit indirectly. To the extent that programs expand domestic production, the impacts can be partially transmitted to world markets through increased exports and lower prices. Therefore, the second section examines the studies concerning measurement of the effects of payments compliant with the non-actionable definition—hereafter denoted as decoupled—on acreage decisions. Decoupled payments may affect farm operators' production decisions by altering their access to capital (credit constraints effects), their expectations of future payments (expectations effects), their production costs' coverage (farmers entry/exit effects), or their risk preferences and income variability (wealth and insurance effects). Studies related to the wealth and insurance effects are closely examined.

3.1 Literature Review Pertaining to Acreage Response

One of the most commonly researched areas in agricultural economics is acreage response analysis. The factors which determine the amount of acres farmers allocate to various crops are essential to farm policy decision makers. Thus, agricultural economists have focused on modeling acreage response[1]. In what follows we review some of the past research done on acreage response.

The estimation of farmer supply response was considerably improved by Nerlove's seminal paper on partial adjustment and adaptive expectations in 1958. In the Nerlove model, farmer acreage decisions were influenced by price expectations (the Nerlove model assumes that past prices govern expectations about the normal level of future price levels, with more recent prices having a greater weight) and production adjustments. Since that time, a large body of literature has modified and revised the Nerlove model when examining supply response (Askari and Cummings, 1977). Some of the acreage response literature extending the basic Nerlovian framework are examined below.

Some studies have considered alternative price expectation specifications ranging from naive expectations or a simple one-period lag (Bailey and Womack, 1985; Duffy, Richardson and Whlgenant, 1987; Chembezi and Womack, 1992) to the weighted geometric lagged function of the previous years' market price (Chavas and Holt, 1990; Massow and Weersink, 1993; Krause and Koo, 1996), futures prices (Gardner, 1976; Morzuch, Weaver and Helmberger, 1980; Wu and Adams, 2001; Goodwin, Vandeveer, and Deal, 2004; Goodwin and Mishra, 2006; Lin and Dismukes, 2007), a combination of cash and futures prices (Chavas, Pope and

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[1] For estimating crop production, previous literature consists of a larger number of acreage response models compared to supply response models . This is due to the fact that planting decisions are independent of the subsequent weather conditions and, therefore, provide an accurate forecast of planned production compared with observed output (Coyle, 1993).

Kao, 1983). Table 3.1 summarizes some related studies analyzing the impacts of expected prices on acreage response.

Table 3.1: Some Studies related to the Impacts of Expected Prices on Acreage Response

Papers	Type of Price Expectation	Focus of Study	Method
Gardner (1976)	Futures prices	As expected price in supply anaylsis	OLS
Morzuch et al. (1980)	Futures prices	Wheat acreage response	OLS
Chavas et al. (1983)	Cash and futures prices	Corn and soybean acreage response	OLS
Bailey and Womack (1985)	Simple one-period lag	Wheat acreage response	OLS
Duffy et al. (1987)	Simple one-period lag	Cotton acreage response	GLS
Chavas and Holt (1990)	Weighted avg of past prices	Corn and soybean acreage response	SUR
Chembezi and Womack (1992)	Simple one-period lag	Acreage response to gov't programs	GLS
Massow and Weersink (1993)	Weighted avg of past prices	Production effects of gov't programs	SUR
Krause and Koo (1996)	Weighted avg of past prices	Program crops responses	Tobit
Wu and Adams (2001)	Futures prices	Environmental effects of gov't programs	SUR
Goodwin and Mishra (2006)	Futures prices	Land acquisition effects of gov't programs	Probit
Lin and Dismukes (2007)	Futures prices	Production effect of gov't program	SUR

Note: OLS, SUR and GLS represent ordinary least square, seemingly unrelated regression and generalized least square.

Some other studies have extended the Nerlove model by incorporating the role of risk in acreage allocation. In these studies, risk typically enters the Nerlove model through expected utility optimization by a farmer. The empirical evidence suggests that risk variables are often significant in explaining agricultural production decisions (e.g. Just, 1974). Gabriel and Baker (1980) indicated that there are two major sources of risk in farms: (1) unstable agricultural markets that affect price variability and (2) environmental factors that influence yield variability. Studies incorporating the effect of price risk on crop acreage have considered alternative measures for price variances ranging from a simple three-year moving average of squared deviations between expectations and realized prices (Behrman, 1968) to a weighted three-year moving average of squared deviations between expectations and realized prices (Lin, 1977; Traill, 1978; Sengupta and Sfeir, 1982; Chavas and Holt, 1990; Coyle, 2005; Sckokai and Moro, 2006), an adaptive expectations measure of the variance of price (Just, 1974, 1976; Pope and Just, 1991; Antonovitz and Green, 1990), time-varying variance within the autoregressive conditional heteroskedasticity (ARCH) framework (Aradhyula and Holt, 1990; Holt, 1993). Studies examining the effect of both price and yield risk on acreage response (Massow and Weersink, 1993; Duffy, Shalshali and Kinnucan, 1994; Lin and Dismukes, 2007) have considered the variance measure of yield using moving weighted average of squared deviations between crop yields and their trend yields. Some studies analyzing the impacts of risk on acreage response are summarized in table 3.2.

The Nerlove model has also been extended by considering the role of government programs. Examples are Houck and Ryan (1972), Morzuch, Weaver and Helmberger (1980), Duffy, Richardson and Whlgenant (1987), McIntosh and Shideed (1989), Chembezi and Womack (1992), Massow and Weersink (1993), Coyle, Wei and Rude (2008), Sckokai and Moro (2006),

Table 3.2: Some Studies related to the Impacts of Risk on Acreage Response

Papers	Type of Risk	Focus of Study	Method
Behrman (1968)	Simple 3-yr moving avg p var	Rice, kenaf, corn and cossava acreage response	ML
Lin (1977)	Weighted 3-year moving avg r var	Wheat acreage response	ML
Sengupta and Sfeir (1982)	Weighted 3-yr moving avg p and y var	Risk aversion impact on supply response	OLS
Chavas and Holt (1990)	Weighted 3-yr moving avg p var-cov	Corn and soybean acreage response	SUR
Pope and Just (1991)	Adaptive expectations p var-cov	Risk structure in potato supply response	OLS
Massow and Weersink (1993)	Weighted 3-yr moving avg r var-cov	Production effects of gov't payments	SUR
Duffy et el. (1994)	Weighted 3-yr moving avg p var-cov	Program crops responses	SUR
Coyle (2005)	Weighted 3-yr moving avg p var	Investment effects of gov't farm programs	OLS & GMM
Sckokai and Moro (2006)	Weighted 3-yr moving avg p var-cov	Production effects of decoupled payments	ML

Notes: p, y and r var-cov denote price, yield and return variance-covariance matrix, respectively. ML and GMM represent maximum likelihood and generalized method of moments, respectively.

Lin and Dismukes (2007). This concept will be examined in greater detail in the next section.

A major portion of the acreage response literature focuses on modeling a single commodity, for instance, Houck and Ryan (1972), Ryan and Abel (1973), Lidman and Bawden (1974), Morzuch, Weaver and Helmberger (1980), Reed and Riggins (1981), Bailey and Womack (1985), Duffy, Richardson and Whlgenant (1987), Ahouissoussi, McIntosh and Wetzstein (1995), Govindasamy and Jin (1998). Single commodity studies are potentially incomplete because they fail to incorporate all alternative uses of land. Moreover, single-equation models, unlike multiple-equation models, fail to capture the interaction among the error terms. Since acreage decisions are made among competing commodities, a system framework is the appropriate modeling technique. Such a technique incorporates contemporaneous covariance of disturbances across the equations and yields efficient estimators (Banerjee, 2004). There have been relatively few papers extending the Nerlove model or other acreage response models to a system of multiple crops. Binkley and McKinzie (1984), Kraker and Paddock (1985), Bewley, Young, and Colman (1987), Barten and Vanloot (1996), Holt (1999), and Coyle (1999) are examples.

Since a system of equations provides information about the allocation of land (which is fixed in supply) to any one use and its substitutability to other uses, Binkley and McKinzie (1984) specify a system of crop acreage demands as a function of expected net returns and government programs. However, Binkley and McKinzie's analysis has some serious limitations. Even though they consider behavioural constraints such as convexity and linear homogeneity, they fail to discuss separability, adding-up, duality and assumptions necessary for symmetry in an acreage demand model. Moreover, Binkley and McKinzie discuss symmetry conditions, but do not use or test for symmetry in their empirical analysis. The system approach typically can accommodate behavioural constraints and imposing such theoretical restrictions as symmetry, homogeneity, and curvature (say, convexity in prices of the profit function) which are important for two reasons. First, these testable restrictions may be used to validate the theoretical framework. Second, imposing these restrictions may be useful in improving the efficiency of estimation, as well as improving the usefulness of empirical results for policy analysis.

Since a system of crop acreage models deals with allocation of land for multiple outputs, the shares allocated to each of the crops (which act as probabilities) are non-negative and they all add up to unity. In the literature, a multinomial logit functional form has been adopted for acreage demands so that predicted shares are non-negative for all possible prices. Kraker and Paddock (1985), and Bewley, Young and Colman (1987) have all used the Theil's (1969) multinomial extension of the linear logit model to specify a system of crop acreage demands conditional on all crop output prices and total crop acreage. However, they do not highlight behavioral foundations for a system of acreage demands through the links, for example, between acreage demands and a behavioral model such as competitive profit maximization. Moreover, some disadvantages with the multinomial logit approach are that the multinomial logit models tend to become increasingly complex with an increase of the number of crops (while other functional forms such as translog share equations yield positive predicted shares over the sample period), each logit equation must share a common term, coefficients in individual share equations are not identified, and any variable having a significant influence on one share must have a significant influence on all shares (Bewley, Young and Colman, 1987).

Since model diagnostic issues such as multicollinearity are common in multiproduct models of the acreage response system, crop acreage demands are commonly misspecified by adopting highly restrictive functional forms. In doing so, acreage response models have omitted many of the possible cross-price effects between crops (e.g. Burt and Worthington, 1988). Coyle (1993) presents an alternative approach to the specification of systems of crop acreage responses by adopting restrictions on coefficients implied by fundamental behavioral theory. Given the assumption of weak separability between broad groups of enterprises (crops and livestock), Coyle's two-stage aggregation model specifies a linear system of acreage equations as a function of all product prices, all variable input prices, levels of quasi-fixed capital and total amount of crop acreages by assuming (expected) profit maximization and by applying duality theory. The effects of multicollinearity in the system are reduced because of separability and dynamic specifications. Further, the model developed by Coyle (1993) is based on formal economic models, and therefore it takes into account the reciprocity, homogeneity and adding-up restrictions. From the standpoint of behavioral consistency, Coyle's dual approach to estimate area allocation decisions is a significant addition to the previous contributions by Binkley and McKinzie (1984) and Bewley, Young and Colman (1987).

The constraints imposed by total acreage have not been incorporated into acreage demand models specifications reported in the literature (as they have been for other agricultural supply models, for instance, by Chambers and Lee, 1986) and estimates of acreage scale elasticities defined as the response of a particular crop area to an increase in total agricultural land typically have not been reported. Barten and Vanloot (1996) by emphasizing scale elasticities derive a system of (linear) acreage allocation models using the basic mean-variance utility framework. The system they estimate represents a first-order differential acreage allocation model. The authors show that estimates of price and scale elasticities may be readily obtained from their model. The Barten and Vanloot's specification is useful in estimating acreage response with time-series data but has limited application to cross-sectional or panel data. Holt (1999) extends Barten and Vanloot's analysis to deal with cross-sectional and panel data by showing that a levels version of the basic Barten and Vanloot's acreage allocation model is readily attainable, and derives an acreage allocation model as a function of total acreages available, expected net returns and state-specific dummy variables. Holt uses the same framework as Barten and Vanloot, which is consistent with certainty equivalent profit maximization and constant absolute risk aversion, and so his model is useful for maintaining the theoretical properties of homogeneity, symmetry and adding-up.

The acreage response models that incorporate risk effects have been modeled for commodities on a single equation basis, for instance, by Traill (1978), Just (1974), and Krause, Lee and Koo (1995). The single equation nature of these supply models can only be a partial representation of the more complete supply system that may represent the agricultural producer's decision problem. Thus, generalizing risk response models to system of equations may be desirable, and it has been pursued by Chavas and Holt (1990), Coyle (1999), and Lin and Dismukes (2007).

Under assumptions of certainty or risk neutrality, complete supply systems are commonly applied using flexible functional forms for dual representations of technology (such as profit and cost functions). Coyle (1999) has extended this dual approach under risk which greatly simplifies the derivation of coherent systems of output supply and input demand equations. His analysis, however, relies on a mean-variance objective function and this approach, which is consistent with constant risk aversion and normality of profit distribution, is an approximation to the more general expected utility model. Chavas and Holt (1990) developed a system of acreage supply response models under general expected utility maximization. They found that the acreage decision is a function of expected net returns for the own and competing crops, variance-covariance of the net returns, and farm household wealth. Chavas and Holt's framework is also useful for maintaining the theoretical constraints of homogeneity and symmetry.

In general, reviewing the literature pertaining to acreage response shows that future prices or adaptive expectations, and the weighted three-year moving average of variances are the main proxies used for expected prices and expected variance-covariance of prices, respectively. Moreover, since single commodity studies fail to incorporate all alternative uses of land, the importance of considering risk in a multicrop framework and cross-commodity risk effects is apparent.

3.2 Literature Review Pertaining to the Impact of Decoupled Payments on Acreage Response

By recognizing that domestic farm support programs could distort trade, in the 1994 Uruguay Round Agreement on Agriculture (URAA) of the World Trade Organization (WTO), member countries of the WTO decided to reduce the trade distortions that are caused by domestic farm subsidies. As a result, members were provided with incentives to shift their supports for farmers toward decoupled income support by defining these subsidies as non-actionable.

The impact of any type of government payments on acreage decisions depends on the nature of the program through which support is provided, the incentives that it creates and the behaviour of farmers in response to those incentives. If government payments affect the relative profitability of alternative crops, profit maximizing farmers are likely to adjust their production plans in response to such payments. In the short run, farmers' responses are likely to be reflected in the amount of land allocated to alternative crops and amounts of variable inputs (such as fertilizer and labour). In the long run, farmers' responses are likely to be reflected in the level of investment in machinery and other quasi-fixed assets (and possibly in the total amount of land in production). If the amount of government payments increases with the volume of production and the additional revenue obtained from expanding production (the returns obtained from selling the crop plus government payments) exceeds the additional costs of that production, then the above effects (changes in the amount of land allocated to alternative crops in the short-run and in the level of investment in machinery and other quasi-fixed assets in the long-run) would be apparent.

Farm programs are thought of as being coupled if there is a strong or direct link between the determination of the program benefit and the farmer's production and market conditions (such as prices). In contrast, farm programs are thought of as being decoupled if program benefits do not depend on the farmer's production or market conditions. Although decoupled payments are determined based on existing information pertaining to the commodities production, actual production in the current year does not affect the level of payments. The figures used to determine payments relate to historical data. Thus, decoupled payments do not depend on current production or on actual market prices. Considering this, it seems that it would be unlikely to find evidence of an effect of decoupled payments on acreages response.

However, there are several mechanisms in which decoupled payments can indirectly affect agricultural production (OECD, 2001; OECD, 2004). These are as follows: first, if farmers are constrained by credit limitations, then the additional income generated by decoupled payments may increase their access to borrowed capital. With the opportunity to borrow more funds, a farm operator's profit maximizing production levels could increase[1]. If farmers face capital constraints, then decoupled payments may relax these constraints by influencing the supply of loans to agricultural producers. If the additional income is provided by a known stream of future decoupled payments (rather than the uncertain stream of producers' market returns), lenders consider the risk of non-repayment to be lowered and so they will be more willing to lend to farmers. Also, decoupled payments may increase the value of fixed assets, particularly land, which represents an increase in farmers' equity. Hence, the farmers' ability to secure loans may be increased.

Second, decoupled payments could affect farmer expectations by linking current decisions to future payments. Expectations about future payment changes could alter current production decisions. If a farmer believes future decoupled payments will be based on current production, they may increase the production of those crops for which they expect to receive

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[1] Although decoupled payments have the potential to increase the liquidity of credit constrained farmers, for this to apply, firstly there has to be a market failure in capital markets. Imperfect capital markets provide an insufficient supply of capital to agricultural borrowers. Also, imperfect capital markets provide a supply of capital at a price (interest rate) which exceeds its opportunity cost in other uses. Secondly, farmers have to use the funds provided by decoupled payments in investment for enhancing production rather than for any other uses.

the future payments[1].

Third, if production is unprofitable at prevailing market prices, then the additional income provided by decoupled payments may enhance the ability of farmers to cover fixed and variable production costs and, therefore, decoupled payments may increase production in the short run[2]. Also, the existence of decoupled payments may prompt some farmers to remain in agriculture, rather than exiting the industry. In this case, the provision of decoupled payments would result in production of supported crops being maintained at a higher level than the case when decoupled payments are not provided. Moreover, farmers may be operating on the downward part of their average total cost curve, i.e. under increasing returns to scale. In this case, it would be economically rational to use some or all of the additional revenue from decoupled payments to expand production.

Fourth, decoupled payments may accrue to landowners through higher land rents and land values. This can lead to land remaining in agriculture. If the farmer is the landowner, this can make credit more accessible to farmers, and therefore can affect production.

Fifth, decoupled payments that serve to increase wealth may lead to changes in the risk preferences of farm operators. If farmers are risk averse, the increase in wealth created by the payments may make farmers less risk averse and cause them to expand production by planting more risky crops (wealth effect). Moreover, if decoupled payments vary inversely with market prices, since this would reduce income variability, these payments may lead the farm operator to increase production (insurance effect).

Therefore, decoupled payments may affect farm operators' production decisions by altering their access to capital, their expectations of future payments, their production costs' coverage, or their risk preferences and income variability. These relationships all posit that decoupled payments indirectly affect production decisions. Some researchers find little evidence of decoupled payments influencing production (Goodwin and Mishra, 2005), while others claim that the relationship may be significant (Hennessy, 1998). In what follows, we review six sets of available literature about how decoupled payments affect production. We briefly[3] review the available literature on how decoupled payments affect production by relaxing the capital constraints faced by farmers, by altering farmers' expectations of future

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[1] For there to be a link between current payments and these production decisions, farmers have to believe that the existence of payments today is a predictor of payments in the future, or they have to believe that current levels of payments provide an indication of what future payment levels would be.

[2] For this to apply, farmers must choose to use decoupled payments to cover production costs, rather than to increase their consumption or savings.

[3] See Bhaskar and Beghin (2009) for more details.

payments, by reducing farm exits, and by increasing land values. Then, we assess the studies which examine the affect of decoupled payments on production in general. We end with a focus on the literature regarding the effects of decoupled payments on risk attitude and income variability, and therefore the production changing effects of decoupled payments.

3.2.1 Credit Constraints Effects

Barry, Bierlen and Sotomayor (2000) test the "pecking order theory of firm investment" in the context of farm businesses. This theory predicts that firms initially prefer to use lower cost internal funds to finance investments, followed later by higher cost external funds as necessary. More specifically, they examine whether the investment decisions of farms operating in imperfect financial markets (where there are gaps between a farm's costs of internal and external sources of investment funds) are sensitive to the availability of internal funds. They use farm-level panel data for 1990-1994 from the state of Illinois and estimate a simultaneous farm financial system—a system of long term debt, short term debt, investment and leasing payments equations with cash flow (which includes the government payments) as an exogenous variable in the system among other variables—using a GMM procedure. The results support the pecking order theory, indicating that a strong cash flow leads farmers to increase investment while reducing debts or refraining from borrowing. An additional dollar of cash flow in the full sample of farms leads to about 0.60 dollar in additional investment. By splitting the sample into high credit risk farms and low credit risk farms, the authors find that an additional dollar of cash flow leads to about 0.70 dollar in additional investment among high credit risk farms and about 0.50 dollar in additional investment among low credit risk farms.

Roe, Somwaru, and Diao (2003) examine whether the production flexibility contract payments (PFC)—an instrument of the U.S. 1996 Federal Agriculture Improvement and Reform (FAIR) Act—to farmers have intertemporal effects on resource allocation and production decisions to the extent that they may be trade distorting. They consider this issue in an intertemporal and economy wide context. First, the authors examine the link between PFC payments and land values by a simple regression analysis using data from statistical reporting districts in Minnesota for the period 1994 to 2000. Their results suggest a positive correlation between government payments and land value, a ten percent change in government payments led to a 3.24 percent change in land values between 1994 and 2000. This appreciation in land values affects investment by increasing farmer's access to credit as land is used as collateral. Next, the authors examine the effects of PFC payments on resource allocation and production under perfect and imperfect capital markets using an intertemporal three sector general equilibrium (GE) model of the U.S. economy based on the year 1997. PFC payments are incorporated in the model as a lump-sum transfer from urban households to the rural households who own land and undertake agricultural production. PFC payments are assumed to be 6.11 billion dollars in 1997 and are paid to farmers in each period of time from 1997 in perpetuity. The steady state solutions of the model with and without (considered as the benchmark) the PFC payments are compared. The results indicate that if agricultural capital markets are complete, then the key effects of payments over time are to increase the value of land (the 6.112 billion dollars payment, in the short run, causes land values to exceed their values in the benchmark by almost 9 percent, and by about 8.3 percent in long-run), but they have no effect on production. If capital markets are not complete (or liquidity constraints prevail in agriculture), there are production effects, but they are small (0.18 percent) in the short run[1]. In the long run, payments cause no resource allocation and output effects[2] and the only long-term effect of payments is to increase land values and land rental rates. Table 3.3 summarizes papers related to the credit constraint effects of decoupled payments.

Table 3.3: Some Studies related to the Credit Constraint Effects of Decoupled Payments

Papers	Focus of Study	Method	Result(s)
Barry et al. (2000)	To examine the sensitivity of farm investment decisions in imperfect financial markets to the availability of gov't payments	Farm-level panel data for 1990-1994 from Illinois is used to estimate a simultaneous farm financial system by GMM method	An additional dollar of cash flow leads to about 0.60 dollar in additional investment
Roe et al. (2003)	To examine the production effect of PFC	An intertemporal 3-sector GE model is applied to 1997 U.S. data	Increase in PFC (decoupled payment) by \$6.11 bn leads to increase in production by 0.18 % and decrease in rental rate on capital by 0.1%

3.2.2 Expectations Effects

Tileu and Roberts (1998) analyze decoupled payments in the U.S. and European Union. They argue that farmers, based on their past experience, may be justified in believing that establishing a basis of high production may provide the basis for higher payments under future

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[1] In this case, direct payments tend to cause capital deepening (the rental rate of capital in agriculture declines by 0.1 per cent in the first 10 years as compared to the benchmark), to increase the employment of labour, and to increase the value of land.

[2] In the long run, the differences in the rental rates of capital within agriculture and within the rest of the economy are arbitraged away and there is convergence to the benchmark.

supports, and this would give them an incentive to expand output. Therefore, expectations about the impact of current production decisions on future support could reduce the extent of possible decoupling and lead to market distortions. If a farmer believes that a future government payment will update a crop base acreage based on how much crop is produced today, he/she may substitute the production of a currently more profitable crop for the production of a program crop.

Lagerkvist (2005) examines how agricultural policy uncertainty affects farmland investment incentives. He considers two types of uncertainty related to 2003 Mid Term Review (MTR)[1] reform of the direct payment system within the Common Agricultural Policy (CAP) of the European Union area payment: (i) uncertainty about the timing of the reform; and (ii) uncertainty about the level of post-reform payment. Lagerkvist develops a dynamic stochastic programming model of the short-term required rate of return (RR) for farmland investment to capture farmland investment incentives and then derives solutions for the adjustment of the RR of farmland, based on expectations about the timing of an area payment reform and the size of the post-reform area payments. Numerical analysis based on survey data from a sample of Swedish farmers, designed to assess the subjective probability beliefs (expectations) of farmers concerning reform of the CAP area payment system, indicates that the pre-reform RR taking into account timing uncertainty is less than the RR with complete certainty. Moreover, the pre-reform RR under both timing and post-reform area payment uncertainty and a non-positive correlation between the timing of the reform and the post-reform payment is found to be less than the RR when only timing uncertainty is considered. Generally, Lagerkvist suggests that lack of complete information causes inefficiency by inducing farm operators to over-invest before the reform date if they expect a reform that is likely to reduce their area payment.

Sumner (2003) analyzes, among other things, the implications of the Farm Security and Rural Investment Act of 2002 (FSRIA)[2] for crops production. The most interesting change in the FSRIA is the updating of the base areas and base yields from the fixed 1981-1985 bases in the old law. This updating in the 2002 Farm Bill caused farmers to revise estimates of the probability of future updating. This means that, in deciding what to plant on payment-base acres, the effect of current production on the present value of future payments becomes

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[1] In 2003 the European Council agreed upon a new reform of its Common Agricultural Policy (CAP). This reform was decided in the context of a mid-term review of the Agenda 2000 CAP reform.

[2] The Federal Agriculture Improvement and Reform (FAIR) Act of 1996 was superseded by the Farm Security and Rural Investment Act (FSRIA) of 2002.

a more important factor. If farmers expect a large effect from current area and yield on the base used for future payments, then they will plant more of the program crop now to build a program base for the future (i.e. a link between current production decisions and anticipated payments). Sumner constructs the degree of linkage between payments with potentially updated bases and current production and evaluates how much a current update affects that degree of linkage. The degree of linkage depends on the probability that the program remains operative in the future, the probability that an update occurs, how the new base affects payments compared to how the current program operates in that regard and other factors (the expected future payment rate relative to the current payment rate and the expected marginal effect of current area planted on the new base). The degree of linkage is sensitive to the probabilities and discount factor used. A high degree of linkage implies that payments such as the decoupled direct payments with potentially updated bases in the future have a strong link to current production.

McIntosh, Shogren and Dohlman (2007) examine two features of the U.S. Farm Security and Rural Investment Act (FSRIA) of 2002: (i) the prospect of earning countercyclical payments (CCPs) on the farmer's endowment of historically produced base crop acreage when prices of these crops fall below predetermined target prices; and (ii) the option for farmers to update the allocation of base crops—from which direct payments (DPs) and CCPs are determined—to reflect recent (1998-2001) production history. They use experimental economics to study the effects of CCPs and base acre updating on supply response under price and policy uncertainty. Each participant is endowed with a fixed number of tokens (i.e., acres) and asked to allocate them to a Blue option (representing a program crop) and a Red option (representing a non-program crop or a crop that has not been planted earlier). These allocation decisions are made under three policy situations, each incorporating direct payments (DPs): (a) price uncertainty without CCPs; (b) price uncertainty with CCPs; and (c) price uncertainty as well as uncertainty regarding base acreage updating (policy uncertainty) with CCPs. The authors explore the panel data allocation choices using a random-effects model and the results indicate that with CCPs, laboratory decision makers increased their investment in the the program crop (Blue option) relative to the absence of CCPs, despite payments being decoupled from current production decisions. When base acreage updating and policy uncertainty is added, they continued to allocate more acres toward the program crop than under a more policy-neutral environment[1]. These results

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[1] There was a 5.43 per cent shift in base acres towards the program crop with the CCPs case. Under the

provide evidence that both the CCPs and the possibility of future base updating introduce new incentives for farmers that make cropping decisions based on government payments, rather than expected market returns.

Coble, Miller and Hudson (2007), also, analyze the impact of two instruments of the U.S. Farm Security and Rural Investment Act of 2002 (FSRIA), direct and counter-cyclical payments, on the producer expectations for base acreage and yield updating (and therefore on incentives to alter production decisions). They use survey data from Iowa and Mississippi farmers during 2005 to assess the value that producers place on the opportunity to update base acres and program yields using a contingent valuation approach and to gain insight into the subjective expectations of farmers for base updating and whether these expectations might influence current plantings. In the survey, they ask questions regarding the probability of base and program yield update occurring for direct and counter-cyclical payments, whether payment rates will change or remain the same and if farmers made any adjustments in current acreage to affect future program payments. Results suggest that on average producers think that the chance of updating in direct and counter-cyclical payments is about 40 per cent, and only 17 per cent of these producers indicate making adjustments to acreage or yields in anticipation of updating. Moreover, the authors use a censored probit model with the dependent variable as the willingness to accept (WTA) a buyout of a potential base updating opportunity (which captures the value that farmers place on the opportunity to update base acres) and independent variables as expectation of an update, age, risk aversion, farm income, etc. They find that the WTA increases with a greater expectation of an update and a higher percent of farm income. Based on the regression results, the mean WTA across both states is 48.16 dollars per acre. Table 3.4 summarizes papers related to the expectation effects of decoupled payments.

3.2.3 Farmers Entry/Exit and Structural Change Effects

Chau and de Gorter (2005) examine the effects of decoupled payments on exit decisions by farmers, and therefore on production. They address the question as to whether decoupled payments subsidize production and at times cross-subsidize exports. Using the two-stage profit maximization problem of a producer (first stage, whether or not to incur the fixed cost; and second stage, the choice of an output level given input prices, target price for domestic consumption and world prices), the authors develop a generalized theoretical model of cross-

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policy risk case there was a shift of 7.92 per cent in base acres towards the program crop.

Table 3.4: Some Studies related to the Expectation Effects of Decoupled Payments

Papers	Focus of Study	Method	Result(s)
Lagerkvist (2005)	To examine farm investment effects of area payments under timing and support uncertainty through a dynamic stochastic programming model	Numerical analysis based on survey data from a sample of Swedish farmers	Expected decrease in area payments leads to over-invest
McIntosh et al. (2007)	To examine the production effect of CCPs under price and policy uncertainty	Estimation of a random-effects model using data obtained from an experiment	Policy uncertainty leads to a shift of 7.92% in base acres towards the program crop
Coble et al. (2007)	To examine the effect of occurring base acreage updating for CCPs and to analysis the effect of these expectations on the value that farmers place on the opportunity to update base acres	A censored probit model using survey data from Iowa and Mississippi farmers in 2005	A greater expectation of an update leads to increase in willingness to accept a buyout of the right to update

subsidization in which farmers receive both coupled and decoupled support. The size of coupled and decoupled taxpayer financed income support is modeled by an ad valorem subsidy (which is incorporated in the model through the unit revenue farmers receive for exports) and a lump sum subsidy (which is incorporated in the model through a fixed revenue), respectively. There are farmer-specific fixed costs and variable costs. From the second stage of profit maximization, the authors obtain the result that decoupled payments do not affect farm level output decisions, but these payments can impact aggregate output by distorting the exit incentives in the first stage of profit maximization. Decoupled payments allow farmers to incur fixed costs, and thus allow those with higher fixed costs to stay in production. Otherwise these farmers would have exited the industry. The authors employ their theoretical framework in an empirical example using the production and cost structure of the U.S. wheat sector to show the comparative effects of loan deficiency payments (LDPs)—as a coupled payment—to production flexibility contract (PFC) payments—as a decoupled payment. The results are broadly consistent with their analytical findings, and indicate that in the long run with the possibility of exits, totally removing PFC payments leads three per cent of the farmers to exit the industry, and leads to a reduction in production and exports.

Gaisford and Kerr (2001) look at the effects of decoupled payments on long-run entry and exit decisions. Subsidies based on historic output levels increase long-run output above the level that otherwise would have prevailed, because they are typically designed to keep some farmers in business that would otherwise go bankrupt and have an incentive to exit the industry. As a result, imports will be lower or exports will be higher than would otherwise have been expected.

3.2.4 Land Markets Effects

Schertz and Johnston (1998) conduct a study in four major U.S. agricultural regions, the Great Plains, the Corn Belt, the South and California, based on the responses of farm managers or operators to the production flexibility contract payments (PFC) as an instrument of the 1996 Federal Agriculture Improvement and Reform (FAIR) Act. Based on the survey results, the authors conclude that the PFC payments inflate land prices and land rents because of their non-stochastic nature. In the case of cash leases much of the payments pass on to the landowner by increased rents. In the case of crop share leases, payments create incentives for the landowner to adjust the lease to take advantage of the PFC payments, for example in some cases landowners shifted to cash leases.

Gohin, Guyomard, and le Mouel (2000) provide a theoretical framework for analyzing the agricultural supply responses (land and production) to various support policy instruments and examine whether the Green Box specific criteria for decoupled income support are well-designed (no or minimal trade distortion effects). They use a static partial equilibrium model with two perfectly competitive mono-product sectors (with a constant returns to scale production technology) using a variable input, a specific factor and a fixed allocatable factor such as land. They consider domestic support instruments such as output subsidies, variable input subsidies, and decoupled payments based on the specific factor, and on land. Optimal output supply and derived input demands are determined by a two-stage profit maximization process[1]. Land prices are determined endogenously by the market clearing condition for land. Land prices are computed under two alternative assumptions: land homogeneity and heterogeneity. Comparative static analysis indicates that production effects induced by a policy instrument depend on whether this instrument is applied only in one sector or in both sectors, whether this instrument is implemented alone or in conjunction with other instruments and whether the production technology is different. When a same direct support instrument (or a same set of instruments) is applied in two countries with different agricultural production technologies and factor mobility situations, it may lead to very different production effects[2]. Hence, since the Green Box decoupling criteria do not take into account these aspects related to production conditions (which vary widely across countries), they may prove to be insuffi-

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[1] In the first stage, the output and variable input optimal quantities are determined for a given land allocation. In the second stage, optimal land allocation is determined by considering the price of land in optimization.

[2] Comparative static analysis shows that land-based direct payments affect land prices, land allocation and, hence, output supplies. Thus, such a policy instrument may not be considered as decoupled from production.

cient both to ensure decoupling and to take account of the relative degree of decoupling of various income support instruments.

Dewbre, Anton and Thompson (2001) employ the policy evaluation matrix (PEM) model to examine both analytically and empirically the effects of direct payments on trade and income transfer efficiency. The authors consider the four main categories of support provided to crop producers in OECD countries: market price support, area payments or payments based on land use (one requiring production for eligibility and the other that land be kept in arable use), payments based on use of purchased inputs, and output payments. The analysis is based on a two-region (OECD countries and rest of the world) model of equilibrium in the world market for a representative crop. Analytical solutions to this model are developed to compare the production, trade, and income effects of the different support measures. The paper focuses exclusively on the effects of support measures produced through their incidence on relative prices. These relative prices measure the effect on production, trade, and farm income of a given change in support provided by any one of the three categories of direct payments, relative to the estimated impact on production, trade and farm income of the same monetary change in market price support. The effect of area payments on production, trade and farm income, which arises because of their impact on land prices, is compared with market price support as the reference category. The analytical results show that there is a decreasing marginal impact on production, trade, and farm income for all support measures studied when there is a large initial rate of support. In theory, depending on the initial patterns of support and the size of the country in trade, any ranking of policy measures is possible. Then, the authors employ a policy simulation analysis of the model using data from two base years—1987 and 1998—and parameter estimates derived mainly from reviews of published studies. The results from model simulation indicate that the area payments are a less trade distorting way of supporting farm incomes as compared to the other three forms of support. Within the area payments, the one requiring only land remain in agricultural use has a smaller effect on trade than the one which requires production of eligible crops[1]. Input subsidies have a larger impact on trade as compared to the market price supports. Results obtained in the analysis show that input subsidies prove to be the most inefficient form of support in terms of providing income support while area payments prove to be the most efficient.

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[1] In 1998, production impacts ratios of area payments (requiring land be kept in arable use) with respect to market price support are 0.09 in U.S., 0.06 in EU and 0.10 in Canada.

Roberts, Kirwan and Hopkins (2003) examine the effect of government payments (the production flexibility contract payments (PFC), loan deficiency payments (LDP) and other payments) on land rents (and consequently on production) using data from the 1992 and 1997 U.S. Agricultural Census across 75,858 farms. Based on the economic theory that land rents should equal expected returns less payments for factors other than land (and including government payments), the authors regress land rents on net returns and government payments. Results of fixed-effect model indicate that government payments had a significant impact on land rents. For the 1997 cross section, rents increase between 0.33 dollar and 1.55 dollars for each government payment dollar (in 1997 PFC payments were the major government payments). For the 1992 cross section, the effect on land rents is smaller reflecting the transitory component of government payments in that year.

Goodwin, Mishra and Ortalo-Magne (2003) use U.S. data to estimate the effect of government payments on farmland values for 13,606 farms from 1998 to 2001. The net present value of a farmland is the sum of expected future cash flows discounted according to the risk of these cash flows. Cash flows from the same source have the same discount factor. The authors consider three sources of future cash flows: market returns, government payments and the non-agricultural returns to land. In their regression models, they consider determinants of land rents as follows: market price index, returns (excluding government payments) to the typical acre of land, and the normalized yield indicator (showing the inherent profitability of one farm relative to other farms) that represent agricultural returns from the market; the total value of housing permits issued in the county in which the farm is located, population density, and population growth rates that represent the capital gains inherent in land in areas facing non-agricultural demands for agricultural land at the rural-urban interface; production flexibility contract payments (PFC), loan deficiency payments (LDP), disaster assistance payments, conservation reserve program payments (CRP), and an aggregate of other farm program payments. In the regression analysis, each government program has been considered separately as programs differ according to support provided. Also, the uncertainty associated with each program differs. The result of probability-weighted bootstrapping approach confirms that government payments affect land values. For example, PFC payments have a positive and significant effect on farmland values, with a dollar increase in PFC payments leading to an increase in land values of 4.94 dollars per-acre .

Frandsen, Gersfelt and Jensen (2003) employ a computable general equilibrium (CGE) model to analyze the production and trade impacts of decoupling income supports of the more recent reform (Agenda 2000) of the Common Agricultural Policy (CAP) in the EU. The benchmark model is constructed for the period 1997-2013 and captures the structure of the domestic support in the EU. The benchmark model is compared with the scenario where all domestic support is converted into a single region specific decoupled payment to land (among two other scenarios). Under this scenario, there is a substantial increase of 75.1 per cent in land prices for the EU as a whole. If all EU countries are treated individually, land prices also increase. Moreover, the results indicate a decrease in the production of wheat, other grains, oilseeds, bovine animals, and cotton by 6.9, 5.6, 8.9, 11, and 63 per cent respectively. These decreases reflect the high level of domestic support for these commodities under Agenda 2000. The authors conclude that the existing domestic support payments in the EU affect production decisions and, hence, distort trade. Further, the value of this support is capitalized in significantly higher European land prices than would otherwise prevail.

Gohin (2006) employs a static, multi-sector computable general equilibrium (CGE) model of the EU15 economy with perfect competition in all markets and constant returns to scale to analyze the production impact of the 2003 Common Agricultural Policy (CAP) Mid Term Review (MTR). Using 1995 data to calibrate the technological and political parameters, the author adopts two different assumptions about the modeling of Agenda 2000 direct payments. Under the first assumption, arable crop direct payments will be fully capitalised in the land rental price at the 2008 projection (the capitalisation rate is 100 per cent) and beef premiums are not constrained by any maximum limit, which represents current modelling of Agenda 2000 direct payments in different studies and is called the standard approach. Under the second assumption, arable crop direct payments are partly capitalised in land (by 50 per cent) at the 2008 projection and beef premiums are only paid on a limited number of animals. They call this the alternative model. Under both assumptions, direct payments are based on land use and therefore increase land rents by 164 per cent under the first assumption and 38.5 per cent under the second, and the direct payments seem to have a moderate degree of coupling. The 2003 MTR reform requires the decoupling of direct support by the creation of a Single Farm Payment (SFP). In his simulation, Gohin assumes that the CAP MTR entails Agenda 2000 arable crop direct payments are reduced by 90 per cent, the slaughter premium on adult animals is reduced by 80 per cent and the suckler cow premium and the special beef premium are reduced by 50 per cent and 90 per cent respectively. It is also assumed that the SFP has no market effects. The simulation results indicate that under both assumptions, land rents decrease by at least 80 per cent. There are also negative impacts on arable crop and beef production. The results of the standard model indicate soft wheat and beef production decrease by 1.6 per cent and 3.6 per cent respectively (similar to the other studies). The results of the alternative model (which acknowledges imperfections in the land market as well the eligibility rules of beef premiums) are in the same direction but the magnitude of the impact differs with a decrease of 7.3 per cent in soft wheat production and a 1.2 per cent decrease in beef production. The varying results in the two models suggest that the impacts of the CAP MTR are sensitive to the modeling of the Agenda 2000 direct payments. Table 3.5 summarizes papers related to the land market effects of decoupled payments.

Table 3.5: Some Studies related to the Land Market Effects of Decoupled Payments

Papers	Focus of Study	Method	Result(s)
Gohin et al. (2000)	To analyze theoretically the agricultural supply responses (land and production) to various support policy instruments including direct payments based on land	Comparative static analysis using a static partial equilibrium model	Land-based direct payments affect land allocation and so output supplies
Dewbre et al. (2001)	To examine the production and trade effects of area payments (among other forms of support) using their effects on land prices	A policy simulation analysis of the policy evaluation matrix (PEM) model in OECD countries using data 1998	In 1998 production impacts ratios of area payments (requiring land be kept in arable use) with respect to market price support are 0.09 in U.S., 0.06 in EU and 0.10 in Canada
Roberts et al. (2003)	To examine the effect of government payments (PFC, LDP and other payments) on land rents (and therefore on production)	Estimating fixed effect model (of land rents equal to expected returns less payments for factors other than land and including government payments) using data from the 1992 and 1997 U.S. Agricultural Census across 75858 farms	In 1997 cross section, for each government payment dollar (in 1997 the production flexibility contract payments were the major government payments) rents increase between 0.33 dollar and 1.55 dollars
Goodwin et al. (2003)	To estimate the effect of U.S. government payments on farmland values	Estimation of the net present value model of a farmland which includes government payments using probability-weighted bootstrapping approach for 13606 farms from 1998 to 2001	A dollar increase in PFC payments leads to an increase in land values of 4.94 dollars per-acre
Frandsen et al. (2003)	To analyze the production and trade impacts of decoupling income supports of the Agenda 2000 of the CAP in the EU	Employ a multi-regional, static computable general equilibrium (CGE) model which captures the features of the domestic support in the EU for the period 1997-2013	Under the scenario that all domestic support is converted into a single region specific decoupled payment to land, there is a substantial increase of 75.1% in land prices for the EU as a whole
Gohin (2006)	To analyze the production impact of the 2003 Common Agricultural Policy (CAP) Mid Term Review (MTR)	Employs a static, multi-sector computable general equilibrium (CGE) model of the EU15 economy and policy simulation based on the 1995 data as an initial point	Agenda 2000 area payments increase land rents by 38.5% and the 2003 MTR single farm payments decrease land rents by 81.8%

3.2.5 General Effects

Adams, Westhoff, Willott and Young (2001) study empirically the production effect of fixed production flexibility contract payments (PFC) and market loss assistance (MLA) payments as two instruments of the U.S. Federal Agriculture Improvement and Reform (FAIR) Act of 1996. They examine the effect of PFC and MLA payments on the total area planted to wheat, corn, sorghum, barley, oats, cotton, rice and soybeans in eleven states using data for the years 1997-2001. Two hypotheses of whether the PFC and MLA payments have an impact on total area planted to the major crops and whether the PFC and MLA payments (as decoupled payments) have a different impact on total area planted than do returns from market sales and marketing loans (as coupled payments) are tested. For the first hypothesis, the authors estimate two econometrics equations, in one equation total area is regressed on state dummy variables and sum of expected real gross per acre market returns (by assuming naive expectations) and loan programs, in another equation the sum of four income sources (gross market returns, marketing loans, PFC payments, and MLA payments) is added to the first equation as a single independent variable. The results indicate that PFC and MLA payments do have some direct effect on the area planted (the estimated elasticity on PFC/MLA payment variable is 0.026). For the second hypothesis, the authors also estimate two econometrics equations, in one equation total area is regressed on state dummy variables and the sum of four income sources, in another equation the sum of PFC and MLA payments is added to the first equation as a single independent variable. The results do not provide a clear indication whether PFC and MLA payments have different effects on area planted than market returns and marketing loans. The authors conclude that although the results in this study provides weak evidence that PFC and MLA payments do affect directly the total area devoted to crop production, there are some indirect mechanisms by which acreage decisions could be affected by decoupled payments. It should be noted that the results in the study are based on the assumptions that the elasticities are the same across states and on naive expectations on part of the farmers' in the computation of expected market returns and expected MLA payments.

Guyomard, Le Mouel, and Gohin (2004) analyse and compare four agricultural income support programs (an output subsidy, a land subsidy, and decoupled payments with and without mandatory production) according to their ability to support farmer' incomes, increase the number of farmers, reduce negative externalities arising from non-land input use and minimize trade effects (four policy objectives). To compare the impacts of the four income support programs, they are standardised to an equal budget cost basis. For each policy objective, one program is considered to be more efficient than another if for the same budget cost, the impact of the first program on this objective is greater than the impact of the second program on the same objective. The authors' one sector static model under certainty is based on three equilibrium equations, representing equilibrium in the output market (with aggregate supply equal to domestic demand and exports), equilibrium in the land market (with aggregate supply equal to aggregate demand) and an exit/entry condition. The exit/entry decisions depend on decoupled payments with mandatory production and so they appear in the exit/entry condition and they increase the number of farmers. The decoupled payments without mandatory production does not enter the three equilibrium equations. It has thus no impact on the output price, the land price or the number of producers. It has a positive impact on the individual profit of a producer and so on total profit, but no impact on the other three policy targets. Two main conclusions from the analysis are obtained; firstly, none of the four income support programs dominates others for the four policy goals. Second, for each policy target, the ordering of the four income support programs depends on conditions—elasticity of output supply with respect to land used and/or the derived demand elasticity of land with respect to output—that cannot be predicted by theory alone. The analytical results also indicate that the decoupled payments without mandatory production is most efficient way of supporting farmers' income with the least distortion of trade while the decoupled payments with mandatory production are the most efficient in maintaining or increasing the number of farmers.

Serra, Zilberman, Goodwin, and Hyvonen (2005b) assess the impact of decoupled payments on the use of crop protection inputs by analyzing the effect of the post-MacSharry Common Agricultural Policy (CAP) reforms in the EU on the use of pest control inputs (that have potentially negative effects on the environment) in two sectors - the cereal, and oilseed and protein crop (COP) sectors. By decomposing the profit maximization problem into two main problems: profit maximization and abatement cost minimization, optimal crop supplies, input demands, and land allocations are obtained by applying the Hotelling-Shephard lemma to the optimization problem. Using a two-step process, damage abatement functions are specified to capture the contribution of the pest control inputs in reducing crop damage in the first step, and the parameters of the crop protection products demand among the two sectors are estimated. In the second step, the direct effect of area payments on a system of crop supplies and land allocations is estimated. The optimal use of pesticides depends on output and land allocation which are directly affected by area payments. Therefore, the authors derive the elasticity of demand for pest control inputs with respect to price support measures and area payments. They hypothesize and find that the input response to decoupled (area) payments is less than their response to price support measures, using a sample of French farms over the period 1994 to 1999 (elasticity estimates with respect to area payments is 0.35 and to price support is 1.04 for cereals, and to area payments is 0.39 and to price support is 1.20 for oilseeds and protein crops). It is suggested that the 1992 CAP reforms involved a certain degree of policy decoupling. However, decoupled payments, though less distorting than price supports, continued to influence farmers' decisions. Based on the estimated parameters, the authors simulate the effects of shocking the model in accordance with the changes introduced by Agenda 2000 (decrease in cereal intervention prices and increase in its area payments, and reduction in area payments for oilseeds and protein crops) and the 2003 Mid-Term Review (combination of a number of direct payments such as area payments into a single farm payment—SFP). The implementation of Agenda 2000 results in a reduction in the use of crop protection inputs slightly more than 3 per cent, and a shift in land allocation away from oilseed and protein crops to cereals. Implementation of the 2003 Mid-Term Review suggests the use of crop protection inputs declines by 11 per cent, and cereal acreage and production fall while oilseeds and protein crops acreage remains almost constant.

An alternative approach by Bastian et al. (2008) and Nagler et al. (2009) uses experimental economics techniques (laboratory markets) to assess the impacts of a decoupled policy alternative called a buyout bond scheme on production decisions. Under the buyout bond scheme, producers in receipt of a buyout bond would garner a guaranteed stream of income during a transition period of fifteen to twenty five years in exchange for giving up all future government program subsidies. This bond would have financial value and could be sold over its life, allowing producers to receive income annually or in a lump sum. Data from five experiment treatments, no policy, deficiency payment (i.e. coupled price-support treatment), annually paid bond subsidy, and lump-sum bond subsidy, were analyzed through simple descriptive statistics, using a standard convergence model, and graphically. The convergence model provides a way to describe mean convergence levels over time and compare differences in these convergence levels across experimental treatments. The results indicate that production under the traditional deficiency-payment program treatment is higher than with no policy in effect. In combined-policy scenarios where bond payments were preceded by coupled deficiency payments production drops to at or near levels with no policy in place. These results suggest, in laboratory markets, bond schemes will act as fully decoupled programs and will not introduce production distortions into the market. However, it should be noted that these studies do not take into account the indirect impacts of a bond scheme policy such as expected changes in income and wealth. Table 3.6 summarizes some papers related to the general effect of decoupled payments.

Table 3.6: Some Studies related to the General Effect of Decoupled Payments

Papers	Focus of Study	Method	Result(s)
Adams et al. (2001)	To examine empirically the production effect of fixed production flexibility contract payments (PFC) and market loss assistance (MLA) payments	OLS estimation of the total area planted to 8 crops in eleven states from 1997 to 2001 on PFC and MLA (among other variables)	Acreage increases by 0.026
Guyomard et al. (2004)	To examine the effect of decoupled payments with and without mandatory production on farmers' income, number of farmers, non-land input use and trade	Analytical one sector static model under certainty based on three equilibrium equations: equilibrium in the output market, equilibrium in the land market and an exit/entry condition	Decoupled payments with mandatory production increase number of farmers and decoupled payments without mandatory production increase individual profit of farmers and so total profit
Serra et al. (2005b)	To assess the impact of decoupled payments on the use of crop protection inputs in the cereal, and oilseed and protein crop sectors	By decomposing the profit maximization problem into two main problems: profit maximization and abatement cost minimization, optimal crop supplies, input demands (optimal use of pesticides depends on output and land allocation which is directly affected by area payments), and land allocations are obtained and then estimated using SUR for a sample of French farms observed from 1994 to 1999	The input response to area payments is less than their response to price support measures, elasticity estimates with respect to area payments is 0.35 and to price support is 1.04 for cereals, and to area payments is 0.39 and to price support is 1.20 for oilseeds and protein crops

3.2.6 Wealth and Insurance Effects

Burfisher, Robinson, and Thierfelder (2000) study the indirect links between decoupled payments and production in the United States, Canada, and Mexico through the mechanism of risk reduction. They use a three country computable general equilibrium model (CGE) and incorporate risk into the model by quantifying variance in returns and farmers' subjective risk averse preferences as a risk premium. The risk premium is a function of an absolute risk aversion coefficient, real farm income including government payments and the coefficient of variation of real returns per acre for each crop. Risk premiums are like taxes that reduce the optimal output of risk averse producers below that of risk neutral farmers. In this framework that the effect of increased decoupled payments on production is captured through a decrease in the risk premium farmers are assumed to respond to risk in returns only through their production decision[1]. Farmers in the United States and Canada are assumed to tolerate risk twice as much as farmers in Mexico[2]. This is because subsistence agriculture is common in Mexico. Using time series data from 1979 to 1995 on prices, yields, area, and the 1997 real farm programs (the most recent year for which OECD subsidy data were available by assuming farmers received the real, 1997 level of payments throughout 1979-1995), the authors consider Production Flexibility Contract payments (PFC) in the United States, Net Income Stabilization Accounts (NISA) in Canada and Procampo in Mexico and calculate risk premiums in 1997 for corn, wheat, feed grains and oilseeds. They examine the effect of a 50 per cent increase in decoupled payments from 1997 levels of real expenditure on PFC, NISA and Procampo on risk premiums. Although risk premiums decrease, the effects of a 50 per cent increase in direct payments on output via the decreased risk premiums are relatively small in all three countries, and impacts vary by country and by crop depending on differences among crops in variability of returns. U.S. output of oilseeds rises by 1.1 per cent and output of wheat rises by 0.5 per cent. Mexican output of wheat and feed grains increase by 0.7 per cent, while the output of oilseeds, a crop characterized by a low risk premium, declines by 0.3 per cent, as resources shift into more risky crops. The effects of increased payments on output of corn and feed grains in Canada are close to zero.

Young and Westcott (2000) examine the production impact of production flexibility contract (PFC) payments (that are not related to current farm-level production or market prices and requiring compliance with conservation, wetland, planting flexibility provisions, and keeping the land in agricultural uses) and other program payments (such as crop and revenue insurance, marketing loans and disaster assistance payments) in the U.S. They suggest that the potential for PFC payments to change the production decision depends largely on the strength of the wealth effects. The authors calculate the production impact of PFC payments (which were over $36 billion) on corn, barley, oats, sorghum, rice, wheat and upland cotton over the period 1996-2002 by assuming wealth elasticities of acreage between 0.087 and 0.270, which were taken from the Chavas and Holt (1990) study. PFC payments increased aggregate acreage by 180,000 to 570,000 acres annually. The increased acreage is allocated across crops by market returns. Production of riskier crops and production in riskier regions also occurs.

Serra, Zilberman, Goodwin, and Featherstone (2005a) study the impact of U.S. decou-

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[1] There are actually many other channels through which farmers can reduce risk such as hedging or off-farm employment.

[2] In the United States and Canada, it is assumed that farmers tolerate loss in one of five years, while in Mexico farmers are assumed to tolerate loss in one of ten years.

pled payments mandated by the Federal Agriculture Improvement and Reform (FAIR) Act (in which price supports were reduced in favor of Production Flexibility Contract (PFC) payments) on agricultural production decisions taken both at the intensive and extensive levels. They develop a theoretical model of production under price uncertainty and analyze non-risk neutral farmers' responses to decoupled government payments. It is suggested that farmers make their production decisions with the aim of maximizing the expected utility of their wealth (market revenue plus lump sum payments as decoupled transfers). By assuming that the coefficient of risk aversion is a function of a farm's expected wealth, the authors derive the elasticity of production with respect to decoupled payments. It is shown that an increase in decoupled government transfers increases decreasingly absolute risk aversion farmers' willingness to assume more risk, which in turn stimulates production (i.e. a change in decoupled transfers leads to risk preference adjustment and hence a change in production). The elasticity of production with respect to stochastic price is also derived. It is shown that higher prices influence production by increasing marginal income and by reducing risk (while decoupled payments only influence producers' behavior through reducing risk).

In order to predict the magnitude of the effects of decoupling, the authors specify a single aggregate output produced through a Cobb-Douglas production function using two variable inputs, chemical inputs and fertilizers. They estimate jointly risk preference and technology parameters using the full information maximum likelihood (ML) method based on farm-level data for the years 1998-2001 from Kansas, and national level aggregate data. Results show that though lump sum payments are not fully decoupled in the presence of risk and uncertainty, their effects on agricultural production are likely to be of a very small magnitude (the decoupled payment elasticity of output is near zero, 0.006, and smaller than the price elasticity). Moreover, a reduction in price supports compensated exactly by an increase in decoupled payments leads to a small reduction in agricultural output. The decoupled payments elasticity of chemical inputs and fertilizer are 0.0064. Finally, the elimination of PFC payments would cause the abandonment of almost 6 per cent of the farms (effect of decoupled payments on the extensive margin).

Serra, Zilberman, Goodwin, and Featherstone (2006) analyze the impact that decoupled payments have on input use and on output mean and variance when farmers face both output and price risk. It is assumed that producers maximize their expected utility of wealth which includes market revenue and decoupled payments. By totally differentiating the first-order conditions of the expected utility maximization problem, the effects of decoupled payments on input use, mean output and output variability are analytically determined. For the single output, single input model, under the assumption of a decreasingly risk averse producer (DARA) and a risk-increasing input (like fertilizers) an increase in decoupled payments increases the demand for the input, and the output mean and variability. This happens because the impact of decoupled payments on input use is determined by an interaction between the wealth effect (caused by the change in the coefficient of risk aversion as a result of a change in wealth) and the effect of the impact of a change in input use on the variability of wealth. Specifically, decoupled transfers reduce the degree of DARA farmers' aversion to risk. If the input is risk increasing in the sense that it increases output variability, it will also increase the variability of wealth. Thus, by introducing the decoupled payments, decreasingly absolute risk averse (increasingly absolute risk averse) farmers who are now more (less) willing to assume more risk, will respond by increasing (decreasing) the use of inputs and consequently increasing (decreasing) the output mean and variability. If the input is risk decreasing (like irrigation), the effect of decoupled payments on input use is indeterminate. The effect of an increase in price on input demand, and output mean and variability is also indeterminate under any of the assumptions.

Using a model with three inputs (pesticides, fertilizers, and a composite input that comprises other variable inputs such as seeds and fuel oil), the authors estimate a system encompassing the technology structure and the three first order conditions of the utility maximization problem (using non-linear three-stage least-squares) for assessing the effects of the U.S. Federal Agriculture Improvement and Reform (FAIR) Act of 1996 (in which price supports were reduced in favour of Production Flexibility Contract (PFC) payments) on production decisions taken by a sample of Kansas farmers for the period 1998-2001.

The estimated parameters indicate that all inputs are risk increasing and farmers in the sample exhibit decreasingly absolute risk averse preferences. Decoupled payments elasticities for the three inputs (pesticides is 3.46E-6, fertilizer is 3.90E-6 and other variable inputs—seed, gas, fuel oil, etc.—is 5.79E-6), and the output mean (3.92E-6) and variance (4.56E-6) are positive, but statistically insignificant. Price elasticities for the inputs are positive, though only the elasticities for pesticide (0.57) and fertilizer (1.48) are statistically significant. Price elasticities for output mean (1.24) and variance (1.29) are positive and statistically significant. Therefore, from the empirical results it is concluded that for the sample of Kansas farms, a reduction in price support compensated by a decoupled payment may result in a decrease in output mean and variance by reducing the use of risk-increasing inputs.

Goodwin and Mishra (2006) evaluate empirically the effects of decoupled payments on acreage decisions (and also the purchase of new land) by analyzing the U.S. production flexibility contract (PFC) payments and market loss assistance (MLA) payments using farm-level data taken from four years of the USDA survey—1998-2001—for three acreage equations (corn, soybeans and wheat) in the Corn Belt region. The analysis is reinforced by an aggregate analysis of county level acreage allocations. The empirical framework is based on expected utility maximization of wealth which is given by initial wealth plus market profits, direct government payments and non-farm activities. The optimal acreage response is derived as a function of lagged acreage, stochastic output price, input price, payments based on market conditions (such as market loss assistance payments), direct decoupled payments and the farm's wealth (calculated as total assets less total debts).

By emphasizing the risk mechanism and the credit constraints mechanism as indirect ways by which decoupled payments affect production, the authors include in the model not only PFC and MLA payments directly but also the farmer's level of risk aversion and credit constraints. A farmer's level of risk aversion is proxied by the ratio of his insurance expenditures over his total expenses. The PFC-insurance interaction term in the model captures the effect that PFC payments can have on risk aversion, and therefore on acreage decisions. Credit constraints are proxied by the debt-to-asset ratio of the farm. The PFC-debt-to-asset ratio interaction term in the model captures the effect that PFC payments might have on the farm's financial leverage, and therefore on acreage decisions.

The results indicate that although the direct effects of PFC payments on acreage decisions are positive and significant (except in the wheat acreage decision), the effects are small. The debt to asset interaction terms are not statistically significant in any equations. This may suggest that the existence of credit constraints does not affect acreage decisions. The coefficient of the PFC-insurance term in every case is negative but insignificant. Thus the exact mechanism—wealth effects, risk, capital constraints—by which PFC payments affect acreage is not identified. The overall elasticities, including both the insurance and debts-to-assets ratio interaction effects, are 0.0344, 0.0246, and 0.0333 for corn, soybeans, and wheat, respectively. MLA direct effects on corn acreage are stronger than the direct effect of PFC payments, though the effect on soybeans and wheat are not significant. Moreover, by considering probit models of the acquisition of new land for 1999, the authors find that PFC payments lead to less idling land, but no significant impact on land transactions.

Goodwin and Mishra (2005) extend the research of Goodwin and Mishra (2006)[1] using more recent farm-level data for the years 2002 and 2003 to examine the effect of the U.S. counter-cyclical payments (CCP) and decoupled payments on acreage decisions. This study is able to condition recent acreage allocations on farms' historical base acreages (measured as average disaster payments 1994-2001 per acre). The authors estimate an updated version (using many of the same variables) of the acreage-response equations evaluated by Goodwin and Mishra (2006) and the results confirm the findings of earlier research that the effects of decoupled payments on acreage are small.

The authors also consider responses to a number of survey questions regarding factors that influence acreage decisions and the allocation of decoupled payments receipts among farm and nonfarm uses. The percentage of the farmers indicated counter-cyclical payments and decoupled payments as important factors in their acreage decisions are 12.3 per cent and 21 per cent, respectively. Farmers note the cost of inputs as the most important factor influencing their production decisions. Crop rotation issues and the expected commodity price are the second most important factors.

The authors use a Tobit model with double censoring to relate a number of farm characteristics to the proportion of direct payments that farmers indicate they use on the farm. The results indicate that the highly leveraged operators are more likely to use decoupled payments on the farm. This is consistent with the argument that decoupled payments may indirectly affect production through their effect on credit-constrained farmers. Highly risk-averse operators are less likely to allocate direct payments to the farm while wealthy farm operators are more likely to use decoupled payments on the farm. This is consistent with arguments that wealth increases may result in risk-averse farmers being willing to accept more risk by expanding their farm operation.

Meilke and Weersink (1990) examine the effects of government stabilization programs on total crop area and the allocation of that area to individual crops in eastern and western Canada over the time period 1972 to 1988. For eastern Canada, a system of area response equations for the five crops (barley, soybeans, oats, corn and wheat) are estimated using seemingly unrelated regression. In eastern Canada, since the Agricultural Stabilization Act and provincial programs are generally targeted to specific crops, expected government payments are explicitly incorporated into the price expectations for each crop. Naive expectations are

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[1] Note that Goodwin and Mishra's study in 2005 is an extension to their earlier research in February 2006, although the earlier research was later published.

assumed for these government payments. Each crop acreage in eastern Canada is specified as a function of own crop return, other crops' returns, and variability in net returns[1], among other factors.

For western Canada, a system of area response equations for the seven crops (barley, bread wheat, canola, oats, flax, rye and durum wheat) are estimated. In western Canada, the Western Grains Stabilization Act (WGSA) payments are based on average previous five years net cash flow for a market basket of grains. As it is difficult to include the effect of WGSA in the returns expectations for each individual crop, it is specified as a separate variable in the western Canada model. Each crop acreage in western Canada is specified as a function of own crop return, other crops' returns, variability in net returns[2] and the expected WGSA payments[3], among other factors.

The estimated coefficients are simulated under two scenarios to determine the effect of government programs on crop area. In the first scenario, government payments are only excluded from the calculation of the risk measure while, in the second scenario, the payments are also excluded from expected returns. In eastern Canada, removing government payments from the risk measure reduces total area by 0.5 percent with the majority of the reduction occurring in corn area. Total area harvested would be reduced by 1.4 percent on average with a complete removal of government support. In western Canada, the increase in the variability of measured returns, resulting from the elimination of WGSA payments, leads to a reduction in total harvested area by an average of 0.02 percent, while removing WGSA payments from expected returns, as well as the risk measure, reduces total area by 1.59 percent with the largest absolute decrease for bread wheat.

Miranda, Novak and Lerohl (1994) examine the effect of the Canadian Western Grains Stabilization Act (WGSA) on acreage response. They estimate a nonlinear rational expectations model of aggregate acreage supply (for six major grain crops) for the Canadian Prairie between 1976 and 1990 by accounting directly for a structural model of the WGSA in their

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[1] A risk measure which is common to all crops is defined as a weighted average of the squared deviations of the actual returns (the sum of the market price and the government payment per unit of crop, expressed in real terms by dividing by the input price index, multiplied by the crop yield) and expected returns (a weighted average of past annual returns) for the past three periods.

[2] A risk measure which is common to all crops is defined as a weighted average of the squared deviations of the actual returns (the weighted average of the actual returns for each crop where the weights are the average area planted to each crop from 1972 to 1988) and expected returns (the weighted average of the expected returns for each crop where the expected returns for each crop is a three year distributed lag of the annual returns) for the past three periods. This risk variable is adjusted for government payments.

[3] The expected WGSA payments are the fitted values in the regression of the net WGSA payments on the expected returns in the current year, the average of the returns in the previous five years, and the ratio of actual marketings to actual production in the current year as compared to the previous five years.

estimation framework. An aggregate acreage supply equation is considered as a function of expected revenue and the variance of revenue. A system of grain market equations including grain price, grain marketings, on-farm dispositions, and yield is estimated. Using the estimated parameters which give the western Canadian grain market equations and nine deterministic structural equations which describe WGSA payouts, rational ex ante expectation and variance of per-hectare revenues are computed by Gauss-Hermite numerical integration methods. Then, the effect of ex ante means and variance of per-hectare revenues on acreage response is estimated. Finally, using the estimated coefficients, the impact of the WGSA on acreage decisions was simulated by computing ex ante means and variance of revenues under factual scenario (with WGSA implementation) and counterfactual scenario (without WGSA implementation). The results indicate that the WGSA increased acreage planted to eligible crops by over 4 per cent during its 15 years of operation. Most of this increase (2.4 per cent) was related to the risk (variances of revenue) reduction effects of the program, the remainder (1.7 per cent) to increases in expected revenues.

Chavas and Holt (1990) study the impact of U.S. price support programs on acreage decisions under risk, for corn and soybeans from 1954 to 1985. They develop an acreage supply response model under expected utility maximization of total wealth for a farm household subject to budget and acreage constraints and derive the household's optimal acreage decision as a function of expected net returns for the own and competing crops, second moment of the distribution of the net returns, and initial wealth. Then, through examining theoretical restrictions, total wealth (initial wealth plus market returns) as well as expected crop net returns and variance-covariance of crop prices appears in the model specified for estimation. The effect of the government price support program is incorporated into the model by truncation of the the price distribution.

Variances and covariances of crop prices (risk) are found to be statistically significant in most cases. Elasticities with respect to initial wealth are statistically significant and 0.087 for corn and 0.270 for soybeans. The hypothesis of constant absolute risk aversion over the period of analysis for corn and soybean farmers is rejected and the positive wealth effect is consistent with decreasing absolute risk aversion. In order to show the importance of considering risk in a multicrop framework, the authors simulate the acreage response models at various price support levels for corn and soybeans. Due to the truncation effects, changing the support price levels will influence the means, variances and covariances of prices. The model simulations indicate that there is some range over which increasing the support price for corn will result in more acres planted to soybeans because the risk reducing effect of a price support program influencing acreage substitution dominates the mean price effect. This result emphasizes the importance of cross-commodity risk effects and the risk-reducing role of government support payments.

Massow and Weersink (1993) assess the impact of government support programs on acreage response under price and production risk in the province of Ontario in Canada from 1965 to 1990. Following Chavas and Holt (1990), they start from the maximization of the expected utility of wealth and derive the optimal acreage decisions as a function of initial wealth, expected profit for the own and competing crops, and the expectations of the higher moments of the profit distributions. In order to incorporate the effect of government programs, the authors truncate the subjective price and yield distributions at the support level. Estimation of the system of acreage response functions for white beans, corn, soybeans and winter wheat indicates that the signs of variables are generally consistent with theory. The change in acreage of all four crops due to changes in the expected variability of the revenues is less than acreage changes due to changes in levels of expected revenues, which shows the impact of risk relative to expected returns (for example, elasticity with respect to own revenue for winter wheat is 0.158 and with respect to own-variance is -0.018).

The null hypothesis that farmers are risk-neutral is rejected which indicates the need to include some measure of risk in acreage response models. The constant absolute risk aversion hypothesis is also rejected which implies the need to include a wealth variable in acreage response estimations. Using the estimated coefficients, the authors simulate various government policy scenarios over 1980-1989 to measure how any scenario will affect the average expected revenue and variability of revenue, and therefore the crop acreages. The results indicate that the National Tripartite Stabilization Program (NTSP) had the most potential to affect acreage decisions, considerably increasing the level of white bean acreage by 24.3 per cent. The Agricultural Stabilization Act (ASA) increased average corn acreages by 2.9 per cent at the expense of the portfolio of alternative crops (soybeans and winter wheat acreages decreases by 2 percent and 7 percent, respectively). Although the Gross Revenue Insurance Program (GRIP) had the least potential for misallocation of land among crops since it provided a consistent measure of support to all of the crops, it produced an acreage response of 3.6 per cent, on average.

Lin and Dismukes (2007) examine whether the Counter-Cyclical Payments (CCPs) in the U.S. 2002 Farm Act have an impact on farmers' acreage decisions. Following the theoretical framework developed by Chavas and Holt (1990), the acreage response model—both the linear acreage and acreage share specifications—under risk is estimated using SUR for major program crops (corn, soybeans, and wheat) in the North Central region (including Ohio, Indiana, Illinois, Missouri, Iowa, Minnesota, Wisconsin, and Michigan) during 1991-2001. Truncated means, variances and covariances of per unit crop prices are used to reflect government price support provided to farmers through commodity loan programs. The results indicate that the expected net returns for corn and soybeans are statistically significant with expected signs for own and cross effects under both the linear and acreage-share specifications. The expected net return for wheat has the expected sign and is statistically significant in both model specifications. Of all the revenue variance and covariance variables (i.e. risk variables) considered, only the coefficients of soybean revenue variance in soybean linear acreage and acreage-share equations are statistically significant. Soybeans' own-variance risk elasticity ranges from -0.043 (linear acreage model) to -0.050 (acreage share model).

The null hypothesis that coefficients of all risk variables in each acreage equation are jointly zero is rejected in the soybean equation suggesting the importance of risk in farmers' soybean acreage decisions. It is not rejected in the corn and wheat acreage equations. The null hypothesis that all coefficients of the initial wealth variable are jointly zero is rejected in both the linear and acreage-share models, which shows that wealth has an important effect on farmers' acreage decisions. Overall, an increase in initial wealth will lead to an increase in acreage planted to all crops, which implies that farmers exhibit decreasing absolute risk aversion. The effect of initial wealth on individual field crops varies, positive for soybeans (0.136 to 0.163) and negative for corn (-0.037 to -0.051) and wheat (-0.190 to -0.201).

Using the estimated coefficients in a linear acreage model, the authors simulate the effects of counter-cyclical payments on acreage decisions for 2005 in major field crops in the North Central region by comparing two scenarios: market conditions without counter-cyclical payments, and market conditions with counter-cyclical payments. In the absence of CCPs, truncation of the commodity price distribution is limited to commodity loan programs. In contrast, CCPs add another truncation to commodity price distributions (in addition to that of commodity loan programs), which is conditioned on the expected farm price. The truncation point of CCPs is determined by apportioning CCPs (which are calculated from the 2003 base acreage) to planted acreage that is estimated from the linear acreage model using 1991-2001 data. The effect of counter-cyclical payments on acreages appears to be small, with an increase of 80,000 acres for corn and 50,000 acres for wheat while soybean acreage remains unchanged. However, the authors mention that the effects of CCPs may go beyond their short-run effects on farmers' acreage decisions; longer term, there may be structural implications to the extent that these payments keep farmers in business.

Hennessy (1998) develops a theoretical framework to show the production effects of decoupled programs in stochastic environments (in addition to coupled programs). He models a risk-averse farmer, maximizing expected utility from profit. The farmer earns support-adjusted profit which is the summation of stochastic profit from the market and a decoupled payment. The model decomposes the production impacts of decoupled programs under uncertainty into wealth and insurance effects. Under the conditions that: (i) farmer's preferences display decreasing absolute risk aversion; (ii) the risk faced by the farmer reduces his optimal level of the choice variable so that a risk-reducing policy can mitigate the choice variable-depressing impacts of risk; (iii) support-adjusted profit increases with risk and; (iv) the decoupled payment reduces the risk faced by the farmer, the optimal choice of the farmer increases as the magnitude of support increases. The decoupled programs reduce the coefficient of absolute risk aversion by increasing expected income (wealth effect) as well as reducing the degree of risk faced by farmers by lowering the variability of income (insurance effect). The author also shows that under constant absolute risk aversion and conditions (ii), (iii) and, (iv), the optimal choice of the farmer increases as the magnitude of support increases. In this case, wealth effects are absent and the optimal choice is only influenced by insurance effects due to the reduced income variability induced by the increase in government supports. A decoupled program must be invariant to the source of uncertainty for the insurance effect to be absent (for example a deterministic lump sum payment rather than an income-contingent payout) and in this case government support will induce a pure wealth effect for preferences that do not reflect a constant absolute risk aversion. Thus, income support policies that are assumed to be decoupled are not, in fact, decoupled and may affect production decisions.

Moreover, in order to obtain some measure of the magnitudes of the wealth and insurance effects of a target price program based on fixed yield (i.e. a decoupled structure), Hennessy conducts empirical simulation for a 400-acre corn farm in Iowa. The results indicate that an increase in the magnitude of support programs could increase input use (nitrogen) by a maximum of 15 per cent (through both wealth and insurance effects), while the increase in production is small with a maximum of 2.75 per cent (through both wealth and insurance effects). By controlling for the wealth effect, it seems that the insurance effects are much larger than wealth effects.

Following Hennessy (1998), Sckokai and Moro (2006) examine the impact of the new Mid-Term Review single farm payment of the European Union's Common Agricultural Policy (CAP) on acreage decisions by considering both the insurance and wealth effects of policy changes. By assuming that risk arises due to uncertain prices and that farmers display constant relative risk aversion preferences, and by adopting nonlinear mean-variance risk preferences, the dual expected utility function is specified and then output supply, input demand, and land allocation equations are derived (using Hotelling Lemma) as a function of initial wealth, expected output prices, input prices, variance-covariance of prices, and crop-specific area payments, among other variables. The authors use farm level data from the Italian Farm Accounting Data Network to empirically estimate a ten equation system of output supply (corn, durum wheat, other cereals, oilseeds), input demand (seeds and chemicals, and other inputs), and land allocation (land to corn, land to durum wheat, land to other cereals, land to oilseeds) over 1993-1999[1]. As both expected cereal prices and the corresponding elements of the variance-covariance matrix are influenced by the existence of the guaranteed minimum prices for cereals during the period of 1993-1999, the price distribution at the minimum price level is truncated.

The null hypothesis that all variance and covariance coefficients are jointly equal to zero is rejected which implies a rejection of risk neutrality. The estimated results indicate that the fraction of significant elasticities with respect to the risk-related explanatory variables (output price variances-covariances and initial wealth) is around 50 per cent. The area payments elasticities with respect to output (acreage) are 0.014 (0.014) for corn, 0.072 (0.056) for durum wheat, 0.087 (0.088) for other cereals 0.015 (0.005) for oilseeds. The parameters estimated over the 1993-1999 period are then used to simulate the effects of the combination of the Agenda 2000 and the 2003 Mid-Term Review (MTR) reforms, through a scenario with a decrease in cereal intervention prices partially compensated by an increase in cereal area payments, which have been transformed, together with oilseed payments, into a single farm payment (SFP). Under this scenario, the insurance effect has been derived by shocking the model with the change in income/wealth variability only, the relative price/payment effect by

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[1] Since many farms in the sample do not produce some of the crops, the problem of corner solutions for some outputs exists. The fraction of farms not producing ranges from a minimum of 41 percent to a maximum of 62 percent for the five outputs. To deal with corner solutions, the authors use the two-step estimation procedure. In the first step, the five probit models (one for each output) are estimated using the level of some quasi-fixed inputs (capital, family labor, and land) and two sets of dummy variables representing geographical location (North, Center, and South) and altitude (mountains, hills, and plains) as explanatory variables. In the second step, the first-stage probit estimates of the corresponding parameters are used in a new form of a system of ten simultaneous equations.

shocking the model with the changes in prices and payments only, and the wealth effect by shocking the model with the change in wealth (resulting from the discounted value of future payments guaranteed by the MTR reform, SFP) only. The simulation results show that the introduction of the non-stochastic SFP reduces income variability and offsets the impact of the increased price variability due to reduction in the intervention price. While the size of the wealth effect is positive but quite small, the insurance effect may generate up to a 7 per cent increase in acreage, which implies that the size and direction of acreage are strongly influenced by the impact of CAP reforms on farm income/wealth variability.

Coyle, Wei and Rude (2008) study the hypothetical impacts of the Canadian Agricultural Income Stabilization (CAIS) program on crop production under risk aversion and output price uncertainty for wheat, barley, canola and other crops (oats, rye, flax) in Manitoba over 1966-2002 (which is prior to CAIS implementation). First, an autoregressive distributed lag crop yield model is specified as a function of expected price (which includes crop specific government payments related to Crop Insurance and Gross Revenue Insurance Program and an index of net transportation costs) and price variance[1], initial wealth (which is defined as the sum of value of capital stock in crop production minus related debts. Initial wealth also includes various government payments for crops that are not commodity specific), weighted mean and variance of weather stations, and the covariance between government payments and crop market prices (to capture an insurance effect resulting from government payments including Net Income Stabilization Account program, Agriculture Income Disaster Assistance, Western Grains Stabilization Act program, Western Grains Transportation Act program). Note that since the production homogeneity condition implied by constant relative risk aversion CRRA states that output supply is homogeneous of degree zero in expected output price, input price, price variances, and initial wealth, all monetary variables are normalized by an input price index and variance-covariance elements are normalized by squared price. Then, a static econometric model of Manitoba crop acreage (share) demands conditional on yields is also estimated as a function of expected revenues and variance-covariance in revenues[2] per acre for own and competing crops, initial wealth, a variance of weather indexes (serving as a proxy for weather/yield uncertainty), and variable input price indexes. All monetary variables in acreage equation are normalized by a Tornqvist revenue per acre index for other

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[1] By assuming disjoint technologies (and similar capital/acreage ratios across crops), crop yield can be modelled independently of cross price effects.

[2] By assuming that only prices are stochastic, an adaptive expectation scheme is used to calculate expected prices and variance-covariance elements.

crops and variance-covariance elements are normalized by squared revenue index. Long run impacts on output are the sum of long run impacts on yields plus long run impacts on acres.

The authors develop an analytical model of crop production response to CAIS over 1966-2002. In farm maximization problem, they consider the expected farm wealth as the expected value of the summation of initial wealth, market income and total payouts under the CAIS. Then, expected effective prices and initial wealth are derived using the first order conditions. Since increases in current income reduce current payouts under CAIS, CAIS has a substantial impact on expected effective prices for outputs and inputs. It is calculated that CAIS leads to approximately seven percent increases in expected effective output prices relative to effective input prices. Under CRRA, CAIS leads to the substantial change in effective prices relative to nominal wealth which implies a substantial increase in relative wealth by 33 percent. Moreover, under CAIS relative price uncertainty is calculated to increase by 14 percent. Using estimated elasticities of the econometric models, calculations show that under CRRA assumption, annual crop production increases by six per cent for wheat, nine per cent for barley, and decreases by one per cent for canola for a hypothetical implementation of CAIS over 1966-2002[1]. Table 3.7 summarizes some papers related to the wealth and insurance effects of decoupled payments.

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[1] The authors consider the standard program of Gross Revenue Insurance program (GRIP) as a benchmark for the CAIS. After calculating the percentage change in farm level crop output prices due to GRIP (indemnities minus farmer premiums) relative to market prices, and correlations of total indemnities with a Divisia index of market prices for all crops, the econometric models is used to simulate the impacts of the price support and insurance effects of GRIP on output. By comparing the effects of GRIP and CAIS, for wheat and barley, CAIS impacts on long run yields arising from increases in relative effective prices and increases in normalized wealth are less substantial than the simulated impacts for the historical GRIP, which provided large and transparent subsidies to crop prices.

Table 3.7: Studies related to the Wealth and Insurance Effects of Decoupled Payments

Papers	Focus of Study	Method	Result(s)
Chavas and Holt (1990)	To study corn and soybeans acreage response to the U.S. price support programs under risk	Expected utility maximization model and incorporating government programs into the model by truncation technique, and estimation of a SUR model from 1954 to 1985	Acreage elasticities with respect to wealth are statistically significant and 0.087 for corn and 0.270 for soybeans, and with respect to variances-covariances (risk) are -0.001 for corn and -0.017 for soybeans
Massow and Weersink (1993)	To assess acreage response to government support programs under price and production risk in Ontario	Used the same framework as Chavas and Holt for white beans, corn, soybeans and winter wheat from 1965 to 1990	The results indicate that the National Tripartite Stabilization Program had the most potential to affect acreage decisions, considerably increasing the level of white bean acreage by 24.3 per cent.
Miranda et al. (1994)	To examine acreage response to the Canadian Western Grains Stabilization Act (WGSA) in Canada	Using four equations which describe the western Canadian grain market and nine deterministic structural equations which describe WGSA payouts, the rational ex ante expectation and variance of per-hectare revenues are computed by Gauss-Hermite numerical integration methods. Then, the effect of ex ante means and variance of per-hectare revenues on acreage response is estimated for six major grain crops for the Canadian Prairies between 1976 and 1990	The WGSA increased acreage by over 4 per cent, most of this increase (2.4 per cent) was related to the risk (variances of revenue) reduction effects of the program, the remainder (1.7 per cent) to increases in expected revenues
Hennessy (1998)	To develop a theoretical framework to show the production effects of decoupled programs in stochastic environments	Modelling a risk-averse farmer, maximizing expected utility from profit and proposing that decoupled programs reduce the coefficient of absolute risk aversion by increasing expected income (wealth effect) as well as reduce the degree of risk faced by farmers by reducing the variability of income (insurance effect) and therefore increase optimal choice of the farmer, and simulating a target price program based on fixed yield (i.e. a decoupled structure) to a single 400 acre continuous corn farm in Iowa	An increase in the magnitude of support program could increase input use (nitrogen) by a maximum of 15 per cent (through both wealth and insurance effects), while the increase in production is small with a maximum of 2.75 per cent (through both wealth and insurance effects)

Table 3.7: Continued

Papers	Focus of Study	Method	Result(s)
Burfisher et al. (2000)	To study the indirect links between decoupled payments and production in the U.S., Canada, and Mexico through the mechanism of risk reduction	Using a computable general equilibrium model (CGE) with a risk premium and simulating the effect of a 50% increase in decoupled payments from 1997 levels of real expenditure on production flexibility contract payments (PFC) in the U.S., net income stabilization accounts (NISA) in Canada and Procampo in Mexico on risk premiums	U.S. output of oilseeds rises by 1.1% and output of wheat rises by 0.5%. Mexican output of wheat and feed grains increase by 0.7 % and the output of oilseeds (a crop characterized by a low risk premium) declines by 0.3%. The effects of increased payments on output of corn and feed grains in Canada are close to zero
Young and Westcott (2000)	To examine the production impact of production flexibility contract (PFC) payments in the U.S.	Calculating the production impact of PFC payments of $36 billion over the period 1996-2002 by assuming wealth elasticities of acreage between 0.087 and 0.270 from Chavas and Holt (1990)	PFC payments increased aggregate acreage by 180000 to 570000 acres annually
Serra et al. (2005a)	To study the impact of U.S. Production Flexibility Contract (PFC) payments on production decisions taken both at the intensive and extensive levels in the presence of price uncertainty	Developing a theoretical model of production under price uncertainty by considering that farmers take their production decisions with the aim of maximizing the expected utility of their wealth (market revenue from sales of a single output and decoupled payments), and estimating jointly risk preference and technology parameters by Full Information Maximum Likelihood using farm-level data for the years 1998-2001 from Kansas	An increase in decoupled government transfers increases decreasingly absolute risk aversion farmers' willingness to assume more risk, which in turn stimulates production. The decoupled payments elasticity of output is 0.006, the decoupled payments elasticity of chemical input and fertilizer are 0.0064, and the elimination of PFC payments would cause the abandonment of almost 6 per cent of the farms

Table 3.7: Continued

Papers	Focus of Study	Method	Result(s)
Serra et al. (2006)	To analyze analytically and empirically the impact that decoupled payments have on input use and on output mean and variance when farmers face both output and price risk	Using a model with three inputs (pesticides, fertilizers, and seeds and fuel oil), a system of the technology structure and the three first order conditions of the utility (of wealth which includes market revenue and decoupled payments) maximization problem is estimated for assessing the effects of the U.S. Production Flexibility Contract (PFC) payments on production decisions taken by a sample of Kansas farmers for the period 1998-2001	Decoupled transfers reduce the degree of DARA farmers' aversion to risk. If the input is risk increasing in the sense that it increases output variability, it will also increase the variability of wealth. Thus, by introducing the decoupled payments, decreasingly absolute risk averse farmers who are now more willing to assume more risk, will respond by increasing the use of inputs and consequently increasing the output mean and variability. Decoupled payments elasticities for pesticides is 3.46E-6 for fertilizer is 3.90E-6 and for other variable inputs-seed, fuel oil etc.-is 5.79E-6, and for the output mean is 3.92E-6 and for the output variance is 4.56E-6, but statistically insignificant
Goodwin and Mishra (2006)	To evaluate empirically the effects of the U.S. production flexibility contract (PFC) payments on acreage decisions	Maximizing the expected utility of wealth and including into the model not only PFC and MLA payments directly but also the farmer's level of risk-aversion (proxied by the PFC-insurance interaction term) and credit constraints (proxied by The PFC-debt-to-asset ratio interaction term) using farm level data from 1998 to 2001 for three acreage equations (corn, soybeans and wheat) in the Corn Belt region	The acreage overall elasticities with respect to decoupled payments, including both the insurance and debts-to-assets ratio interaction effects, are 0.0344, 0.0246, and 0.0333 for corn, soybeans, and wheat, respectively (and not statistically significant)

Table 3.7: Continued

Papers	Focus of Study	Method	Result(s)
Sckokai and Moro (2006)	To examine the impact of the new Mid-Term Review single farm payment of the European Union's Common Agricultural Policy (CAP) on acreage decisions by considering both the insurance and wealth effects of policy changes	Using the dual expected utility function under uncertain prices and constant relative risk aversion preferences and estimating a ten-equation system of output supply (corn, durum wheat, other cereals, oilseeds), input demand (seeds and chemicals, and other inputs), and land allocation (land to corn, land to durum wheat, land to other cereals, land to oilseeds) over 1993-1999 using farm level data from the Italian Farm Accounting Data Network, and then simulating the effects of the combination of the Agenda 2000 and the 2003 Mid-Term Review (MTR) reforms	The area payments elasticities with respect to output (acreage) are 0.014 (0.014) for corn, 0.072 (0.056) for durum wheat, 0.087 (0.088) for other cereals 0.015 (0.005) for oilseeds. The simulation results show that by introduction of the non-stochastic SFP the size of the wealth effect is positive but quite small, and the insurance effect may generate up to a 7 per cent increase in acreage
Lin and Dismukes (2007)	To examine the acreage response to the Counter-Cyclical Payments (CCPs) of the U.S. 2002 Farm Act	Estimating the acreage response model-both the linear acreage and acreage share specifications-under risk using SUR for major program crops (corn, soybeans, and wheat) in the North Central region from 1991 to 2001 by considering the truncation effect of government price supports provided to farmers through commodity loan programs, and then simulating the effects of counter-cyclical payments on acreage decisions for 2005	The effect of initial wealth on individual field crops are 0.136 for soybeans and -0.037 for corn and -0.190 for wheat. The null hypothesis that coefficients of all risk variables in each acreage equation are jointly zero is rejected in the soybean equation while it is not rejected in the corn and wheat acreage equations. The simulation results show that the effect of counter-cyclical payments on acreage appears to be small, with an increase in acreage of 80,000 acres for corn and 50,000 acres for wheat while the soybeans acreage remains unchanged.

Table 3.7: Continued

Papers	Focus of Study	Method	Result(s)
Coyle et al. (2008)	To study the hypothetical impacts of Canadian Agricultural Income Stabilization (CAIS) program on crop production	An autoregressive distributed lag (ADL) crop yield model and a static econometric model of crop acreage (share) demands are estimated in Manitoba for wheat, barley, canola and other crops (oats, rye, flax) over 1960- 2002, long run impacts on output are the sum of long run impacts on yields plus long run impacts on acres, and then hypothetical impacts of CAIS on crop outputs are simulated over 1966-2002, which is prior to CAIS	Under constant relative risk aversion (CRRA), it is calculated that CAIS leads to 7 percent increases in relative expected effective prices. CAIS leads to the substantial change in effective prices relative to nominal wealth which implies a substantial increase in relative wealth by 33 percent. Moreover, under CAIS relative price uncertainty is calculated to increase by 14 percent. Using estimates elasticities of the econometric models, calculation shows that annual crop production increases by 6 per cent for wheat, 9 per cent for barley, and decreases by 1 per cent for canola due to hypothetical implementation of CAIS over 1966-2002.

In general, the literature pertaining to the impact of government payments on acreage decisions through risk mechanisms clearly shows that support policies that are decoupled in a deterministic world can affect the decisions of the risk averse producers when there is uncertainty. However, theoretical studies on impact of decoupled payments on acreage response lack a detailed theoretical model of how acreage decisions will be affected by stabilizing farm profit as well as the higher expected profit. In the next section, we try to fill this gap by modelling the farmers' acreage decisions under uncertainty and deriving a measure inside the theoretical framework to capture the insurance effect of government policies as well as the wealth effect.

Chapter 4

Theoretical Framework

This chapter provides the theoretical basis for an empirical analysis on the effect of government crop payments on acreage decisions. The chapter is organized as follows. First, by applying the literature on risk and uncertainty to agriculture, we examine the optimal level of farmers' choice variables under uncertainty and show how government payments affect this optimal choice. In this section, different types of uncertainty in agriculture including price and production risks as well as technological and policy risks, are explained. Then, in order to understand how risk affects production decisions, following Hennessy (1998) a producer who maximizes the expected utility of random profit, as a function of a vector of choices such as input use by the producer, a vector of exogenous parameters including government payments and input prices, and a single random variable representing the uncertainty such as output price, is considered. Using the first-order condition under uncertainty, the optimal level of choice variables is determined. Similarly, by maximizing the profit function, the optimal choice under certainty is also determined. The solution under uncertainty is compared with the solution when uncertainty is removed and it is shown that uncertainty reduces the level of the choice variable selected by a risk averse decision maker. Next, the government payments impact on the farmer's optimal choice is investigated. It is shown that under an uncertain environment there are three channels through which governments payments can influence farmer's decision: (1) the coupling or direct (price) impacts that influences the optimal choice by increasing the marginal effect of input on profit (through changes in output/input prices); (2) the wealth impacts arising from the higher average profit resulting from the government payments; (3) the insurance impact that influences the optimal choice because it stabilizes profit.

Second, the optimal acreage decisions under uncertainty, which includes three main factors demonstrated in the previous section, are derived and specified. The three factors are price, wealth and insurance. Hence, the model is able to incorporate the effect of government payments on acreage decisions through all three of these channels. In this section, following Chavas and Holt (1990), a farm household maximizing expected utility of total wealth (initial wealth plus profit from different crops) subject to budget constraint and acreage constraint is considered. From the first-order condition, an optimal acreage choice for each crop as a function of initial wealth, expected profits and variance of profits (profit distributions determinants) is derived. Following this derivation, the properties of the optimal acreage decision, including symmetry and homogeneity, are discussed.

However, Chavas and Holt's model is not able to capture the insurance effect (i.e. the stabilization of total income) which has been emphasized in the literature. Since Canadian farm income stabilization and support policy has moved toward a whole farm approach that targets net income and uses a moving average mechanism to temporally smooth income, it possesses income-supporting (wealth effect) and income-stabilizing (insurance effect) attributes. The existing literature controls for the wealth effect through changes in average total income arising from government supports, however the insurance effect is captured only through an ad hoc measure. Given the nature of Canadian whole farm programs which attempt to stabilize producers' income, to examine empirically the whole farm programs, a model is needed to capture the insurance effect arising from these programs. To solve this problem, through the theoretical restriction channel, we contribute to the literature by incorporating the insurance effect (income stabilization) ignored by Chavas and Holt (1990) into our theoretical model. Based on the theoretical discussions regarding the role of insurance effect in acreage decisions, the theoretical restrictions examined by Chavas and Holt (1990) are extended, which enables us to include this effect in our model specification. Next, using a first-order Taylor series expansion and based on our modification, we have a specification different from the one by Chavas and Holt (1990), i.e. the optimal acreage choice for each crop is specified as a function of total wealth; i.e. initial wealth plus total profit (wealth effect), individual crop expected profits and variances (coupling/price effect), and variance of total profit (insurance effect). Government payments are incorporated into the model by the truncation of the profit distributions such that crop-specific programs can influence the acreage decisions by coupling (price), wealth and insurance effects and whole farm programs can influence the acreage decisions by wealth and insurance effects.

Finally, the expected signs for explanatory variables are analytically derived based on the portfolio theory.

4.1 Decision Making under Uncertainty

Two important concepts in the economic modelling of individual choice are optimization (the rational behavior of economic agents) and equilibrium (the balancing of individual claims in a market setting). When uncertainty exists, application of both of these concepts raises modelling problems (Moschini and Hennessy, 2001). In optimization under uncertainty, in particular, one needs to determine what exactly is being optimized. Although a universally satisfactory answer to this question is not accessible, the major analytic tool for solving decision problems under uncertainty is the expected utility model. The expected utility hypothesis states that the individual assigns a utility value to each mutually exclusive activity with an associated probability distribution that is an outcome of a decision. The preferred choice has maximum expected utility.

The expected utility theorem provides a complete theory of choice under uncertainty[1]; therefore, it is widely used by economists to formally describe individual decisions under risk and uncertainty[2]. It was Bernoulli who first formulated the expected utility theorem in 1738, when he postulated that an extra dollar has more value to a poor man than to a rich man[3]. Using a set of behavioral axioms, von Neumann and Morgenstern (1944) extended the concept to the case of an expected utility model, where a representative agent maximizes expected utility subject to an endowment constraint. In the expected utility framework, maximizing the expected utility of consequences is equivalent to the problem of selecting the action that induces the most preferred probability distribution. The expected utility model allows us to capture the notion of risk aversion as a fundamental feature of the problem of choice under uncertainty by assuming concavity of the utility function. In Appendix A, the expected utility theory and the risk aversion definition are briefly presented (See Mas-Colell, Whinston and Green, 1995, chapter 6, for details).

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[1] However, note that despite its normative appeal, the expected utility framework is not able to describe some features of individual behavior under risk and, therefore, it has recently come under intense scrutiny and a number of generalizations of the expected utility model have been proposed (Quiggin, 1993).

[2] According to Knight (1921), there is a distinction between uncertainty and risk. Risk arises when the stochastic elements of a decision problem can be characterized in terms of numerical objective probabilities, whereas uncertainty refers to decision making with random outcomes that lack such objective probabilities. With the widespread acceptance of probabilities as subjective beliefs, Knight's distinction between risk and uncertainty is meaningless and we will ignore it in this study. Thus, the notions of uncertainty and risk are interchangeable here.

[3] See the translation by Somer (1954).

4.2 Agricultural Decision Making under Uncertainty

In this section, by applying the literature of risk and uncertainty to agriculture, we specifically examine the optimal level of farmers' choice variables under uncertainty and show how government payments affects this optimal choice. First, we briefly present the main sources of uncertainty in agriculture. Then, we show how the existence of uncertainty affects the optimal choice by the farmer. Finally, the effect of government payments through three channels, coupling, wealth and insurance, on the farmer's optimal choice is examined.

4.2.1 Uncertainty in Agriculture

It is useful to start by outlining the main sources of uncertainty in the agriculture sector. First, in agriculture the amount and quality of output that will result from a given bundle of inputs are not known with certainty, i.e., the production function is stochastic. This production uncertainty is due to the fact that uncontrollable elements, such as weather, play a fundamental role in agricultural production. As long production lags are dictated by the biological processes that underlie the production of crops and the growth of animals, time itself plays a particularly important role in agricultural production. Hence, the effects of uncontrollable factors are heightened in agriculture. Although there are parallels in other production activities, production uncertainty is an important feature of agricultural production.

Price uncertainty is also a standard attribute of agricultural activities. Due to the biological production lags mentioned above, production decisions have to be made far in advance of realizing the final product, so that the market price for the output is not known at the time these decisions have to be made. Moreover, price uncertainty exists because of the inherent volatility of agricultural markets. Such volatility may be due to demand fluctuations, which are particularly important when a sizable portion of output is destined for the export market. Also, production uncertainty, as discussed earlier, contributes to price uncertainty because price needs to adjust to clear the market. In this process some typical features of agricultural markets (a large number of competitive producers, relatively homogeneous output, and inelastic demand) are responsible for considerable price volatility, even for moderate production shocks.

When longer-term economic problems are considered, additional sources of uncertainty are relevant to agricultural decisions. Technological uncertainty in agricultural production relates to the evolution of production techniques that may make quasi-fixed past investments obsolete. It is clear that the randomness of new knowledge development affects production technologies in all sectors. However, what makes it more relevant to agriculture is the fact that technological innovations in agriculture are the product of research efforts carried out elsewhere, for instance, by firms supplying inputs to agriculture, such that competitive farmers are captive players in the process. Policy uncertainty also plays an important role in agriculture. Economic policies have impacts on all sectors through their effects on taxes, interest rates, exchange rates, regulation, provision of public goods, and so on. However, because governments in many countries intervene in agriculture sector, and because in recent times, revisions to these policy interventions are needed (examples include the recent WTO commitment induced changes in key features of the agricultural policies of the United States and the European Union, or the emerging concerns about the environmental impacts of agricultural production), this source of uncertainty creates considerable risk for agricultural activities.

4.2.2 Agricultural Decisions under Uncertainty

The main risks that a typical farmer faces are due to the fact that output prices are not known with certainty when production decisions are made and that the production process contains sources of uncertainty which include factors that are important for production but are outside the complete control of the farmer such as weather conditions, pest infestations, and disease outbreaks. Therefore, it is important to understand how these main sources of risk affect production decisions.

As mentioned earlier, in decision making under uncertainty the problem of selecting the action that induces the most preferred probability distribution reduces to that of maximizing the expected utility of consequences. Therefore, as suggested by Hennessy (1998), consider a producer who maximizes expected utility of random profit and faces a profile of profit opportunities $z(a, \beta, \tilde{\varepsilon})$ where a is a vector of choices (actions) such as input use by the producer, β is a vector of exogenous parameters including government payments and input prices, and $\tilde{\varepsilon}$ is a single random variable such as output price that follows the cumulative distribution function $F(\varepsilon)$ and $\varepsilon \in [0, 1]$. The objective of a risk-averse producer is written as:

$$\max_{a} \qquad E[U(z)] = \int U(z) dF(z) \tag{4.1}$$

then,

$$\max_{a} \qquad \int_0^1 U[z(a,\beta,\varepsilon)]dF(\varepsilon) \tag{4.2}$$

where $U(.)$ is increasing and concave, profit $z(.)$ is assumed to increase in ε (this condition is necessary to ensure monotonicity of utility in ε or this assumption combined with $U_z(.) \geq 0$, indicates that higher values of the random variable are preferred to lower values.), and the objective function is concave in a to satisfy the second-order condition, $\Delta \equiv E\{U_{zz}[.][z_a(.)]^2 + U_z[.]z_{aa}(.)\} < 0$. The first-order condition is

$$\Omega = \int_0^1 U_z[z(a,\beta,\varepsilon)]z_a(a,\beta,\varepsilon)dF(\varepsilon) = 0 \tag{4.3}$$

with parameterized solution at the value $a^* = a[F(\varepsilon),\beta]$.

To examine how uncertainty affects the level of the choice variable selected by a risk averse individual, following Kraus (1979) and Katz (1981), we will compare the solution under uncertainty with the solution when uncertainty is removed by setting the random element equal to its mean (i.e., setting $\tilde{\varepsilon} = \bar{\varepsilon}$). When uncertainty is removed, risk preferences are irrelevant, and the producer's problem is to

$$\max_{a} \qquad z(a,\beta,\varepsilon) \tag{4.4}$$

which yields the vector of first-order conditions as

$$z_a(\hat{a},\beta,\bar{\varepsilon}) = 0 \tag{4.5}$$

with the optimal choice $\hat{a}$. When uncertainty exists, then the first-order condition in (4.3) can be expressed as

$$E[U_z(.)z_a(.)] = 0 \tag{4.6}$$

Since $Cov[U_z(.), z_a(.)] = E[U_z(.)z_a(.)] - E[U_z(.)]E[z_a(.)]$, the first-order condition under uncertainty can be written as

$$Cov[U_z(.), z_a(.)] + E[U_z(.)]E[z_a(.)] = 0 \tag{4.7}$$

To show the impact of risk we compare a^*, the solution under uncertainty, with $\hat{a}$. If

$z_{a\varepsilon}(.) \geq 0$ together with risk aversion, implies that the covariance term must be negative[1]. As marginal utility ($U_z(.)$) is positive, satisfaction of the first-order condition requires that $E[z_a(a^*, \beta, \tilde{\varepsilon})] \geq 0$. If $z_{a\varepsilon\varepsilon}(.) \leq 0$, then Jensen's inequality implies $E[z_a(\hat{a}, \beta, \tilde{\varepsilon})] \leq 0$[2]. It follows that $E[z_a(a^*, \beta, \tilde{\varepsilon})] - E[z_a(\hat{a}, \beta, \tilde{\varepsilon})] \geq 0$. As the only difference between the two expectations is the evaluation of a, and because $z_a(.)$ is decreasing in a ($z_{aa} < 0$), then $a^* < \hat{a}$. In fact, because $z_{a\varepsilon}(.) \geq 0$, that is, an increase in a renders the payoff function more sensitive to the source of risk, the risk-averse producer will reduce sensitivity by decreasing a. A parallel analysis of equation (4.7) shows that when $z_{a\varepsilon}(.) \leq 0$ and $z_{a\varepsilon\varepsilon}(.) \geq 0$, then risk aversion implies $a^* \geq \hat{a}$. Thus, the impact of the existence of uncertainty on optimal choice by a risk averse individual depends on the second and third cross-derivatives of the payoff function ($z_{a\varepsilon}$ and $z_{a\varepsilon\varepsilon}$).

4.2.3 Government Payments Impact on Agricultural Decisions under Uncertainty

Now we look at marginal changes in the decision environment such as government payments, as represented by an increase in β. Following Ormiston (1992), we differentiate the first-order condition under uncertainty (equation (4.3)) partially with respect to a and β to obtain[3]

$$\frac{da^*}{d\beta} = \frac{1}{\Delta}\int_0^1 A[z] z_\beta(.) U_z[.] z_a(.) dF(\varepsilon) - \frac{1}{\Delta}\int_0^1 U_z[.] z_{a\beta}(.) dF(\varepsilon) \tag{4.8}$$

---

[1] Note that if ε increases, z_a increases since $z_{a\varepsilon} > 0$, and also z increases since $z_\varepsilon > 0$ and so U_z decreases since $U_{zz} < 0$ (risk aversion). Therefore, there is a negative relationship between U_z and z_a.

[2] If z_a is a concave function in ε (i.e. $z_{a\varepsilon\varepsilon} \leq 0$), then by Jensen's inequality we can write:

$$E[z_a(\hat{a}, \beta, \tilde{\varepsilon})] \leq z_a(\hat{a}, \beta, \bar{\varepsilon})$$

because from the first order condition in (4.5) we have $z_a(\hat{a}, \beta, \bar{\varepsilon}) = 0$, then we can write:

$$E[z_a(\hat{a}, \beta, \tilde{\varepsilon})] \leq 0.$$

[3] First-order equation under uncertainty, equation (4.3), was

$$\Omega = \int_0^1 U_z[z(a, \beta, \varepsilon)] z_a(a, \beta, \varepsilon) dF(\varepsilon) = 0$$

By totally differentiating with respect to a and β, we have:

$$\frac{d\Omega}{da} = \int_0^1 U_{zz}[.] z_a^2(.) dF(\varepsilon) + \int_0^1 U_z[.] z_{aa}(.) dF(\varepsilon) = 0$$

and

$$\frac{d\Omega}{d\beta} = \int_0^1 U_{zz}[.] z_\beta(.) z_a(.) dF(\varepsilon) + \int_0^1 U_z[.] z_{a\beta}(.) dF(\varepsilon) = 0$$

where $A[.] = -U_{zz}[.]/U_z[.]$ is the absolute risk-aversion function defined earlier. Now we can partition the effect of β on a^* into three elements, the coupling impact, the wealth impact, and the insurance impact (Hennessy, 1998).

4.2.3.1 Coupling Impact

The coupling impact is represented by the expression $-\frac{1}{\Delta}\int_0^1 U_z[.]z_{a\beta}(.)dF(\varepsilon)$ in (4.8) and has the sign of $z_{a\beta}(.)$ (note that $U_z > 0$ and $\Delta < 0$). If β acts to increase the marginal effect of a on payoff $z(.)$, then it will increase the producer's disposition to use a. For example, a price subsidy (on output or input) is coupled because this kind of government supports increases directly the marginal effect of input on profit through higher output prices.

4.2.3.2 Wealth Impact

The wealth and insurance effects are presented in the first term on the right-hand side of (4.8). If $J(.,\varepsilon) \equiv A[.]z_\beta(.)$, so the expression is $Q \equiv \frac{1}{\Delta}\int_0^1 J(.,\varepsilon)U_z(.)z_a(.)dF(\varepsilon)$. Integrating by parts yields [1]

$$Q \equiv 1/\Delta\left[J(.,v)\int_0^v U_z(.)z_a(.)dF(\varepsilon)|_{v=0}^{v=1} - \int_0^1\int_0^v U_z(.)z_a(.)dF(\varepsilon)\frac{dJ(.,v)}{dv}dv\right] \tag{4.9}$$

By the first-order condition (4.3) the first integral term equals zero. Then,

$$Q \equiv -\int_0^1\int_0^v \frac{1}{\Delta}U_z(.)z_a(.)dF(\varepsilon)\frac{dJ(.,v)}{dv}dv \tag{4.10}$$

where v is used as the dummy variable of integration for the variable ε. To identify wealth and insurance effects note that, if $z_{a\varepsilon}(.) \geq 0$, the first-order condition (4.3) implies that the

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Then, by implicit differentiation's definition, we have:

$$\frac{da}{d\beta} = -\frac{d\Omega/d\beta}{d\Omega/da} = -\frac{\int_0^1 U_{zz}[.]z_\beta(.)z_a(.)dF(\varepsilon) + \int_0^1 U_z[.]z_{a\beta}(.)dF(\varepsilon)}{\int_0^1 U_{zz}[.]z_a^2(.)dF(\varepsilon) + \int_0^1 U_z[.]z_{aa}(.)dF(\varepsilon)}$$

Since the denominator is the second-order condition under uncertainty which was called $\Delta(< 0)$, we can write:

$$\frac{da}{d\beta} = \frac{-\int_0^1 U_{zz}[.]z_\beta(.)z_a(.)dF(\varepsilon)}{\Delta} - \frac{\int_0^1 U_z[.]z_{a\beta}(.)dF(\varepsilon)}{\Delta}$$

Defining $A[.] = -U_{zz}[.]/U_z[.]$, equation (4.8) can be obtained.

[1] If $f(x)$ is continuously differentiable and $g(x)$ is continuous, integrating by parts' definition requires

$$\int f(x)g(x)dx = f(x)\int g(x)dx - \int (f'(x)\int g(x)dx)dx$$

.

expression $\int_0^v U_z(.)z_a(.)dF(\varepsilon)$ (which is equal to $E[U_z z_a] = Cov[U_z, z_a] + E[U_z]E[z_a]$) is never positive because of the positivity of marginal utility $U_z(.)$ and because $z_a(.)$ is negative at low ε and increases to be positive at high ε. Since $\Delta < 0$, Q is positive if $dJ(., v)/dv \leq 0$. Differentiate to obtain

$$dJ(., v)/dv = z_\beta(.)A_z[.]z_\varepsilon(.) + A[.]z_{\beta\varepsilon}(.) \tag{4.11}$$

The first part of this expression is called the wealth effect because its negativity depends upon the DARA (decreasing absolute risk aversion) property and the sign of $z_\beta(.)$ (recall that $z_\varepsilon(.) \geq 0$). All other things equal, if β shifts the distribution of payoffs rightward ($z_\beta(.) \geq 0$), and if preferences are DARA ($A_z[.] < 0$), then a increases.

4.2.3.3 Insurance Impact

The second part of equation (4.11), $A[.]z_{\beta\varepsilon}(.)$, is the insurance effect. If the shift in β acts to stabilize income, that is if $z_{\beta\varepsilon}(.) \leq 0$ which insures that the support policy actually acts to mitigate risk, then optimal a tends to increase. For example, if the government supports producers through decoupled payments, such as payments based on the previous five years of income (which are not based on the level of current output or prices), government payments can lead to a profit distribution with higher mean and lower variance, and therefore increase in optimal choice by producers. In this case, both wealth and insurance effects act to increase optimal a. To remove the insurance effect, a decoupled program must be invariant to the source of randomness i.e. $z_{\beta\varepsilon}(.) = 0$[1], while preferences must be constant absolute risk aversion (CARA) for the wealth effect to be absent i.e. $A_z = 0$.

4.3 The Theoretical Model of Acreage Decisions

In this section, the optimal acreage decisions under uncertainty are derived and specified. The three main channels affecting the optimum outlined in the previous section - price, wealth and insurance impacts - are incorporated. Hence, the model is able to incorporate the effect of government payments on acreage decisions by influencing these channels. First, following Chavas and Holt (1990), optimal acreage choice for each crop as a function of initial wealth, expected profits and variance of profits (profit distributions determinants) is derived.

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[1] However, for many decoupled support policies, the magnitude of support is conditional on the evaluation of risk source (ε).

Then, properties of the optimal acreage decision including symmetry and homogeneity are discussed. Since Chavas and Holt's model does not address the insurance effect emphasized in the literature, the symmetry restrictions provided by Chavas and Holt are extended in a way such that the model has the potential to include explicitly the insurance effect in addition to the wealth effect. Next, the optimal acreage choice for each crop is specified as a function of total wealth i.e. initial wealth plus total profit (wealth effect), expected profit for individual crops and their variances (coupling/price effect), and the variance of total profit (insurance effect). Government payments are incorporated into the model through truncation of the profit distributions. Finally, the expected signs for explanatory variables are analytically derived based on the portfolio theory.

4.3.1 The Model

In this section, we modify Chavas and Holt's (1990) expected utility model for acreage decisions. Consider a farm household producing n crops, agricultural revenue is given by

$$R = \sum_{i=1}^{n} p_i y_i A_i \tag{4.12}$$

where p_i is the market price of the ith crop, A_i is the number of acres devoted to the ith crop and y_i is the corresponding yield per acre, $i = 1, ..., n$. The total cost of agricultural production is

$$C = \sum_{i=1}^{n} c_i A_i \tag{4.13}$$

where c_i shows the cost of production per acre of the ith crop. In the present case, revenue (R) is a risky variable because output prices $p = (p_1, ..., p_n)$ and crop yields $y = (y_1, ..., y_n)$ are not observed by the household when production decisions are made. Input prices and per acre costs (c_i), however, are known at the time crop acreages are allocated.

The household faces the budget constraint

$$I + R - C = qG \qquad \text{or} \qquad I + \sum_{i=1}^{n} p_i y_i A_i - \sum_{i=1}^{n} c_i A_i = qG \tag{4.14}$$

where I denotes exogenous income (initial wealth) and G is an index of household consumption of goods purchased with corresponding consumer price index q, qG presents household consumption expenditures. Initial wealth may be held in risky assets. Thus, following Chavas

(1987), the initial wealth is also modelled here as random variable. The above equation states that initial wealth (I) plus farm profit ($R - C$), which can be called total wealth ($I + R - C = \mathrm{W}$), is equal to consumption expenditures (qG). The constraint on acreage decisions (or adding-up constraint) can be represented by

$$f(\mathbf{A}) = 0 \tag{4.15}$$

where $\mathbf{A} = (A_1, ..., A_n)$.

Assume that the farm household preferences are represented by a von Neumann-Morgenstem (v.N-M) utility function $U(G)$ satisfying $U_G > 0$. If the farm household maximizes expected utility under competition, then the decision model is

$$\begin{aligned} &\max_{A,G} \quad E[U(G)] \\ &\text{s.t.} \quad I + \textstyle\sum_{i=1}^{n} p_i y_i A_i - \sum_{i=1}^{n} c_i A_i = qG \qquad \text{and} \qquad f(\mathbf{A}) = 0 \end{aligned} \tag{4.16}$$

where E is the expectation operator over the random variables. After substituting the budget constraint into the utility function, the maximization problem is expressed as

$$\begin{aligned} &\max_{A} \quad E[U(I/q + \sum_{i=1}^{n}(p_i/qy_i - c_i/q)A_i)] \quad \text{s.t.} \quad f(\mathbf{A}) = 0, \qquad \text{or} \\ &\max_{A} \quad E[U(w + \sum_{i=1}^{n} \pi_i A_i)] \quad \text{s.t.} \quad f(\mathbf{A}) = 0 \end{aligned} \tag{4.17}$$

where $w = (I/q)$ denotes normalized initial wealth and $\pi_i = (p_i/q)y_i - (c_i/q)$ shows normalized profit per acre of the ith crop, and all prices are deflated by the consumer price index q.

In this setting, yields y, output prices p and initial wealth w are random variables with given subjective probability distributions. Consequently, the expectation E is over the uncertain variables y, p and w and is based on the information available to the household at planting time.

If $\mathbf{A}^*$ denotes the optimal acreage choice in optimization equation (4.17), then the Lagrange's equation will be $L = E[U(w + \Pi\mathbf{A}')] + \mu(f(\mathbf{A}))$ where $\mu > 0$ and the first-order conditions ($\frac{\partial L}{\partial \mathbf{A}} = 0$ and $\frac{\partial L}{\partial \mu} = 0$) are written as[1]

$$E[U_W \Pi] + \mu f_{\mathbf{A}} = 0 \tag{4.18}$$

---

[1] The bordered hessian for the second order condition being satisfied is $H = \begin{pmatrix} E[U_{WW}(\Pi)^2] + \mu f_{\mathbf{AA}} & f_{\mathbf{A}} \\ f_{\mathbf{A}} & 0 \end{pmatrix}$.

$$f(\mathbf{A}) = 0 \tag{4.19}$$

where $\Pi = (\pi_1, ..., \pi_n)$ is assumed to be a random variable with mean $\bar{\Pi}$ and variance-covariance matrix σ, $\mathbf{A}' = (A_1, ..., A_n)'$ and $f_{\mathbf{A}} = \partial f / \partial \mathbf{A}$ is a $(1 \times n)$ of vector. We follow Newbery and Stiglitz (1979) and expand U_W around expected wealth W, $\bar{W}' = \bar{w} + \mathbf{A}\bar{\Pi}'$. First-order Taylor series expansion about mean wealth yields $U_W \cong \bar{U}_W + \big((w - \bar{w}) + \mathbf{A}(\Pi' - \bar{\Pi}')\big)\bar{U}_{WW}$, where $\bar{U}_W$ and $\bar{U}_{WW}$ are the first and second-order derivatives of the utility function evaluated at the expected wealth $\bar{W}$. Substituting the Taylor series expansion into the first-order condition (4.18) and rearranging terms yields[1],

$$\bar{U}_W \bar{\Pi} + \bar{U}_{WW} \mathbf{A}\sigma + \mu f_{\mathbf{A}} = 0 \tag{4.20}$$

Therefore, optimal acreage choice in (4.17) depends on expected normalized initial wealth w, expected normalized crop profits per acre $\bar{\pi}_i$, as well as second moment[2] of the distributions of normalized profits per acre, denoted here by $\sigma_{n \times n}$ and initial wealth σ_w (see also Chavas, 1987). Therefore, the optimal acreage decision can be written as $\mathbf{A}^*(\bar{w}; \bar{\Pi}; \sigma; \sigma_w)$.

4.3.2 Properties of the Optimal Acreage Decision

To ensure the robustness of the model's results, in this section we focus on the theoretical restrictions implied by (4.17), which can modify the empirical specification of the acreage decision $\mathbf{A}^*(\bar{w}; \bar{\Pi}; \sigma; \sigma_w)$. Through the theoretical restriction channel, this dissertation makes a contribution to the literature by incorporating the insurance effect (income stabilization) emphasized in the literature, while ignored by Chavas and Holt model (1990), into our theoretical model. Based on the theoretical discussions regarding the role of insurance effect in acreage decisions, the theoretical restrictions examined by Chavas and Holt (1990) are extended, which enables the inclusion of this effect in the model's specification.

---

[1] From (4.18),

$$E[U_W \Pi] \cong E[(\bar{U}_W + ((w - \bar{w}) + \mathbf{A}(\Pi' - \bar{\Pi}'))\bar{U}_{WW})\Pi]$$

then,

$$E[U_W \Pi] \cong \bar{U}_W E[\Pi] + \bar{U}_{WW} \mathbf{A}[E(\Pi'\Pi) - E(\Pi')E(\Pi)]$$

then,

$$E[U_W \Pi] \cong \bar{U}_W \bar{\Pi} + \bar{U}_{WW} \mathbf{A}\sigma,$$

note that σ is crop profit variance-covariance matrix with order $n \times n$.

[2] Note that since here we follow Newbery and Stiglitz (1979) and use only the first-order Taylor series expansion for approximation of U_W, the optimal acreage is a function of first and second moments and not higher moments of the distributions of profits. In general Taylor series expansion, it is usually found that because $U_k/k!$ becomes smaller at a rather faster rate than moments i.e., M_k becomes larger as k increases, terms beyond those involving the higher moments add insignificantly to the precision of the approximation.

First, by considering the relationship between the wealth compensated and uncompensated acreage decision functions, Chavas and Holt (1990) have shown that the acreage decision is affected by expected total wealth (wealth effect). However, the theoretical framework provided by Hennessy (1998) suggests a role for an insurance effect in acreage decisions. Hence, we should also consider the relationship between income stabilization compensated and uncompensated acreage decision functions. Based on this modification, the model has a specification different from the one by Chavas and Holt (1990), i.e. acreage response would be a function of variance of total profit in addition to the expected total wealth, expected individual crop profits and the variance-covariance of individual crop profits. The procedure that shows total wealth and its variance should be included in the model is as follows.

Following Chavas (1987), consider the compensation function C defined implicitly as follows

$$\{V(w+C,.) = \max_{s.t. f(\mathbf{A})=0} E[U(w+C+\Pi\mathbf{A}')] = U^0\}$$

where V denotes the indirect objective function and C is the certain amount of money that must be given to (or paid by, if negative) the decision maker in order to keep him at a particular level of utility U^0. The compensation function, as defined in the above, is a function of $\bar{w}$, $\bar{\Pi}$, σ, σ_w and U^0. The relationships between the uncompensated choice function $\mathbf{A}^*$ and the compensated function $\mathbf{A}^c$ are defined as

$$\mathbf{A}^c(\bar{w}, \bar{\Pi}, \sigma, \sigma_w, U^0) = \mathbf{A}^*(\bar{w} + C(\bar{w}, \bar{\Pi}, \sigma, \sigma_w, U^0), \bar{\Pi}, \sigma, \sigma_w)$$

The above expression indicates how the compensation, C, influences optimal choices (acres). By differentiating with respect to $\bar{\Pi}$ and σ[1], we have

$$\begin{pmatrix} \frac{\partial \mathbf{A}^c}{\partial \bar{\Pi}} & \frac{\partial \mathbf{A}^c}{\partial \sigma} \end{pmatrix}_{n\times n(n+1)} = \begin{pmatrix} \frac{\partial \mathbf{A}^*}{\partial \bar{\Pi}} & \frac{\partial \mathbf{A}^*}{\partial \sigma} \end{pmatrix}_{n\times n(n+1)} + \begin{pmatrix} \frac{\partial \mathbf{A}^*}{\partial C} \end{pmatrix}_{n\times 1} \cdot \begin{pmatrix} \frac{\partial C}{\partial \bar{\Pi}} & \frac{\partial C}{\partial \sigma} \end{pmatrix}_{1\times n(n+1)} \qquad (4.21)$$

or in an expanded form, we have

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[1] Note that Chavas and Holt (1990) consider only the differentiation with respect to $\bar{\Pi}$ and do not take into account another element σ in the choice functions.

$$\begin{pmatrix} \frac{\partial A_1^c}{\partial \bar{\Pi}_1} & \cdots & \frac{\partial A_1^c}{\partial \bar{\Pi}_n} & \frac{\partial A_1^c}{\partial \sigma_{11}} & \frac{\partial A_1^c}{\partial \sigma_{12}} & \cdots & \frac{\partial A_1^c}{\partial \sigma_{nn}} \\ \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial A_n^c}{\partial \bar{\Pi}_1} & \cdots & \frac{\partial A_n^c}{\partial \bar{\Pi}_n} & \frac{\partial A_n^c}{\partial \sigma_{11}} & \frac{\partial A_n^c}{\partial \sigma_{12}} & \cdots & \frac{\partial A_n^c}{\partial \sigma_{nn}} \end{pmatrix} = \begin{pmatrix} \frac{\partial A_1^*}{\partial \bar{\Pi}_1} & \cdots & \frac{\partial A_1^*}{\partial \bar{\Pi}_n} & \frac{\partial A_1^*}{\partial \sigma_{11}} & \frac{\partial A_1^*}{\partial \sigma_{12}} & \cdots & \frac{\partial A_1^*}{\partial \sigma_{nn}} \\ \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial A_n^*}{\partial \bar{\Pi}_1} & \cdots & \frac{\partial A_n^*}{\partial \bar{\Pi}_n} & \frac{\partial A_n^*}{\partial \sigma_{11}} & \frac{\partial A_n^*}{\partial \sigma_{12}} & \cdots & \frac{\partial A_n^*}{\partial \sigma_{nn}} \end{pmatrix} + \begin{pmatrix} \frac{\partial A_1^*}{\partial C} \\ \cdots \\ \frac{\partial A_n^*}{\partial C} \end{pmatrix} \cdot \begin{pmatrix} \frac{\partial C}{\partial \bar{\Pi}_1} & \cdots & \frac{\partial C}{\partial \bar{\Pi}_n} & \frac{\partial C}{\partial \sigma_{11}} & \frac{\partial C}{\partial \sigma_{12}} & \cdots & \frac{\partial C}{\partial \sigma_{nn}} \end{pmatrix} \tag{4.22}$$

Levy and Markowitz (1979) have demonstrated that the mean-variance model is appropriate as a second-order Taylor series approximation to all risk-averse utility functions. In order to determine $\frac{\partial A_i^c}{\partial \bar{\Pi}_j}$ and $\frac{\partial A_i^c}{\partial \sigma_{ij}}$ $(i, j = 1, ..., n)$, for simplicity the expected utility in the above can be considered as having the form $U = \bar{W} - \frac{1}{2}\tau\sigma_W$, where $\bar{W}$ is expected total wealth, τ shows the non-constant coefficient of risk aversion, i.e. $\tau(\bar{W}, \sigma_W)$, and σ_W is the variance of total wealth. One can define $\bar{W} = \bar{w} + \bar{\Pi}\mathbf{A}' = \bar{w} + \sum_{i=1}^n \bar{\Pi}_i A_i$, where expected total wealth is expected initial wealth, $\bar{w}$, plus expected income from the market, and $\sigma_W = \sigma_w + \mathbf{A}\sigma\mathbf{A}' = \sigma_w + \sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij}$, where σ is a variance-covariance matrix of crop profits.

If U^0 is a particular level of utility which is intended to be maintained through the compensation, when components of $\bar{W}$ and σ_W changes, one can write $U^0 = \bar{w} + C + \sum_{i=1}^n \bar{\Pi}_i A_i - \frac{1}{2}\tau(\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)$. Thus, by taking the total differential, we have,

$$\frac{\partial C}{\partial \bar{\Pi}_j} = -\frac{\big(A_j - \frac{1}{2}\tau_{\bar{W}} A_j (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)}{\big(1 - \frac{1}{2}\tau_{\bar{W}} (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)} = -A_j^c \tag{4.23}$$

and

$$\frac{\partial C}{\partial \bar{w}} = -\frac{\big(1 - \frac{1}{2}\tau_{\bar{W}} (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)}{\big(1 - \frac{1}{2}\tau_{\bar{W}} (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)} = -1 \tag{4.24}$$

In addition, we can obtain,

$$\frac{\partial C}{\partial \sigma_{ij}} = -\frac{-\big(\frac{1}{2}\tau A_i A_j + \frac{1}{2}\tau_{\sigma_W} A_i A_j (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)}{\big(1 - \frac{1}{2}\tau_{\bar{W}} (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)} \tag{4.25}$$

and

$$\frac{\partial C}{\partial \sigma_w} = -\frac{-\big(\frac{1}{2}\tau + \frac{1}{2}\tau_{\sigma_W} (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)}{\big(1 - \frac{1}{2}\tau_{\bar{W}} (\sum_{i=1}^n \sum_{j=1}^n A_i A_j \sigma_{ij} + \sigma_w)\big)} \tag{4.26}$$

where $\tau_{\bar{W}}$ and $\tau_{\sigma W}$ are partial derivative of τ with respect to total expected wealth and its variance.

From equation (4.22), we have

$$\frac{\partial A_i^c}{\partial \bar{\Pi}_j} = \frac{\partial A_i^*}{\partial \bar{\Pi}_j} + \frac{\partial A_i^*}{\partial C}\frac{\partial C}{\partial \bar{\Pi}_j} = \frac{\partial A_i^*}{\partial \bar{\Pi}_j} + \frac{\partial A_i^*}{\partial \bar{w}}\frac{\partial \bar{w}}{\partial C}\frac{\partial C}{\partial \bar{\Pi}_j} \tag{4.27}$$

Evaluating (4.23) and (4.24) at $C = 0$ and by substituting equations (4.23) and (4.24) into (4.27), we have

$$\frac{\partial A_i^c}{\partial \bar{\Pi}_j} = \frac{\partial A_i^*}{\partial \bar{\Pi}_j} - \frac{\partial A_i^*}{\partial \bar{w}} A_j^* \tag{4.28}$$

A_i^c is the wealth compensated acreage decision, holding utility constant. The matrix of compensated effects $\frac{\partial A_i^c}{\partial \bar{\Pi}_j}$ in expression (4.28) is symmetric, positive semidefinite (Chavas, 1987). Expression (4.28) also indicates that the slope of the uncompensated function $\frac{\partial A_i^*}{\partial \bar{\Pi}_j}$ can be decomposed as the sum of two terms: the compensated slope (or substitution effect) $\frac{\partial A_i^c}{\partial \bar{\Pi}_j}$ which maintains a given level of utility plus the wealth effect $(\frac{\partial A_i^*}{\partial \bar{w}} A_j^*)$.

Further from equation (4.22), we have,

$$\frac{\partial A_i^c}{\partial \sigma_{ij}} = \frac{\partial A_i^*}{\partial \sigma_{ij}} + \frac{\partial A_i^*}{\partial C}\frac{\partial C}{\partial \sigma_{ij}} = \frac{\partial A_i^*}{\partial \sigma_{ij}} + \frac{\partial A_i^*}{\partial \sigma_w}\frac{\partial \sigma_w}{\partial C}\frac{\partial C}{\partial \sigma_{ij}} \tag{4.29}$$

Evaluating (4.25) and (4.26) at $C = 0$ and by substituting equations (4.25) and (4.26) into (4.29), we have

$$\frac{\partial A_i^c}{\partial \sigma_{ij}} = \frac{\partial A_i^*}{\partial \sigma_{ij}} - \frac{\partial A_i^*}{\partial \sigma_w} A_i^* A_j^* \tag{4.30}$$

A_i^c is the insurance compensated acreage decision, holding utility constant. Expression (4.30) indicates that the slope of the uncompensated function $\frac{\partial A_i^*}{\partial \sigma_{ij}}$ can be decomposed as the sum of two terms: the compensated slope, $\frac{\partial A_i^c}{\partial \sigma_{ij}}$, which maintains a given level of utility plus the insurance effect, $\frac{\partial A_i^*}{\partial \sigma_w} A_i^* A_j^*$, which is emphasized in the literature (Hennessy, 1998) but ignored by Chavas and Holt (1990).

Second, another theoretical restriction is a homogeneity condition which has been derived by Chavas and Pope (1985) in the context of the expected utility model (4.17). In particular, rewriting expression (4.15) as $f(A) = A_1 - g(A_.) = 0$, where $A = (A_1, A_.)$, Chavas and Pope have shown that the following restriction holds at the optimum under any risk preferences

$$\frac{\partial \mathbf{A}^*}{\partial \bar{\Pi}}.\frac{\partial f(\mathbf{A})}{\partial \mathbf{A}} - \frac{\partial \mathbf{A}^*}{\partial w}.\frac{\partial f(\mathbf{A})}{\partial \mathbf{A}}.\mathbf{A} = 0 \tag{4.31}$$

Consider the first-order conditions (4.18), we have $f_{\mathbf{A}} = E[U_W \Pi]/\mu$ and we know that $E[U_W \Pi] = Cov(U_W, \Pi) + E(U_W)E(\Pi)$. Given $\mu \neq 0$, substituting these conditions into (4.31) yields

$$\frac{\partial \mathbf{A}^*}{\partial \bar{\Pi}}(\bar{\Pi} + \varphi) - \frac{\partial \mathbf{A}^*}{\partial w}(\bar{\Pi}' + \varphi')\mathbf{A} = 0 \tag{4.32}$$

where $\varphi = Cov(U_W, \Pi)/E(U_W)$ is an $(n \times 1)$ vector.

Under risk neutrality, $\partial \mathbf{A}^*/\partial w = 0$ and $\varphi = 0$, implying from (4.32) that the acreage decision function A^* is homogenous of degree zero in $\bar{\pi}_j$ (or in output and input prices, p and c), $\sum_{j=1}^{n} \frac{\partial A_i^*}{\partial \bar{\pi}_j} \bar{\pi}_j = 0$. This homogeneity restriction of classical production theory states that production decisions are not affected by proportional changes in all input and output prices. However, under risk aversion, $\varphi \neq 0$ and (4.32) implies that this homogeneity-like restriction takes a different form. In other words, in general under uncertainty the classical result of riskless production theory, which asserts that production decisions depend only on input-output price ratios, does not hold. Pope (1988) has presented some empirical implications of specific forms of risk preferences. In particular, under constant relative risk aversion[1], a positive scaling of wealth does not alter optimal decisions[2]. This implies that decision functions are almost homogenous of degree one in initial wealth, degree one in mean returns $\bar{\Pi}$, degree two in moments of order two, and degree s in moments of order s of π (See Pope, 1988 for details).

4.3.3 Incorporation of Government Programs into the Model

The acreage decision model (4.17) involves uncertainty about prices p and yields y. In this section the influence of government programs on the subjective probability distribution of profits Π is considered. The resulting truncation of the subjective probability distribution of profits will affect expected profits ($\bar{\Pi}$) as well as the second (σ) and higher moments of the profit distribution. Thus, a support program will influence both profit expectations and the

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[1] The coefficient of relative risk aversion is defined as $\tau = (w + \sum_{i=1}^{n} \pi_i A_i)(-\frac{U_{ww}}{U_w})$, where $(-\frac{U_{ww}}{U_w})$ is the coefficient of absolute risk aversion.

[2] According to Pope (1988), a function $h(Z_1, ..., Z_N)$, $h : R^N \rightarrow R$ is said to be almost homogenous of degree $C_1, ..., C_N$ and zero respectively if $h(\lambda^{C_1} Z_1, ..., \lambda^{C_N} Z_N) = \lambda^0 h(Z_1, ..., Z_N)$ where $\lambda \in R^+$, the positive real line.

riskiness of profit.

We consider the normal case since the effects of multivariate truncation are best understood in the context of a normal distribution (See Johnson and Kotz, 1972). Let $\Pi = (\pi_1, \pi_2, ...)$ be a vector of normally distributed random profits with mean $E(\Pi) = \bar{\Pi} = (\bar{\pi_1}, \bar{\pi_2}, ...)$ and variance $\sigma = E(\Pi - \bar{\Pi})'(\Pi - \bar{\Pi})$, where E is the expectation operator. Now, assume that each random profit π_i, is truncated from below at a level H_i. Define the truncated random profits

$$\pi_i^T = \begin{cases} H_i & \text{if} \quad \pi_i < H_i, \\ \pi_i & \text{if} \quad \pi_i \geq H_i, \end{cases} \quad i = 1, 2, ..., n$$

Consider the standardized random profit $e_i = \frac{\pi_i^T - \bar{\pi}_i}{\sigma_{ii}^{1/2}}$ and define $h_i = \frac{H_i - \bar{\pi}_i}{\sigma_{ii}^{1/2}}$. The mean and variance of e_i are derived in Chavas and Holt (1990). The expected value of e_i, is

$$\bar{e}_i = E(e_i) = \phi(h_i) + h_i \Phi(h_i) \tag{4.33}$$

where $\phi(.)$ and $\Phi(.)$ are the standard normal density function and distribution function, respectively. The second moments of e_i, are given by

$$M_{ii} = E(e_i^2) = 1 - \Phi(h_i) + h_i \phi(h_i) + h_i^2 \Phi(h_i) \tag{4.34}$$

and if $i \neq j$,

$$\begin{aligned} M_{ij} = E(e_i e_j) = F(h_i, h_j)\rho_{ij} + [(1 - \rho_{ij}^2)/2 \times 3.14]^{1/2} \phi(Z_{ij}) + h_i \phi(h_j) \Phi(k_{ij}) \\ + h_j \phi(h_i) \Phi(k_{ji}) + h_i h_j \Phi(h_i, h_j) \end{aligned} \tag{4.35}$$

where $F(h_i, h_j) = prob(\pi_i \geq H_i, \pi_j \geq H_j) = \Phi(h_i, h_j) + 1 - \Phi(h_i) - \Phi(h_j)$, $\rho_{ij} = \sigma_{ij}/(\sigma_{ii}\sigma_{jj})^{1/2}$, $Z_{ij} = \{(h_i - 2p_{ij}h_ih_j + h_j)/(l - \rho_{ij}^2)\}^{1/2}$, $k_{ij} = (h_i - \rho_{ij}h_j)/(l - \rho_{ij}^2)^{1/2}$ and $\Phi(h_i, h_j) = prob(\pi_i < H_i, \pi_j < H_j)$. It follows that the mean, variance, and covariance of $\Pi^T = (\pi_1^T, \pi_2^T, ...)$ are

$$\bar{\pi}_i^T = E(\pi_i^T) = \bar{\pi}_i + \sigma_{ii}^{1/2} \bar{e}_i \tag{4.36}$$

and,

$$\sigma_{ii}^T = E(\pi_i^T - \bar{\pi}_i^T)^2 = \sigma_{ii}(M_{ii} - \bar{e}_i^2) \tag{4.37}$$

and,

$$Cov(\bar{\pi}_i^T, \bar{\pi}_j^T) = E(\pi_i^T - \bar{\pi}_i^T)(\pi_j^T - \bar{\pi}_j^T) = (\sigma_{ii}\sigma_{jj})^{1/2}(M_{ij} - \bar{e}_i\bar{e}_j) \tag{4.38}$$

The above expressions provide an analytical evaluation of the truncation effect of a support program on the mean, variance, and covariance of commodity profits. These results will be used to investigate the influence of government programs on crop acreage decisions. Figure 4.1 illustrates the effects of government programs on the mean and variance of commodity profit distribution. When untruncated expected commodity profits are substantially above the guaranteed income by government, the effect of government program on moments of the profit distribution will remain at a minimum. However, when untruncated expected commodity profits are either slightly above the guaranteed income or actually below the guaranteed income, the effects on moments of the profit distributions will be more pronounced.

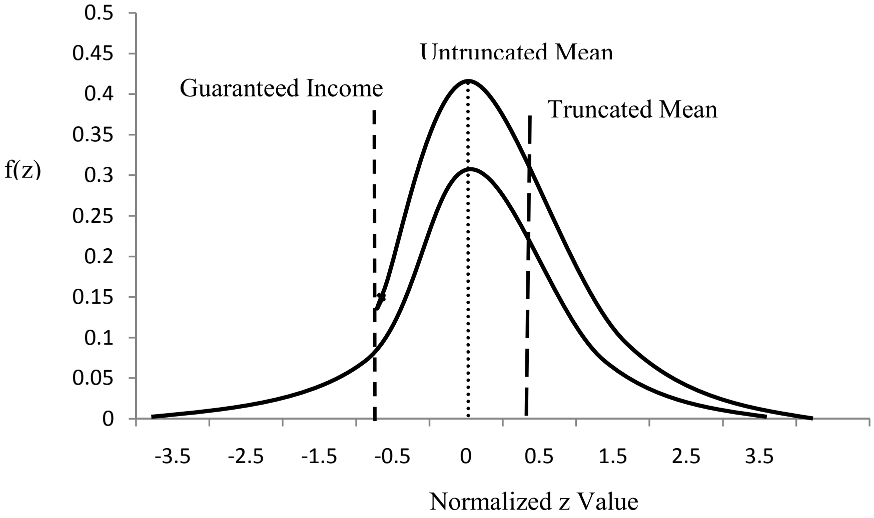

Figure 4.1: The Effects of Government Program Truncation on Crop Profit Distribution

The above expressions show that to derive the truncated mean and variance-covariance of profits we need an untruncated mean and variance-covariance of profits $(\bar{\Pi}, \sigma)$. The formula for untruncated mean and variance-covariance of profits will be discussed in the next chapter.

4.3.4 Model Specification and Hypothesized Signs on Parameters

As explained in part 4.3.1, the optimal acreage decision can be written as $\mathbf{A}^*(\bar{w}; \bar{\Pi}; \sigma; \sigma_w)$. Using the first-order Taylor series expansion, the acreage equations can be specified as

$$A_{it} = a_0 + (\partial A_i/\partial \bar{w})\bar{w}_{t-1} + \sum_{j=1}^{n}(\partial A_i/\partial \bar{\pi}_j)\bar{\pi}_{jt}^T + \sum_{k\geq j}^{n}\sum_{j=1}^{n}(\partial A_i/\partial \sigma_{jk})\sigma_{jkt}^T + (\partial A_i/\partial \sigma_w)\sigma_w + \upsilon_{it} \tag{4.39}$$

where $\bar{\pi}^T$ is the truncated mean of crop profits and σ^T shows the truncated variance-covariance of crop profits. Using (4.28) and (4.30), it follows that equation (4.39) can be expressed alternatively as

$$\begin{aligned} A_{it} = a_0 + (\partial A_i/\partial \bar{w})\bar{w}_{t-1} + \sum_{j=1}^{n}(\partial A_i^c/\partial \bar{\pi}_j + \partial A_i/\partial \bar{w} A_j)\bar{\pi}_{jt}^T + \\ \sum_{k\geq j}^{n}\sum_{j=1}^{n}(\partial A_i^c/\partial \sigma_{jk} + \partial A_i/\partial \sigma_w A_j A_k)\sigma_{jkt}^T + (\partial A_i/\partial \sigma_w)\sigma_w + \upsilon_{it} \end{aligned} \tag{4.40}$$

Letting $\beta_{ij} = \partial A_i^c/\partial \bar{\pi}_j$ and $\gamma_{ijk} = \partial A_i^c/\partial \sigma_{jk}$ be the compensated slopes with respect to $\bar{\pi}$ and σ, respectively, then

$$A_{it} = a_0 + \alpha_i(\bar{w}_{t-1} + \sum_{j=1}^{n} A_j\bar{\pi}_{jt}^T) + \sum_{j=1}^{n}\beta_{ij}\bar{\pi}_{jt}^T + \sum_{k\geq j}^{n}\sum_{j=1}^{n}\gamma_{ijk}\sigma_{jkt}^T + \delta_i(\sum_{k\geq j}^{n}\sum_{j=1}^{n} A_j A_k\sigma_{jkt}^T + \sigma_w) + \upsilon_{it} \tag{4.41}$$

where $\alpha_i = \partial A_i/\partial \bar{W}^1$ and $\delta_i = \partial A_i/\partial \sigma_W$. Note that in equation (4.41), $\sum_{j=1}^{n} A_j\bar{\pi}_{jt}^T$ is equal to the truncated mean of total (farm) profit and along with initial wealth comprises the wealth effect. This wealth effect shows the income-supporting attribute of government policies, that is, higher average income arising from the support policy may affect producer decisions. $\sum_{k\geq j}^{n}\sum_{j=1}^{n} A_j A_k\sigma_{jkt}^T$ is equal to the truncated variance of total profit and along with initial wealth variability comprises the insurance effect. This insurance effect shows the income-stabilizing attribute of government policies; that is, programs may affect optimal decisions by reducing the variance of the farm crop portfolio. In the absence of a priori information about functional form, equation (4.41) provides a local approximation to the decision function $A^*(.)$. Also, the symmetry of (4.28) implies that $\beta_{ij} = \beta_{ji}$, $i \neq j$. Thus,

---

[1] Note that $\partial A_i/\partial \bar{w} = \partial A_i/\partial \bar{W}.\partial \bar{W}/\partial \bar{w}$ and since $\partial \bar{W}/\partial \bar{w} = 1$ (because $\bar{W} = \bar{w} + \bar{\Pi}A'$), therefore $\partial A_i/\partial \bar{w} = \partial A_i/\partial \bar{W}$.

equation (4.41) is convenient for testing and/or imposing the symmetry restrictions (4.28). Equation (4.41) can be used directly for an empirical analysis of acreage decisions.

Considering that the allocation of a given amount of land to different crops is similar to choosing an optimal portfolio of assets, we use portfolio theory to determine the hypothesized relationships (signs) between acreage of a given crop and each of the variables in equation (4.41) including profits, variances and covariances. To do this, the general procedure by which an optimal portfolio is chosen by an investor is first explained. Then, this procedure is applied to the specific case with three products (which gives the same results as N products case) and based on the derived equations the sign of the related variables can be determined.

For finding the optimal portfolio the utility function and efficient sets must be derived in return and variance space. For determining the curvature of utility function, following Anderson, Dillon and Hardaker (1977), the utility of wealth can be written as a second-order[1] Taylor series expansion about a given level of wealth (say W_0)

$$U(W) = U(W_0) + U_W(W_0)(W - W_0) + U_{WW}(W_0)(W - W_0)^2/2! \tag{4.42}$$

If the particular positive linear transformation of subtracting $U(W_0)$ and dividing by $U_W(W_0)$ are made, $U(W)$ is expressed as

$$U(W) = (W - W_0) + \frac{U_{WW}(W_0)}{2U_W(W_0)}(W - W_0)^2 \tag{4.43}$$

and the restriction $U_W > 0$ necessities $1 + 2\frac{U_{WW}(W_0)}{2U_W(W_0)}(W - W_0) > 0$. Assuming $a = cW_0^2 - W_0$, $b = 1 - 2cW_0$, $c = U_{WW}(W_0)/2U_W(W_0)$, where c is negative for risk averse individual because U_{WW} is negative for risk averse individual, positive for risk preferrer and zero for risk neutral, and $\sigma = E(W^2) - [E(W)]^2$, then expected utility of wealth is

$$E[U(W)] = a + bE(W) + c[E(W)]^2 + c\sigma \tag{4.44}$$

For convenience, equation (4.44) is written as

$$U = a + bE + cE^2 + c\sigma \tag{4.45}$$

---

[1] Assuming the derivatives beyond the second are sufficiently small to be ignored, we can use only the second-order Taylor series expansion and the utility function approximation can be written in quadratic form.

The above equation implies a utility surface in the three dimensions, U, E and σ. For constant values of U, the function can be represented by a series of isoutility contours or indifference curves in (E, σ) space. Thus, setting U equal to some constant U^*, rearranging gives

$$\sigma = U^*/c - a/c - bE/c - E^2 \tag{4.46}$$

as the (E, σ) locus of all mean-variance combinations that yield the same level of utility. By totally differentiating and $dU^* = 0$, the decision maker's tradeoff or substitution rate between mean and variance is given by the slope of the isoutility curve, which is

$$dE/d\sigma = -c/(1 + 2cE) \tag{4.47}$$

Since $U_W = 1 + 2\frac{U_{WW}(W_0)}{2U_W(W_0)}(W - W_0) = 1 + 2c(W - W_0) > 0$, its expected value $(1 + 2cE)$ must be positive also. Hence, $dE/d\sigma$ will be positive, zero, or negative within the relevant range according to whether c is negative (for risk averse individual), zero (for risk neutral), or positive (for risk preferrer). As is intuitively obvious, a risk averse decision maker will need increases in mean value to compensate for increased variance if his utility is to remain unchanged.

The second derivative of the isoutility curve is

$$d^2E/d\sigma^2 = [\frac{2c^2}{(1 + 2cE)^2}]dE/d\sigma \tag{4.48}$$

The term in square brackets is always positive, and $dE/d\sigma$ is positive or negative over the relevant range according to whether c is negative or positive. Hence, for a risk averse individual the isoutility curves have positive slope and are convex (increasing slope i.e., the tradeoff rate increases as σ increases), and for a risk loving individual the isoutility curves have negative slope and are concave. The greater the degree of risk aversion or preference (the greater $|c|$ is), the steeper the indifference curves. The above relationships are shown in figure 4.2 which illustrates the respective indifference curves for risk-averse, risk-preferrer and risk-neutral decision makers.

After finding the curvature of utility function in return and variance space, to be able to find the optimal portfolio, in this space the efficient set should also be identified. The efficient set represents the combinations of investments that provide either the highest possible expected return for any specified degree of risk or the lowest possible risk for any specified

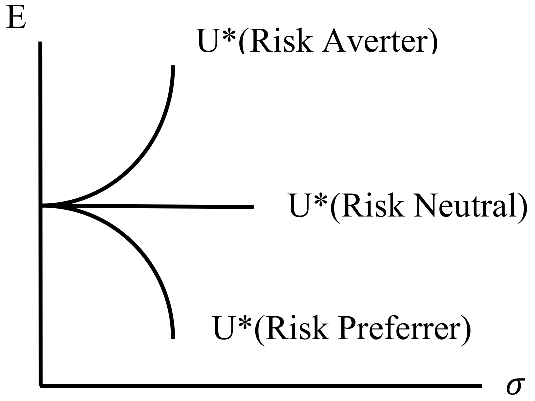

Figure 4.2: Isoutility Curves for $U = a + bE + cE^2 + c\sigma$

expected return. To do this, a set of two risky prospects, i and j, can be considered. This set of prospect mix is called a portfolio. A portfolio with only enterprise i is a low risk portfolio, and a portfolio that is composed only of enterprise j is a high risk portfolio. For any mixture of i and j with A_i ($A_i \geq 0$ and $\sum A_i \leq A$, $i = 1, 2, ..., n$) units of A (total acreage available) devoted to i and $A_j (= A - A_i)$ devoted to j, the expected profit and variance of profit are

$$E = A_i \bar{\pi}_i + (A - A_i)\bar{\pi}_j \tag{4.49}$$

$$\sigma = A_i^2 \sigma_i + 2\rho_{ij}\sigma_i^{.5}\sigma_j^{.5} A_i (A - A_i) + (A - A_i)^2 \sigma_j \tag{4.50}$$

where $\bar{\pi}_i$ denotes the expected profit per unit of investment in prospect i, σ_i shows variance of the per unit profit from prospect i, covariance of the per unit profits from prospects i and j is $\sigma_{ij} = \rho_{ij}\sigma_i^{.5}\sigma_j^{.5}$, and ρ_{ij} is correlation coefficient of the per unit profit from prospects i and j.

In figure 4.3, points $i(A_i\sigma_i^{.5}, A_i\bar{\pi}_i)$[1] and $j(A_j\sigma_j^{.5}, A_j\bar{\pi}_j)$ respectively denote the portfolios with all the units of acreage A devoted to i or to j. Note that the linear form of expected profit equation implies that the proportionate holdings A_i/A in i and $A_j/A = (A - A_i)/A$ in j can be measured by the relative distance along the E axis taken inversely between the E values for i and j. Thus point $B(0, \frac{\bar{\pi}_j\sigma_i^{.5} + \bar{\pi}_i\sigma_j^{.5}}{\sigma_i^{.5} + \sigma_j^{.5}} \cdot A)$ in figure 4.3 corresponds to the portfolio with $A_i/A = DB/DC$, $A_j/A = BC/DC$.

For the case of perfect positive correlation ($\rho_{ij} = 1$), equation (4.50) reduces to

$$\sigma^{.5} = A_i\sigma_i^{.5} + (A - A_i)\sigma_j^{.5} \tag{4.51}$$

---

[1] $i(x, y)$ denotes the coordinates of point i.

Since $\bar{\pi}_i$, $\bar{\pi}_j$, σ_i, σ_j, and A are given, by rearranging (4.51) to give A_i in terms of $\sigma^{.5}$ ($A_i = (\sigma^{.5} - A\sigma_j^{.5})/(\sigma_i^{.5} - \sigma_j^{.5})$), and substituting into (4.49), one has

$$E = (\frac{\bar{\pi}_i - \bar{\pi}_j}{\sigma_i^{.5} - \sigma_j^{.5}})\sigma^{.5} + (\frac{\bar{\pi}_j\sigma_i^{.5} - \bar{\pi}_i\sigma_j^{.5}}{\sigma_i^{.5} - \sigma_j^{.5}})A \tag{4.52}$$

then,

$$\partial E/\partial\sigma^{.5} = \frac{\bar{\pi}_i - \bar{\pi}_j}{\sigma_i^{.5} - \sigma_j^{.5}} \tag{4.53}$$

Since $\bar{\pi}_i < \bar{\pi}_j$ and $\sigma_i^{.5} < \sigma_j^{.5}$, the slope is positive. This shows E to be a linear function of $\sigma^{.5}$ and passing through the points i and j of figure 4.3. Hence, in figure 4.3 if i and j are perfectly positively correlated, all portfolio mixtures of them lie on the straight line joining i and j.

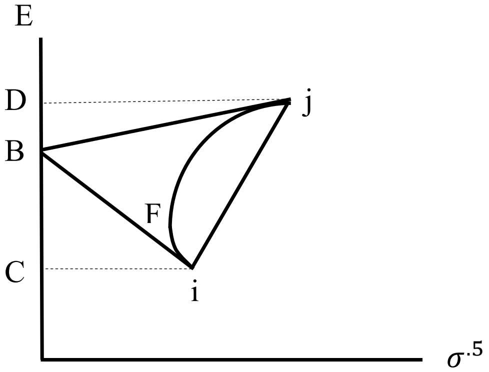

Figure 4.3: The Relation between Correlation and Diversification

If i and j are uncorrelated ($\rho_{ij} = 0$), from equation (4.50) one has

$$\sigma = A_i^2\sigma_i + (A - A_i)^2\sigma_j \tag{4.54}$$

which is always less than σ from (4.51) since $2\rho_{ij}\sigma_i^{.5}\sigma_j^{.5}A_i(A - A_i)$ is always positive. Thus if i and j are uncorrelated, their portfolio mixtures have lower variance than if they are perfectly correlated. By rearranging (4.54) to give A_i in terms of $\sigma^{.5}$ ($A_i = \frac{2A\sigma_j \pm \sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}}{2(\sigma_i + \sigma_j)}$), and substituting into (4.49), one has

$$E = \frac{2A\sigma_j + \sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}}{2(\sigma_i + \sigma_j)}(\bar{\pi}_i - \bar{\pi}_j) + A\bar{\pi}_j \tag{4.55}$$

then

$$\partial E/\partial\sigma^{.5} = \frac{2(\bar{\pi}_i - \bar{\pi}_j)\sigma^{.5}}{\sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}} \tag{4.56}$$

since $\bar{\pi}_i < \bar{\pi}_j$ and all other terms are positive, then $\partial E/\partial\sigma^{.5} < 0$ and $\partial^2 E/\partial(\sigma^{.5})^2 > 0$[1]. Therefore, portfolio mixtures are shown by a decreasing convex curve joining points i and F[2] in figure 4.3. Further

$$E = \frac{2A\sigma_j - \sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}}{2(\sigma_i + \sigma_j)}(\bar{\pi}_i - \bar{\pi}_j) + A\bar{\pi}_j \tag{4.57}$$

and

$$\partial E/\partial\sigma^{.5} = \frac{-2(\bar{\pi}_i - \bar{\pi}_j)\sigma^{.5}}{\sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}} \tag{4.58}$$

since $\bar{\pi}_i < \bar{\pi}_j$ and all other terms are positive, then $\partial E/\partial\sigma^{.5} > 0$ and $\partial^2 E/\partial(\sigma^{.5})^2 < 0$[3]. Therefore, portfolio mixtures are shown by an increasing concave curve joining points j and F in figure 4.3. Indeed, the variance-reducing effect of diversification between uncorrelated prospects is so strong that for a risk averse individual a mixture of them will always dominate the pure prospect with the lower mean. This is shown in figure 4.3 by the negative slope near

---

[1] From (4.56) we can write,

$$\partial^2 E/\partial(\sigma^{.5})^2 = \frac{2(\bar{\pi}_i - \bar{\pi}_j)}{\sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}} - \frac{8(\bar{\pi}_i - \bar{\pi}_j)(\sigma_i + \sigma_j)\sigma}{\sqrt{(4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma))^3}}$$

Rearranging gives,

$$\partial^2 E/\partial(\sigma^{.5})^2 = \frac{2(\bar{\pi}_i - \bar{\pi}_j)}{\sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}}[1 - \frac{4(\sigma_i + \sigma_j)\sigma}{4(\sigma_i + \sigma_j)\sigma - 4A^2\sigma_i\sigma_j}]$$

Since $\bar{\pi}_i < \bar{\pi}_j$, the first part is negative and since $\frac{4(\sigma_i+\sigma_j)\sigma}{4(\sigma_i+\sigma_j)\sigma - 4A^2\sigma_i\sigma_j} > 1$ (when $4A^2\sigma_i\sigma_j < 4(\sigma_i + \sigma_j)\sigma$ or $\sigma > \frac{A^2\sigma_i\sigma_j}{\sigma_i+\sigma_j}$), the second part in bracket is also negative. Therefore, $\partial^2 E/\partial(\sigma^{.5})^2 > 0$.

[2] Note that the coordinates of point F are determined by equating (4.55) and (4.57) i.e. $4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma) = 0$ which gives $F(\sqrt{\frac{A^2\sigma_i\sigma_j}{\sigma_i+\sigma_j}}, A\sigma_j\frac{\bar{\pi}_i - \bar{\pi}_j}{\sigma_i+\sigma_j} + A\bar{\pi}_j)$.

[3] For determining the sign, one can follow the same procedure as previous footnote. From (4.58) we can write,

$$\partial^2 E/\partial(\sigma^{.5})^2 = \frac{-2(\bar{\pi}_i - \bar{\pi}_j)}{\sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}} + \frac{8(\bar{\pi}_i - \bar{\pi}_j)(\sigma_i + \sigma_j)\sigma}{\sqrt{(4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma))^3}}$$

Rearranging gives,

$$\partial^2 E/\partial(\sigma^{.5})^2 = \frac{-2(\bar{\pi}_i - \bar{\pi}_j)}{\sqrt{4A^2\sigma_j^2 - 4(\sigma_i + \sigma_j)(A^2\sigma_j - \sigma)}}[1 - \frac{4(\sigma_i + \sigma_j)\sigma}{4(\sigma_i + \sigma_j)\sigma - 4A^2\sigma_i\sigma_j}]$$

Since $\bar{\pi}_i < \bar{\pi}_j$, the first part is positive and since $\frac{4(\sigma_i+\sigma_j)\sigma}{4(\sigma_i+\sigma_j)\sigma - 4A^2\sigma_i\sigma_j} > 1$ (when $4A^2\sigma_i\sigma_j < 4(\sigma_i + \sigma_j)\sigma$ or $\sigma > \frac{A^2\sigma_i\sigma_j}{\sigma_i+\sigma_j}$), the second part in bracket is negative. Therefore, $\partial^2 E/\partial(\sigma^{.5})^2 < 0$.

i of the curve for $\rho_{ij} = 0$.

If i and j are perfectly negatively correlated ($\rho_{ij} = -1$), from equation (4.50) we have

$$\sigma^{.5} = \pm(A_i\sigma_i^{.5} - (A - A_i)\sigma_j^{.5}) \tag{4.59}$$

By rearranging (4.59) to give A_i in terms of $\sigma^{.5}$ ($A_i = \frac{A\sigma_j^{.5} \pm \sigma^{.5}}{\sigma_i^{.5} + \sigma_j^{.5}}$), and substituting into (4.49), we have

$$E = (\frac{\bar{\pi}_i - \bar{\pi}_j}{\sigma_i^{.5} + \sigma_j^{.5}})\sigma^{.5} + (\frac{\bar{\pi}_j\sigma_i^{.5} + \bar{\pi}_i\sigma_j^{.5}}{\sigma_i^{.5} + \sigma_j^{.5}})A \tag{4.60}$$

then

$$\partial E/\partial\sigma^{.5} = \frac{\bar{\pi}_i - \bar{\pi}_j}{\sigma_i^{.5} + \sigma_j^{.5}} \tag{4.61}$$

since $\bar{\pi}_i < \bar{\pi}_j$ and all other terms are positive, the slope is negative. Points $i(A_i\sigma_i^{.5}, A_i\bar{\pi}_i)$ and $B(0, \frac{\bar{\pi}_j\sigma_i^{.5} + \bar{\pi}_i\sigma_j^{.5}}{\sigma_i^{.5} + \sigma_j^{.5}} \cdot A)$ satisfy equation (4.60). A a result

$$E = (\frac{\bar{\pi}_j - \bar{\pi}_i}{\sigma_i^{.5} + \sigma_j^{.5}})\sigma^{.5} + (\frac{\bar{\pi}_j\sigma_i^{.5} + \bar{\pi}_i\sigma_j^{.5}}{\sigma_i^{.5} + \sigma_j^{.5}})A \tag{4.62}$$

And

$$\partial E/\partial\sigma^{.5} = \frac{\bar{\pi}_j - \bar{\pi}_i}{\sigma_i^{.5} + \sigma_j^{.5}} \tag{4.63}$$

since $\bar{\pi}_i < \bar{\pi}_j$ and all other terms are positive, the slope is positive. Points $j(A_j\sigma_j^{.5}, A_j\bar{\pi}_j)$ and $B(0, \frac{\bar{\pi}_j\sigma_i^{.5} + \bar{\pi}_i\sigma_j^{.5}}{\sigma_i^{.5} + \sigma_j^{.5}} \cdot A)$ satisfy equation (4.62). Thus with perfect negative correlation, it is always possible to find a mixed portfolio with zero standard deviation. In this case, as shown in figure 4.3, the curve for mixtures of i and j consists of two straight lines connecting each of i and j with the zero variance combination depicted by point B.

In sum, the shape of an efficient set depends on the correlation between two crops profits (or covariance terms). As discussed above, diversification often allows the variability of a portfolio's return to be significantly less than the variability of the individual components of the portfolio[1]. As shown in figure 4.4, the degree to which producers can reduce their risk

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[1] As a simple example, if there were two crops of equal mean and variance, the portfolio mean would remain unchanged, but its variance would be

$$\sigma = [A_i^2 + 2\rho_{ij}A_i(A - A_i) + (A - A_i)^2]\sigma_i$$

Minimizing the variance $\partial\sigma/\partial A_i = (2 - 2\rho_{ij})(2A_i - 1) = 0$ gives $A_i = 1/2$, which means that the variance is minimized when the land is divided equally between the two crops because the variances are assumed equal, and we have

$$\sigma = \frac{1 + \rho_{ij}}{2}\sigma_i$$

by diversifying their portfolio depends on the correlation between crop profits. The lower the correlation between two crops profits, the greater the potential benefit to be obtained by diversification (the more will be risk reduction effect of diversification). Combining crops with perfect positive correlation or high positive correlation does not reduce risk in the portfolio. Combining two crops with zero correlation reduces the risk of the portfolio. However, portfolio risk cannot be eliminated. Combining two crops with perfect negative correlation could eliminate risk altogether.

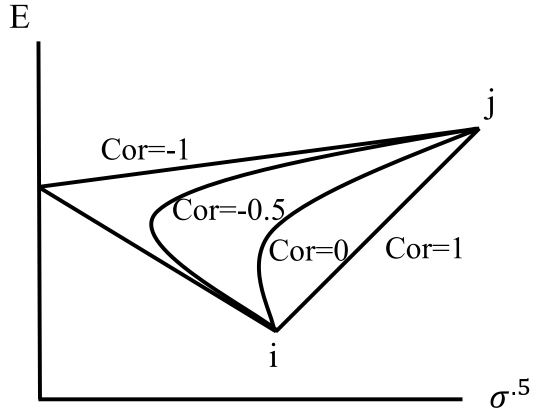

Figure 4.4: The Effect of Different Degrees of Correlation on Efficient Portfolios

For N risky products, the same mathematical procedure as above can be followed to find the efficient set. With many products, any portfolio inside a bullet-shaped region is feasible. The minimum-variance boundary is the set of portfolios that minimize risk for a given level of expected returns (on a graph, the minimum-variance boundary is an hyperbola). The efficient frontier is the top half of the minimum-variance boundary.

The optimal portfolio for a farmer is the member of the efficient set that yields the highest utility and determined by the tangency point between the efficient frontier (figure 4.3, note that it is unusual to have risky prospects that are perfectly correlated. In general, we will have $-1 < \rho_{ij} < 1$, and it is the effect of this that leads to the general shape of the efficient set as shown in figure 4.5.) and the farmer's expected utility indifference curve (figure 4.2). The tangency point indicates the highest level of expected utility the farmer can attain. For the risk averse decision maker with isoutility curves $U^{(1)}$, $U^{(2)}$, and $U^{(3)}$ depicted in figure 4.5, optimal choice is obviously represented by the portfolio corresponding to the point C on the efficient set. This gives him the highest achievable level of utility.

After the explanations about the optimal portfolio choice, without loss of generality this

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which is less than the variance of each crop separately (if $\rho_{ij} < 1$) and much less if ρ_{ij} is negative.

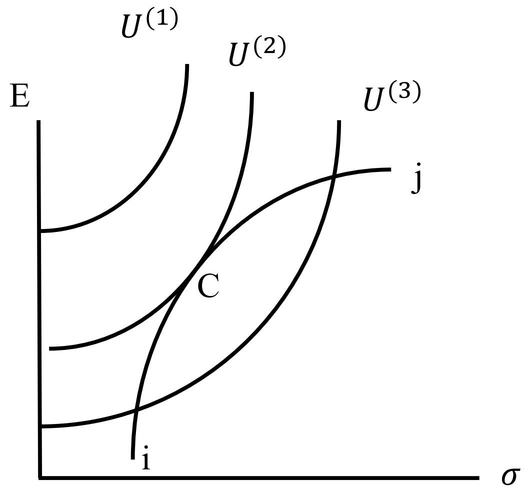

Figure 4.5: An Illustration of (E, σ) Portfolio Analysis $(U^{(1)} > U^{(2)} > U^{(3)})$

procedure can be applied for a three-product case to determine the sign of variables such as return, variance and covariance of individual products on the share of products in the portfolio. Assume that producers choose the portfolio weights that maximize the expected utility U with the common function (the utility function for profit is quadratic so that mean and variance are the only moments relevant to the decision maker's risky choice in maximizing the expected utility)[1]:

$$U = \bar{W} - \frac{1}{2}\tau\sigma_W \tag{4.64}$$

where $\bar{W}$ is expected total wealth, τ shows the coefficient of risk aversion ($\tau > 0$), while all risk-averse farmers seek to avoid risk, different farmers have different levels of risk aversion τ. Low values of τ are consistent with a higher tolerance for risk, while higher values for τ equate to higher degrees of risk aversion. σ_W is the variance of total wealth. One can define $W = w + \Pi\mathbf{A}'$ where total wealth W is initial wealth w and income from the market $\Pi\mathbf{A}'$.

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[1] In using the mean-variance model instead of the more general expected utility models, as Anderson, Dillon and Hardaker (1977) pointed out, if the returns from a risky portfolio are judged to follow a normal distribution, mean-variance portfolio analysis is relevant even if the decision maker's utility function is not quadratic. The reason is that mean and variance-covariance completely specify the normal distribution, which always has odd moments about the mean equal to zero, i.e., $M_k(x) = 0$ for $k = 1, 3, 5, ...$, and even moments about the mean given by $M_k(x) = (k-1)(k-3)(k-5)...(3)(1)V^{k/2}$ for $k = 2, 4, 6, ...$, where V denotes the second moment. In particular, $M_4(x) = 3M_2(x) = 3V^2$. Relevant to the assumption of normality is the fact that, from the central limit theorem of mathematical statistics, the distribution of the sum of n random variables approaches the normal distribution as n increases. Therefore, if profits are normally distributed, the decision maker can rank alternatives using only two parameters, expected value and variance-covariance, without concern to the higher moments of the distribution. Moreover, Levy and Markowitz (1979) have demonstrated that the mean-variance model is appropriate as a second-order Taylor series approximation to all risk-averse utility functions. Modeling acreage response as in this study is one such application of the mean-variance theory that is being used in approximating expected utility as a function of expected profits and variance-covariance of profits.

Thus, we can write

$$U = \bar{w} + \bar{\Pi}\mathbf{A}' - \frac{1}{2}\tau(\mathbf{A}\sigma\mathbf{A}' + \sigma_w) \tag{4.65}$$

where $\mathbf{A}\sigma\mathbf{A}' = \sigma_T$ is variance of total profit.

In the three-crop case i, j, k the portfolio return is calculated as:

$$\bar{\Pi}\mathbf{A}' = A_i\pi_i + A_j\pi_j + A_k\pi_k \tag{4.66}$$

where A_i, A_j, and A_k are the portfolio weights of crops i, j and k, respectively. These are the weights that producers adjust to maximize utility. The expected returns are given by π_i, π_j, and π_k, respectively. The portfolio variance is calculated as:

$$\sigma_T = A_i^2\sigma_i + A_j^2\sigma_j + A_k^2\sigma_k + 2A_iA_j\sigma_{ij} + 2A_iA_k\sigma_{ik} + 2A_jA_k\sigma_{jk} \tag{4.67}$$

where $\sigma_{ij} = \sigma_i^{.5}\sigma_j^{.5}\rho_{ij}$ shows the covariance and ρ_{ij} is i, j crops' return correlation. The standard deviations of crops are given by $\sigma_i^{.5}$, $\sigma_j^{.5}$ and $\sigma_k^{.5}$. Portfolios are chosen by maximizing expected utility subject to the constraint:

$$\begin{aligned} Max \qquad & U = A_i\pi_i + A_j\pi_j + A_k\pi_k - \tfrac{1}{2}\tau\big(A_i^2\sigma_i + A_j^2\sigma_j + A_k^2\sigma_k \\ & +2A_iA_j\sigma_{ij} + 2A_iA_k\sigma_{ik} + 2A_jA_k\sigma_{jk}\big) \\ s.t. \qquad & A_i + A_j + A_k = 1 \end{aligned} \tag{4.68}$$

Substituting $(1 - A_i - A_j)$ for A_k into expected utility function U puts the problem in terms of just two unknowns A_i and A_j:

$$\begin{aligned} Max \qquad & U = A_i\pi_i + A_j\pi_j + (1 - A_i - A_j)\pi_k - \tfrac{1}{2}\tau\big(A_i^2\sigma_i + A_j^2\sigma_j + (1 - A_i - A_j)^2\sigma_k \\ & +2A_iA_j\sigma_{ij} + 2A_i(1 - A_i - A_j)\sigma_{ik} + 2A_j(1 - A_i - A_j)\sigma_{jk}\big) \end{aligned} \tag{4.69}$$

The optimal portfolio weight in i, A_i, can be found by setting $\partial U/\partial A_i = 0$ and solving for A_i which gives:

$$A_i = \frac{\pi_i - \pi_k + \tau(\sigma_k - \sigma_{ik}) - \tau A_j(\sigma_k - \sigma_{ik} + \sigma_{ij} - \sigma_{kj})}{\tau(\sigma_i + \sigma_k - 2\sigma_{ik})} \tag{4.70}$$

In this solution, the optimal portfolio weight in A_i is a function of A_j, which is also unknown. Setting $\partial U/\partial A_j = 0$ and solving for A_j results in:

$$A_j = \frac{\pi_j - \pi_k + \tau(\sigma_k - \sigma_{jk}) - \tau A_i(\sigma_k - \sigma_{ik} + \sigma_{ij} - \sigma_{kj})}{\tau(\sigma_j + \sigma_k - 2\sigma_{jk})} \tag{4.71}$$

Assuming $\sigma_i + \sigma_k - 2\sigma_{ik} = X$, $\sigma_j + \sigma_k - 2\sigma_{jk} = Y$[1], $\sigma_k - \sigma_{ik} + \sigma_{ij} - \sigma_{kj} = Z$, substituting A_j of equation (4.71) in equation (4.70), after some rearranging, leads to the following:

$$A_i = \frac{\big[\pi_i - \pi_k + \tau(\sigma_k - \sigma_{ik})\big]Y - \big[\pi_j - \pi_k + \tau(\sigma_k - \sigma_{kj})\big]Z}{\tau(XY - Z^2)} \tag{4.72}$$

Solving for $\partial A_i/\partial \pi_i$ shows the impact of a change in own return, π_i, on the optimal portfolio weight of i and is given by:

$$\partial A_i/\partial \pi_i = \frac{Y}{\tau(XY - Z^2)} > 0 \tag{4.73}$$

Since $Y > 0$, $\tau > 0$ and $(XY - Z^2) > 0$[2], then the effect of changes in own return on A_i, $\partial A_i/\partial \pi_i > 0$, is positive. The degree of the increase in portfolio weight is dependent upon the variances and covariances of crop returns and the risk aversion of the individual producer. The effect of changes in cross-returns on A_i, $\partial A_i/\partial \pi_j$ and $\partial A_i/\partial \pi_k$ cannot be signed.

The marginal impact of changes in σ_i on the optimal portfolio weight in i, is given by solving for $\partial A_i/\partial \sigma_i$:

$$\partial A_i/\partial \sigma_i = \frac{-\Big(\big[\pi_i - \pi_k + \tau(\sigma_k - \sigma_{ik})\big]Y - \big[\pi_j - \pi_k + \tau(\sigma_k - \sigma_{kj})\big]Z\Big)\Big(\tau Y\Big)}{\big[\tau(XY - Z^2)\big]^2} < 0 \tag{4.74}$$

Since $Y > 0$, $\tau > 0$ and $\Big(\big[\pi_i - \pi_k + \tau(\sigma_k - \sigma_{ik})\big]Y - \big[\pi_j - \pi_k + \tau(\sigma_k - \sigma_{kj})\big]Z\Big) > 0$[3], it follows that the effect of changes in own variance on A_i, $\partial A_i/\partial \sigma_i < 0$, is negative. The effect

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[1] Since $(\sigma_i^{.5} - \sigma_k^{.5})^2 = (\sigma_i + \sigma_k - 2\sigma_i^{.5}\sigma_k^{.5}) > 0$ and $\sigma_{ik} = \sigma_i^{.5}\sigma_k^{.5}\rho_{ik}$, $-1 < \rho_{ik} < 1$, then $X, Y > 0$.

[2] The second-order-condition of the optimization problem in (4.69) implies

$$|H| = \begin{vmatrix} \frac{\partial^2 U}{\partial A_i^2} & \frac{\partial^2 U}{\partial A_i A_j} \\ \frac{\partial^2 U}{\partial A_j A_i} & \frac{\partial^2 U}{\partial A_j^2} \end{vmatrix} < 0,$$

$|H| = \begin{vmatrix} -X & -Z \\ -Z & -Y \end{vmatrix} = -(XY - Z^2) < 0$ which gives $(XY - Z^2) > 0$.

[3] Since A_i implies to the weight of crop i in portfolio, it should be positive ($0 < A_i < 1$). Thus, in equation (4.72) the numerator should have the same sign as denominator. Since denominator is positive

of changes in cross-variances on A_i, $\partial A_i/\partial\sigma_j$ and $\partial A_i/\partial\sigma_k$ cannot be signed.

To find the marginal impact of changes in ρ_{ik} on the optimal portfolio weight in i, solve for $\partial A_i/\partial\rho_{ik}$, which gives:

$$\begin{aligned}\partial A_i/\partial\rho_{ik} = {} & \frac{2\sigma_i^{.5}\sigma_k^{.5}Y(Y-Z)\big[\pi_i-\pi_k+\tau(\sigma_k-\sigma_{ik})\big]-\tau\sigma_i^{.5}\sigma_k^{.5}Y(XY-Z^2)}{\tau(XY-Z^2)^2} \\ & +\frac{\sigma_i^{.5}\sigma_k^{.5}\big[(XY-Z^2)+2\sigma_i^{.5}\sigma_k^{.5}Z(Z-Y)\big]\big[\pi_j-\pi_k+\tau(\sigma_k-\sigma_{kj})\big]}{\tau(XY-Z^2)^2}\end{aligned} \tag{4.75}$$

This reveals the impact that a change in the i and k correlation will have on the optimal weight in i. The marginal effect is determined by the variances and covariances of crop returns, the risk aversion parameter of the individual producer, and the risk premiums ($\pi_i - \pi_k$ and $\pi_j - \pi_k$).

Although in the three-product case (or N products case) one can just determine the expected sign for own return and variance, it is obvious that in the two crops case there is expected sign for all variables because $\partial A_j/\partial\pi_i$ is equal to $-\partial A_i/\partial\pi_i$, $\partial A_j/\partial\sigma_i$ is equal to $-\partial A_i/\partial\sigma_i$, and $\partial A_j/\partial\rho_{ij}$ is equal to $-\partial A_i/\partial\rho_{ij}$[1].

Generally, regrading the expected sign of the variables in equation (4.41), it was shown that the expected own-profit and its variance should have positive and negative impacts respectively on acreage in each equation. The effect of expected cross-profits and other elements of variance-covariance matrix on acreage decisions are not known *a priori.* Although it is expected that the expected total wealth (wealth effect) and its variance (insurance effect) have positive and negative impacts on acreage allocations with no constraint on total acreage, the sign of these variables are not clear *a priori* when the total acreage is assumed to be fixed.

In sum, in this chapter, a contribution to the literature has been made through modelling the farmers' acreage decisions under uncertainty and deriving a measure inside the theoretical framework to capture the insurance effect of government policies as well as the wealth effect. By considering the relationship between income stabilization compensated and uncompensated acreage decision functions, the expected utility maximization framework (under the hypothesis that farmers are risk averse) developed by Chavas and Holt (1990) has been modified which enables the inclusion in our theoretical model of the insurance effect, emphasized

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$((XY-Z^2)>0)$, the numerator has the positive sign, $\Big(\big[\pi_i-\pi_k+\tau(\sigma_k-\sigma_{ik})\big]Y-\big[\pi_j-\pi_k+\tau(\sigma_k-\sigma_{kj})\big]Z\Big)>0$.

[1] As shown in Appendix B, these results for the two crops case are also confirmed based on the first-order conditions in equation (4.20).

in the literature (Hennessy, 1998) but ignored in the Chavas and Holt model (1990). Hence, the acreage response equation is specified as a function of expected crop profits, elements of the variance-covariance matrix of profits, expected total wealth (initial wealth plus market profit), and variance of total wealth. Furthermore, government payments are incorporated into the model through truncation of the probability distribution of profits.

Chapter 5

Empirical Framework and Results

This chapter presents the empirical model, data description and results. A system of nine crop equations is provided and all the relevant elasticities of acreage allocation with respect to the exogenous variables are estimated. If the coefficient of expected total wealth and variance of total wealth variables are statistically significant (insignificant) in the whole system, the whole-farm programs are (are not) production and therefore trade distorting and are not (are) decoupled[1]. The statistically significant coefficients are then used to simulate the impact of recent whole-farm programs—the Western Grain Stabilization Act (WGSA), the Net Income Stabilization Account (NISA) and the Canadian Agricultural Income Stabilization (CAIS)—on crop choices.

The empirical model applies the theoretical model derived in the previous chapter, equation (4.41), to estimate supply responses for spring wheat, durum wheat, oats, barley, rye, peas[2], flax, canola, and hay in the prairie provinces of Canada by formally incorporating the government's grain policies. Farmers' acreage decisions are estimated over 1971-2006 for individual provinces—Manitoba, Saskatchewan and Alberta. Two specifications of the acreage response model are examined in this study: an acreage level model and an acreage share model. The share equations are specified to explain how the shares of total cropland allocated to specific crops respond to the expected profits, profit risks, mean and variance of total wealth, and other exogenous variables. The specification explicitly recognizes that as the share of the combined cropland planted to one commodity, say wheat, increases, the expanded wheat acreage has to come from cropland planted to competing crops, such as barley, canola, or other field crops. In other words, the sum of the acreage shares equal one

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[1] Despite meeting the WTO's legal definition of decoupled payments.

[2] Time series data for other pulse crops like chickpeas and lentils were not available.

(total cropland planted to all field crops is assumed to be fixed).

The empirical model treats all equations as a system of acreage allocation decisions under risk. The linear acreage and acreage-share models (with acreage share (S_i) of the crops in each province as the dependent variable) have the following structure:

$$A_{it} = a_0 + \alpha_i(w_{t-1} + \sum_{j=1}^{9} A_j \bar{\pi}_{jt}^T) + \sum_{j=1}^{9} \beta_{ij}\bar{\pi}_{jt}^T + \sum_{k\geq j}^{9}\sum_{j=1}^{9} \gamma_{ijk}\sigma_{jkt}^T + \delta_i(\sum_{k\geq j}^{9}\sum_{j=1}^{9} A_j A_k \sigma_{jkt}^T) + \varphi_l + A_{it-1} + \upsilon_{it} \tag{5.1}$$

$$\begin{aligned} S_{it} = a_0 + \alpha_i(w_{t-1} + \sum_{j=1}^{9} A_j \bar{\pi}_{jt}^T) + \sum_{j=1}^{9} \beta_{ij}\bar{\pi}_{jt}^T + \sum_{k\geq j}^{9}\sum_{j=1}^{9} \gamma_{ijk}\sigma_{jkt}^T + \delta_i(\sum_{k\geq j}^{9}\sum_{j=1}^{9} A_j A_k \sigma_{jkt}^T) + \\ \varphi_l + S_{it-1} + \upsilon_{it} \qquad \text{and} \qquad \sum_{i=1}^{10} S_i = 1 \end{aligned} \tag{5.2}$$

where A_i is the acreage planted to the ith crop (1 = spring wheat, 2 = durum wheat, 3 = oats, 4= barley, 5= rye, 6= peas, 7= flax, 8= canola, and 9= hay; in acres), S_i is the share of combined acreage of spring wheat, durum wheat, oats, barley, rye, peas, flax, canola, hay and summerfallow planted to the ith crop (1 = spring wheat, 2 = durum wheat, 3 = oats, 4= barley, 5= rye, 6= peas, 7= flax, 8= canola, 9= hay, and 10= summerfallow), w is normalized initial wealth (\$), $\sum_{j=1}^{n} A_j\bar{\pi}_{jt}^T$ is the truncated mean of total (farm) profit (\$) and $\sum_{k\geq j}^{n}\sum_{j=1}^{n} A_j A_k \sigma_{jkt}^T$ is equal to the truncated variance of total (farm) profit (\$), $\bar{\pi}_j^T$ is the truncated expected profits (\$/acre) for jth commodity, σ_{jk}^T is the truncated expected variance-covariance of profits (\$/acre) between jth and kth commodities, φ_l denotes provincial dummies ($l = 1, 2, 3$) or fixed effects to control for persistent provincial factors. A_{it-1} (or S_{it-1}) is a lagged dependent variable for ith commodity and has been included to account for inertia that is attributable to the cost of adjustment in switching from one crop to another[1], and υ_i is the error term.

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[1] This could, to some degree, also reflect the effect of change in crop rotation practices on a specific rotation crop.

5.1 Data Description

5.1.1 Area, Yield, Price and Crop Costs

Assuming that aggregate behavior can be approximated by a representative farm household making decisions according to the theoretical model described, the linear acreage equations (5.1) and acreage share equations (5.2) will be estimated using aggregate data.

The acreage variables $A_1,\ A_2, \ldots, A_9$ (1= spring wheat, 2= durum wheat, 3= oats, 4= barley, 5= rye 6= peas, 7= flax, 8= canola, 9=tame hay) measure acreage planted to each crop (in acres) and were obtained from CANSIM table 001-0010 which provides time series data on seeded area by crops at the provincial level. Yields $y_1,\ y_2, \ldots, y_9$ (tonne/acre) were also obtained from CANSIM table 001-0010. The market prices $p_1,\ p_2, \ldots, p_9$ (\$/tonne) are average farm prices and were obtained from the Manitoba Agriculture, Food and Rural Initiatives, Manitoba Agriculture Yearbook (various years); Alberta Agriculture and Rural Development, the Agriculture Statistics Yearbook (various years); and Saskatchewan Agriculture, Food and Rural Revitalization, Agricultural Statistics (various years) [1].

Initial wealth is defined as the sum of value of capital stock in crop production (machinery and equipment plus land and buildings) minus related debts. Data on value of machinery and equipment and value of land and buildings from CANSIM table 002-007 and outstanding farm debt from CANSIM table 002-0008 indicates that the value of land and buildings greatly exceeds the other two series, and the other two series largely cancel out. For example, in 2006 the value of land and buildings was \$ 10795, 23156 and 45968 million, value of machinery and equipment was \$ 3594, 8129 and 9059 million and total debt was \$ 5805, 7024 and 10996 million in Manitoba, Saskatchewan and Alberta, respectively. Therefore, initial wealth (in \$) is constructed as the value of land and buildings in crop agriculture (Coyle, Wei and Rude, 2008). This is calculated from total crop acres (CANSIM table 001-0010) multiplied by the value per acre of farmland and buildings from CANSIM table 002-003 in Manitoba, Saskatchewan and Alberta for different years.

In Manitoba, all items of costs of crop production[2], in detail, for different crops $c_1,\ c_2, \ldots, c_9$ (\$/acre) were obtained, in responce to a request, from Manitoba Agriculture, Food and Rural Initiatives, Policy Analysis Branch, Crop Production Costs Guidelines (various years)

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[1] Data on durum wheat prices were not available in Manitoba and Alberta. As an alternative, the durum wheat to spring wheat price ratio in Saskatchewan was calculated. Then, durum wheat prices were constructed based on the multiplication of this ratio by spring wheat prices in Manitoba and Alberta.

[2] It should be noted that we subtracted non-allowable costs like rent (land, building and machinery), building/ machinery repairs, and property tax . . . from the respective calculated costs.

for years 1982-2006. For years prior to 1982, the farm input price index[1] in each year to 1982 farm input price index ratio was calculated. Crop costs were constructed based on the multiplication of this ratio by crop costs in 1982. In Saskatchewan, detailed crop costs were obtained, in responce to a request, from Saskatchewan Agriculture, Food and Rural Revitalization, Agriculture, Business and Development Branch, Crop Planning Guide (various years)[2], for the years 1985-2006[3]. The same procedure as used for Manitoba was employed when constructing the crop costs in Saskatchewan in missing years. In Alberta, detailed crop costs were obtained, in responce to a request, from Alberta Agriculture and Rural Development, Crops Economics Unit for the years 1985-2006. For years prior to 1985, crop costs were constructed based on the same method as was used for Manitoba.

To measure yield expectations, actual yields are regressed on a trend variable. The resulting predictions are taken as expected yield as well as the adaptive expectation procedure provided in equation (5.5). For expected farm price, an adaptive expectation scheme built from lagged farm prices as shown in equation (5.4) was used, but in addition the empirical model in this study is forward-looking in that farmers are also assumed to base their expectations on futures prices.

The planting-time crop futures price forecast was taken as the price of December crop futures at planting time from 1979 to 2006[4]. In the cases of spring wheat, oats, barley, flax and canola[5], the futures price were the price of December crop futures on or about

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[1] The farm input price indices (index, 1986=100) were obtained from CANSIM table 328-0001. This table provides a price index for all components of farm inputs at the provincial level for different years.

[2] Crop production costs are reported in different soil zones, black, brown, and dark brown. Since the crop cost data in other provinces were available in only for the black soil zone, we used the black soil zone crop costs in Saskatchewan.

[3] Tame hay production costs were not available in Crop Planning Guide. Hay production cost in 2006 was obtained from the publication Dryland Forage Production Costs, Fact Sheet Saskatchewan Ministry of Agriculture, October 2007. A Saskatchewan hay cost to Manitoba hay cost ratio in 2006 was then calculated. A time series of Saskatchewan hay production costs based on the multiplication of this ratio by hay production cost in Manitoba for different years was then constructed.

[4] There was no data available on future prices for all crops before 1979.

[5] As announced by the Winnipeg Commodity Exchange (WCE) Press Release (September 1995), the canola futures contract price reference point has changed from Vancouver to points in and around Saskatoon from September 1996. In fact, it seems there is a structural change in the reported series data for canola futures price (the reported futures price before 1996 are related to Vancouver as the delivery point while after 1996 they are related to Saskatoon). However, there is no direct and official information to adjust the data after 1996 so that they would be consistent with the data in the previous years. Therefore, to see how this change in delivery points (from Vancouver to Saskatoon) may affect the results, the canola futures price data after 1996 was adjusted based on the approximate information on freight and storage costs. In this adjustment, 52.91 $/tonne (1.20 $/bushel) was added to the futures price in 1997 and from 1998 to 2006 this amount was increased by 2.20 $/tonne (0.05 $/bushel) per year. Estimation results of the model indicate that this adjustment has no significant effect on the coefficients in terms of sign and magnitude. Therefore, the results of the model with data before adjustment for canola futures—which are official data—are reported.

April 30th[1], and are collected from the Canada Grain Council, the Canadian Grain Industry Statistical Handbook (various years) and the Winnipeg Commodity Exchange, Statistical Annual (various years). Since there was no future market for durum wheat, rye, peas and hay, the expected price for these crops were constructed based on the futures price of the commodity that have the highest correlation with these crops[2]. To allow for price differentials across provinces, the futures prices were proportionally adjusted by provincial farm prices[3]. Appendix C shows data descriptive statistics for acreage, yield, price, expected price (futures prices), production cost and initial wealth variables.

5.1.2 Open Market Profit, Mean and Variance-Covariance

By assuming that both price (p_i) and yield per acre (y_i) are random variables (to reflect not only price risk, but also production risk facing producers) and costs of production for the ith crop (c_i) are constant, the untruncated expected profit for ith crop can be derived as follows:

$$\bar{\pi}_i = E(\pi_i) = E(p_i y_i - c_i) = E(p_i y_i) - c_i = Cov(p_i, y_i) + E(p_i).E(y_i) - c_i \tag{5.3}$$

To analyze supply behavior under risk, assumptions about the expectations of prices ($E(p_i)$) and yields ($E(y_i)$) are needed. Adaptive expectations can be used for the normalized prices and yields. That is,

$$E_{t-1}(p_{it}) = \alpha_i + p_{i,t-1} \tag{5.4}$$

where $\alpha_i = E(p_{it} - p_{i,t-1})$ as measured by the sample mean of the past differences between observed prices and prices in the previous period. This computed mean is updated in each period. The assumption stated in (5.4) that expected prices are a function of the average price of the previous year has been successfully employed in previous research (e.g., Houck et al., 1976; Chavas, Pope, and Kao, 1983). Similarly, adaptive expectations for the normalized

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[1] Note that when data for December futures price were not available, we have used November or October futures price.

[2] For example, hay farm prices were regressed on future prices of spring wheat, oats, barley, flax and canola. The highest explanatory power was obtained from barley futures price, which had an R-squared equal to 0.80. Next, A hay futures price was constructed by multiplying the hay farm price by the ratio of barley futures price over its farm price. For the case of durum wheat, peas and rye, the highest explanatory power was obtained from spring wheat, canola and spring wheat with R-squared 0.98, 0.70 and 0.98, respectively.

[3] In each province, the difference between the futures price obtained from the Winnipeg Commodity Exchange and farm prices were calculated and then the province that had the least difference in average (the base province), has been given the collected futures prices. Next, futures prices for the other provinces were constructed by multiplying the farm prices in the province by the ratio of futures prices over farm prices in the base province.

yields is

$$E_{t-1}(y_{it}) = \alpha_i' + y_{i,t-1} \tag{5.5}$$

where $\alpha_i' = E(y_{it} - y_{i,t-1})$ as measured by the sample mean of the past differences between observed yields and yields in the previous period. This computed mean is updated in each period. The covariance measure used for normalized prices and yields is

$$\begin{aligned} Cov(p_i, y_i) = \sum_{j=1}^{3} \omega_j [(p_{i,t-j} - E_{t-j-1}(p_{i,t-j})).(y_{i,t-j} - E_{t-j-1}(y_{i,t-j}))] = \\ 0.5[(p_{i,t-1} - E_{t-2}(p_{i,t-1})).(y_{i,t-1} - E_{t-2}(y_{i,t-1}))]+ \\ 0.33[(p_{i,t-2} - E_{t-3}(p_{i,t-2})).(y_{i,t-2} - E_{t-3}(y_{i,t-2}))]+ \\ 0.17[(p_{i,t-3} - E_{t-4}(p_{i,t-3})).(y_{i,t-3} - E_{t-4}(y_{i,t-3}))] \end{aligned} \tag{5.6}$$

where ω_j represents the declining weighting scheme. These measurements of covariance are also consistent with those used previously in the literature (e.g., Sckokai and Moro, 2006; Lin and Dismukes, 2007; Coyle, Wei and Rude, 2008). By calculating relations (5.4), (5.5), and (5.6) and replacing into relation (5.3) the untruncated expected profits for ith crop ($i = 1, 2, ..., 9$) in \$/acre in each province (Manitoba, Saskatchewan and Alberta) over years 1971-2006 can be calculated[1].

Bohrnstedt and Goldberger (1969) method is followed to calculate the untruncated crop profit variance and covariance for the product of two random variables. Variance for this bivariate profit distribution is (crop costs are assumed constant, resulting in gross revenue and net revenue variance and covariance being the same),

$$\begin{aligned} \sigma_{ii} =& Var(p_i y_i - c_i) = Var(p_i y_i) = E[p_i y_i - E(p_i y_i)]^2 = [E(p_i)]^2 Var(y_i) + [E(y_i)]^2 Var(p_i)+ \\ & E[(p_i - E(p_i))^2.(y_i - E(y_i))^2] + 2E(p_i).E[(p_i - E(p_i)).(y_i - E(y_i))^2]+ \\ & 2E(y_i).E[(y_i - E(y_i)).(p_i - E(p_i))^2] + 2E(p_i).E(y_i).Cov(p_i, y_i) - (Cov(p_i, y_i))^2 \end{aligned} \tag{5.7}$$

If p_i and y_i are bivariate normally distributed, $[(p_i - E(p_i))^2.(y_i - E(y_i))^2] = Var(y_i).Var(p_i) +$

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[1] Nine untruncated expected profits have been calculated over 1971-2006 for each province.

$2(Cov(p_i, y_i))^2$ and all third and higher moments are zero. The variance equation reduces to

$$\begin{aligned} Var(p_i y_i - c_i) = {} & [E(p_i)]^2 Var(y_i) + [E(y_i)]^2 Var(p_i) + 2E(p_i)E(y_i)Cov(p_i, y_i) + \\ & Var(y_i)Var(p_i) + (Cov(p_i, y_i))^2 \end{aligned} \tag{5.8}$$

where $Var(p_i)$ is price variance and $Var(y_i)$ is yield variance and can be calculated as

$$\begin{aligned} Var(p_i) = \sum_{j=1}^{3} \omega_j [(p_{i,t-j} - E_{t-j-1}(p_{i,t-j})]^2 = 0.5[(p_{i,t-1} - E_{t-2}(p_{i,t-1}))]^2 + \\ 0.33[(p_{i,t-2} - E_{t-3}(p_{i,t-2}))]^2 + 0.17[(p_{i,t-3} - E_{t-4}(p_{i,t-3}))]^2 \end{aligned} \tag{5.9}$$

and

$$\begin{aligned} Var(y_i) = \sum_{j=1}^{3} \omega_j [(y_{i,t-j} - E_{t-j-1}(y_{i,t-j}))]^2 = 0.5[(y_{i,t-1} - E_{t-2}(y_{i,t-1}))]^2 + \\ 0.33[(y_{i,t-2} - E_{t-3}(y_{i,t-2}))]^2 + 0.17[(y_{i,t-3} - E_{t-4}(y_{i,t-3}))]^2 \end{aligned} \tag{5.10}$$

Expression (5.9) states that the variance of price is a weighted sum of the squared deviations of past prices from their expected values, with declining weights. These measurements of price risk are also consistent with those used previously in the literature (e.g., Lin, 1977; Traill, 1978; Sckokai and Moro, 2006; Lin and Dismukes, 2007). When price and/or yield are not bivariate normally distributed, (5.8) represents an approximation of variance of profits. The amount of error introduced into variance calculations by using (5.8) instead of (5.7) depends on the degree to which the price and/or yield distributions are non-normal, in combination with the magnitude of price and yield variance.

The untruncated covariance of crop profit between two crops is

$$\begin{aligned} Cov(p_i y_i, p_j y_j) = {} & E(y_i)E(y_j)Cov(p_i, p_j) + E(p_i)E(y_j)Cov(y_i, p_j) + \\ & Cov(y_i, p_j)Cov(p_i, y_j) + Cov(p_i, p_j)Cov(y_i, y_j) + \\ & E(p_i)E(p_j)Cov(y_i, y_j) + E(y_i)E(p_j)Cov(p_i, y_j) \end{aligned} \tag{5.11}$$

where $Cov(p_i, p_j)$ is covariance between prices for crops i and j, with other covariances defined in a similar manner and all covariances in relation (5.11) can be calculated using a relation similar to (5.6). Relation (5.11) collapses to (5.8) when $i = j$. Thus, relation (5.11) could be used to calculate each element of a $n \times n$ untruncated variance-covariance matrix (σ), where n is the number of crops included in the analysis. Using relation (5.11), the untruncated covariance of cross-commodity profits between ith and jth crops ($i = 1, 2, , 9$) in each province (Manitoba, Saskatchewan and Alberta) over years 1971-2006 can be calculated[1].

Untruncated expected total (farm) profit for crops (in \$) is

$$\begin{aligned}
&E(\sum_{i=1}^{n} \pi_i A_i) = E[(p_1y_1 - c_1).A_1 + (p_2y_2 - c_2).A_2 + ... + (p_ny_n - c_n).A_n] = \\
&E[(p_1y_1 - c_1).A_1] + E[(p_2y_2 - c_2).A_2] + ... + E[(p_ny_n - c_n).A_n] = \\
&[E(p_1y_1) - c_1].A_1 + [E(p_2y_2) - c_2].A_2 + ... + [E(p_ny_n) - c_n].A_n
\end{aligned} \tag{5.12}$$

in which each term in square bracket has been calculated using relation (5.3)[2] and $n = 9$ is the number of crops. The untruncated variance of total (farm) profit for crops is

$$\begin{aligned}
&Var[(p_1y_1 - c_1).A_1 + (p_2y_2 - c_2).A_2 + ... + (p_ny_n - c_n).A_n] = \\
&A_1^2[Var(p_1y_1)] + A_2^2[Var(p_2y_2)] + ... + A_n^2[Var(p_ny_n)] + 2A_1A_2[Cov(p_1y_1, p_2y_2)] + \\
&2A_1A_3[Cov(p_1y_1, p_3y_3)] + ... + 2A_1A_n[Cov(p_1y_1, p_ny_n)] + 2A_2A_3[Cov(p_2y_2, p_3y_3)] + \\
&2A_2A_4[Cov(p_2y_2, p_4y_4)] + ... + 2A_2A_n[Cov(p_2y_2, p_ny_n)] + ... + 2A_{n-1}A_n[Cov(p_{n-1}y_{n-1}, p_ny_n)]
\end{aligned} \tag{5.13}$$

in which each term in square bracket has been calculated using relation (5.8) and (5.11)[3].

5.1.3 Government Farm Programs Impacts on Mean and Variance-Covariance of Profits

5.1.3.1 Crop-Specific Programs

As explained in the previous chapter, both expected profits and the corresponding elements of the variance-covariance matrix are influenced by the existence of the government programs, which truncates the profit distribution at the minimum profit level. Assuming a multivariate normal distribution for profits, the computed expected profits, variances and covariances

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[1] In our study, since the number of crops is nine, thirty six untruncated covariance of cross-commodity profits and nine variance of profits over 1971-2006 for each province have been calculated.

[2] Note that in calculation of the untruncated expected total (farm) profit, the truncated expected profit for individual crop was used.

[3] Note that in calculation of the untruncated variance of total (farm) profit, the truncated variance-covariance matrix for individual crop was used.

should be corrected for this truncation. The influence of government programs on the subjective probability distribution of profits for each crop ($\pi_i = (p_i y_i - c_i)$) is considered by crop-specific programs, Crop Insurance, Agricultural Stabilization Act[1], and GRIP, over the period of our study. Therefore, a change in the government crop-specific support programs induces changes in the expected profits and in their variability (variance-covariance matrix) for each crop. Now, assume that each random variable profit ($\pi_i = (p_i y_i - c_i)$) is truncated from below at a level H_i (which is the higher guaranteed profit by crop-specific programs[2]). Expressions (4.36), (4.37), and (4.38) in the previous chapter provide an analytical evaluation of the truncation effect of a crop-specific program on the mean, variance, and covariance of commodity profits.

As an example, consider spring wheat (swh) in Saskatchewan in 1997. Untruncated expected profit $\bar{\pi}_{swh}$ and untruncated expected variance of profit σ_{swh} have been obtained using relations (5.3) and (5.8), respectively. Guaranteed profits (\$/acre) by Crop Insurance and GRIP programs for spring wheat have been calculated and then the higher guaranteed profit (\$/acre) in year 1997 has been chosen as truncation point H_{swh}. Then, $h_{swh} = \frac{(H_{swh} - \bar{\pi}_{swh})}{\sigma_{swh}^{0.5}}$ has been calculated. $\phi(h_{swh}) = \frac{1}{(2\pi)^{0.5}} e^{-\frac{(h_{swh}^2)}{2}}$ and $\Phi\left(h_{swh}\right)$ has been calculated by $normsdist(h_{swh})$ in Excel which returns the standard normal cumulative distribution function. Finally, the truncated expected profit and the truncated variance of profit for spring wheat in Saskatchewan in year 1997 have been obtained by replacing (4.33) and (4.34) into (4.36) and (4.37), respectively.

To calculate the truncated covariance between profits of spring wheat and, for example, durum wheat (dwh), the untruncated covariance between spring wheat and durum wheat profits $\sigma_{swh,dwh}$, the untruncated variances of spring wheat profit σ_{swh} and durum wheat σ_{dwh} have been calculated using relations (5.11) and (5.8). Then, $\rho_{swh,dwh} = \frac{\sigma_{swh,dwh}}{(\sigma_{swh} \cdot \sigma_{dwh})^{0.5}}$ has been obtained. $Z_{swh,dwh} = \left\{(h_{swh}^2 - 2\rho_{swh,dwh} h_{swh} h_{dwh} + h_{dwh}^2)/(1 - \rho_{swh,dwh}^2)\right\}^{0.5}$, and $k_{swh,dwh} = \frac{h_{swh} - \rho_{swh,dwh} h_{dwh}}{\left(1 - \rho_{swh,dwh}^2\right)^{0.5}}$, $k_{dwh,swh} = \frac{h_{dwh} - \rho_{swh,dwh} h_{swh}}{\left(1 - \rho_{swh,dwh}^2\right)^{0.5}}$ have been calculated. $\phi(Z_{swh,dwh})$ is equal to $\frac{1}{(2\pi)^{0.5}} e^{-\frac{Z_{swh,dwh}^2}{2}}$. $\Phi\left(k_{swh,dwh}\right)$ and $\Phi\left(k_{dwh,swh}\right)$ have been obtained using the $normsdist(k_{swh,dwh})$ and $normsdist(k_{dwh,swh})$ in Excel. $F\left(h_{swh}, h_{dwh}\right)$ is equal to $\Phi\left(h_{swh}, h_{dwh}\right) + 1 - \Phi\left(h_{swh}\right) - \Phi\left(h_{dwh}\right)$ in which $\Phi\left(h_{swh}, h_{dwh}\right)$ has been obtained using $binormal(h_{swh}, h_{dwh}, \rho_{swh,dwh})$ com-

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[1] Note that since the ASA is a price support program, the truncation formula were used for the parameters of price distribution (instead of profit distribution). Then, the truncated expected price and the truncated elements of variance-covariance matrix of prices were used for construction of the expected profit and elements of variance-covariance matrix of profits (equations 5.3, 5.8, and 5.11).

[2] The calculation of guaranteed profit by crop-specific government support programs will be provided below.

mand in Stata which returns the joint cumulative distribution of the bivariate normal with correlation ρ; cumulative over (-inf, h_{swh}] and (-inf, h_{dwh}]. Finally, the truncated covariance between spring wheat and durum wheat profits in Saskatchewan in 1997 has been calculated by replacing (4.35) into (4.38).

Therefore, using relations (4.36), (4.37) and (4.38), the truncated expected profit $\bar{\pi}_j^T$ (which in our case of nine crops would be nine individual profit variables), and the truncated covariance of cross-commodity profits, σ_{jk}^T (which in our case would be nine individual variance variables and thirty six covariance variables), in equation (5.1) (or (5.2)) can be constructed in each province over 1971-2006.

In what follows, we explain our method of data construction for guaranteed profit (and guaranteed price under the ASA) by crop-specific programs:

Agricultural Stabilization Act (ASA) The ASA provided payments to producers in every province during periods of low commodity prices. It guaranteed farmers 90 percent of a three-year moving-average price (Schmitz, Furtan and Baylis, 2002). Mandatory support was provided for cattle, hogs, lambs and wool; industrial milk and industrial cream; corn and soybeans; and spring wheat, winter wheat, oats and barley. Among the crops in our study, we calculated the support price in each year, from 1970 to 1976, for spring wheat, oats and barley based on the 90 percent of the previous three-year average prices (\$/tonne). Since the ASA is a price support program, to capture the impact of government program, the truncation formula were used for the parameters of price distribution (instead of profit distribution). Then, the truncated expected price and the truncated elements of variance-covariance matrix of prices were used for construction of the expected profit and elements of variance-covariance matrix of profits (equations 5.3, 5.8, and 5.11).

Crop Insurance The payment mechanism in a Crop Insurance program is based on individual yield coverage which means that a producer can get yield insurance up to a proportion, usually 70 percent or 80 percent, of his or her own ten-year average yield (Schmitz, Furtan and Baylis, 2002). It should be noted that all crop insurance contracts guarantee a price. In each year, we calculated yield guarantee (tonne/acre) as the previous ten-year average yield (y) for each crop in each province multiplied by 0.7. Price coverage (\$/tonne) for each crop has been obtained by request from Saskatchewan Crop Insurance Corporation (SCIC); Manitoba Crop Insurance Corporation (MCIC); and Agriculture Financial Services Corporation (AFSC), Alberta; for the years 1970-2006. We constructed the guaranteed (gross) profit based on the multiplication of yield guarantee by price coverage for each crop in each province over 1970-2006. Then, we obtained the guaranteed profit (\$/acre) by subtracting the crop production costs from guaranteed gross profit.

Gross Revenue Insurance Program (GRIP) In GRIP, farmers were guaranteed a per-acre return on whatever crop they grew. The program guaranteed producers their long-term average yield. The guaranteed price was set by an indexed moving average price (Schmitz, Furtan and Baylis, 2002). In each year (from 1991 to 1995), we calculated the previous fifteen-year average yield (tonne/acre) for each crop in each province as the long-term average yield. Price coverage (\$/tonne) for each crop has been obtained by request from SCIC, MCIC, and AFSC for the years 1991-1995. We constructed the guaranteed profit (\$/acre) based on the multiplication of the long-term average yield by price coverage (minus crop costs) for each crop in each province over 1991-1995.

5.1.3.2 Whole-Farm Programs

The influence of government programs on the subjective probability distribution of total profit is considered by whole-farm programs[1], WGSA, NISA, AIDA/CFIP, and CAIS, over the period of our study. The resulting truncation of the subjective probability distribution of total profit will affect expected total profit as well as the variance of the total profit. Thus, government whole-farm programs will influence both total profit expectations and the riskiness of total profit (variance). If we assume that each random variable total profit is truncated from below at a level H (which is the higher guaranteed profit by whole-farm programs[2]), expressions (4.36) and (4.37) in the previous chapter provide an analytical evaluation of the truncation effect of a whole-farm program on the mean and variance of total profit[3].

For example, consider Saskatchewan in 1995. The untruncated expected total profit and the untruncated variance of total profit have been obtained using relations (5.12) and (5.13), respectively. Guaranteed profit (\$) by NISA program (in 1995, the NISA was implemented by government) in 1995 has been calculated and then chosen as truncation point H. Then, $h =$

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[1] Note that the whole farm programs will truncate the distribution of total profit in which the untruncated total profit's distribution parameters have been obtained through truncated individual crop profit parameters.

[2] The calculation of guaranteed profit by whole-farm support programs will be provided in below.

[3] Note that the truncation expressions in the previous chapter were not used to capture the effect of the CAIS program. Under the CAIS the guaranteed profit is not a specific point and is defined in three different tiers. The procedure to capture the impact of the CAIS is explained below.

$\frac{H-\bar{\Pi}}{\sigma_T^{0.5}}$ has been calculated. $\phi(h) = \frac{1}{(2\pi)^{0.5}} e^{-\frac{(h)^2}{2}}$ and $\Phi(h)$ has been calculated by $normsdist(h)$ in Excel which provides the standard normal cumulative distribution function. Finally, the truncated expected total profit and the truncated variance of total profit in Saskatchewan in 2005 have been obtained by replacing (4.33) and (4.34) in (4.36) and (4.37), respectively. Therefore, using relations (4.36)and (4.37), the truncated expected total profit ($\sum_{j=1}^{9} A_j \bar{\pi}_{jt}^T$) and the truncated variance of total profit ($\sum_{k \geq j}^{9} \sum_{j=1}^{9} A_j A_k \sigma_{jkt}^T$) in equation (5.1) (or (5.2)) can be constructed in each province for 1977-2006.

In what follows, we explain our method of data construction for guaranteed profit by whole-farm programs:

Western Grain Stabilization Act (WGSA) In WGSA[1], payments are based on producers' eligible grain sales. Payment was made when aggregate net cash flow (cash receipts minus cash variable costs) from eligible grain (wheat, oats, barley, rye, flaxseed, canola and mustard seed; from 1988 nine crops are added to the seven previously covered—triticale, mixed grains, sunflower, safflower, buckwheat, peas, lentils, fababeans, canary seed) sales was less than the average net cash flow over the previous five years (Schmitz, Furtan and Baylis, 2002). We derived a net cash flow ($) for 1977-1990 as total crop receipts[2] ($\sum_{i=1}^{9} p_i y_i A_i$) minus total crop production allowable[3] costs ($\sum_{i=1}^{9} c_i A_i$) in each province. The eligible net cash flow in each province was constructed based on the previous five-year average net cash flow. In each province, we used this eligible net cash flow as the guaranteed total profit ($) by WGSA for 1977-1990.

Note that under the WGSA a farmer should pay two percent of gross sales (Freeman, 2005) to the stabilization fund (an amount that was matched by the federal government). Therefore, we adjusted the truncated expected total profit under the WGSA. The adjusted truncated mean of total profit is the initial truncated mean minus two percent of the untruncated mean and two percent of the total cost.

Net Income Stabilization Account (NISA) NISA pay-outs were made when the farmer's net income fell below 70 percent of the previous three-year average (Schmitz, Furtan and Baylis, 2002). We derived net farm income ($) for 1991-2002 as total crop receipts[4]($\sum_{i=1}^{9} p_i y_i A_i$)

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[1] Since the pay-out trigger under the WGSA was based on the aggregate net cash flow of prairie grain producers and the WGSA covered almost all crops in our study, we categorized it into whole-farm programs.

[2] Crop insurance proceeds (CANSIM table 002-0001) are added to total crop income as allowable income.

[3] Note that crop insurance premiums have been considered as allowable production costs in crop cost calculations.

[4] Crop insurance proceeds are added to total crop income as allowable income.

minus total crop production allowable costs[1] ($\sum_{i=1}^{9} c_i A_i$) in each province. We calculated previous three-year average net cash flow. In each province, we used 70 percent of this net farm income as the total profit guaranteed ($) by NISA over 1991-2002.

Note that under the NISA a farmer should pay up to three percent of eligible net sales to a NISA account (and the federal and provincial governments generally make a matching contribution to a NISA account for the individual). Therefore, we adjusted the truncated expected total profit presented under the NISA. The adjusted truncated mean of total profit is the initial truncated mean minus three percent of the untruncated mean.

Agricultural Income Disaster Assistance (AIDA)/the Canadian Farm Income Program (CFIP) In AIDA/CFIP, when producers' net income fell below 70 percent of their three-year, moving-average net income they become eligible for a pay-out (Schmitz, Furtan and Baylis, 2002). Therefore, we used the same procedure as NISA for constructing the guaranteed total profit ($) over 1998-2002.

Note that no premium was paid by the farmer under the AIDA/CFIP. However, participation in NISA maximized benefits from the AIDA/CFIP. The current year's government contribution to NISA was deducted from the AIDA/CFIP program payment for all NISA-eligible AIDA/CFIP participants. NISA participants received the government payment and then had it deducted. AIDA/CFIP participants who were eligible but did not participate in NISA had the deduction only[2]. Therefore, for the truncation, AIDA/CFIP program is considered as the government program over 1998-2002.

Canadian Agricultural Income Stabilization (CAIS) Payments are made when the program year margin falls below the reference year margin. The reference margin is the Olympic average of the last five years' production margins, with highest and lowest years dropped (CAIS Handbook, AAFC). The amount of government funds is determined by the extent of margin decline. The program measures the extent of farmer decline using three tiers, with Tier 1 representing the smallest decline and Tier 3 representing the largest decline. If the program year margin is between 85-100 percent of the reference margin, government pays fifty percent of the decline (Tier 1). If the program year margin is between 70-85 percent of the reference margin, government pays seventy percent of the decline (Tier 2) in addition

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[1] Note that crop insurance premiums have been considered as allowable production costs in crop cost calculations.

[2] Note that it is assumed that farmers participated into the NISA program in order to maximize the benefits from the AIDA.

to the Tier 1. If the program year margin is between 0-70 percent of the reference margin, government pays eighty percent of the decline (Tier 3) in addition to the Tier 1 and Tier 2 (See figure 2.3). In an unlikely case when production margin is negative, the government pays sixty percent of loss.

We derived net margin ($) for 2003-2006 in each province as total crop allowable receipts ($\sum_{i=1}^{9} p_i y_i A_i$) minus total crop production allowable costs ($\sum_{i=1}^{9} c_i A_i$) in each province[1]. In each year, we dropped the highest and lowest previous five-year margins and then calculated a three-year average margin. For truncation of profit distribution in each year, the announced payment calculation procedure by the CAIS was applied. Given the expected mean and variance of untruncated profit distribution, we created 10,000 random numbers from this normal distribution. After sorting these numbers, we identified the values above and below the reference margin. Values above the reference margin were left unchanged but values below the reference margin were adjusted based on the CAIS payment procedure (Tiers 1, 2, and 3). The mean and variance of the new series are considered as truncated expected mean and variance. Note that the truncation formula presented in the previous chapter are not appropriate here because the guaranteed profit by the CAIS is not a specific point and is defined in three different tiers.

5.2 Estimated Results

5.2.1 Coefficients and Elasticities

As indicated earlier, the acreage response model treats farmers' planting decisions for spring wheat, durum wheat, oats, barley, rye, peas, flax, canola, hay in the three prairie provinces. To have the most consistent estimation results, we estimate the model with different specifications and different data sets using seemingly unrelated regressions (SUR). We specify the acreage equations in both acres level and share, equations 5.1 and 5.2. Moreover, each of these equations is estimated using two sets of data: one contains adaptive expectations for the expected prices and yields, the other one uses the future prices as the expected prices and trend yield as the expected yield. Then, among the different estimations, we choose the model where its results are more consistent with theoretical expectations and which has a

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[1] To be allowable, income and expenses must be directly related to the primary production of agricultural commodities. The CAIS Handbook provides some examples of allowable and non-allowable income and expense items. For instance, crop insurance proceeds are considered as allowable income and crop insurance premiums are considered as allowable expenses.

higher R-square or lower Mean Square Error (MSE).

To have reliable and theoretically consistent estimations, three restrictions are imposed (these restrictions are the same as what apply to the AIDS demand system across expenditure share equations) that are implied by the theory. As inferred by expression (4.28), symmetry restrictions require that individual crop cross-profit regression coefficients across the acreage equations be equal; that is, $\beta_{12} = \beta_{21}, \beta_{13} = \beta_{31}, ..., \beta_{19} = \beta_{91}, \beta_{23} = \beta_{32}, ..., \beta_{29} = \beta_{92}, \beta_{34} = \beta_{43}, ..., \beta_{39} = \beta_{93}, \beta_{45} = \beta_{54}, ..., \beta_{49} = \beta_{94}, \beta_{56} = \beta_{65}, ..., \beta_{59} = \beta_{95}, \beta_{67} = \beta_{76}, ..., \beta_{69} = \beta_{96}, \beta_{78} = \beta_{87}, \beta_{79} = \beta_{97}, \beta_{89} = \beta_{98}$. Thirty-six symmetry constraints were imposed. As discussed in the theoretical framework, the acreage decision functions are almost homogenous of degree one in initial wealth, degree one in mean returns, and degree two in moments of order two. This means that if expected total wealth and expected crop profits are multiplied by λ and elements of variance-covariance matrix and variance of total wealth are multiplied by λ^2, the acreage decisions would not change. If the acreage equations are estimated in logarithm form, we can impose the homogeneity restriction on coefficients in each equation (sum of total wealth and individual crop profits coefficients plus crop variance-covariance and variance of total wealth coefficients is equal to zero). However, we are not able to estimate equations in logarithm form because the covariance variables may be negative in the observations. The homogeneity property can be maintained within the empirical model by normalization (due to the specification of the variables) as it is common in the literature (Sckokai and Moro, 2006; Coyle, Wei and Rude, 2008). Therefore, we normalized the monetary variables by a numeraire (a Tornqvist[1] net return per acre index)[2], where the elements of variance-covariance matrix were normalized with the squared return of the numeraire. To maintain adding-up restrictions (the sum of the shares for these ten category crops equals one or total cropland is assumed to be fixed over time), we dropped one crop acreage equation, summerfallow[3]. In fact, the share (acre level) for summerfallow was treated as a residual, which was not directly estimated to avoid singularity in the disturbance covariance matrix.

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[1] Tornqvist index is a discrete approximation to a continuous Divisia index which is a weighted sum of the growth rates of the various components. The growth rates are defined as the difference in natural logarithms of successive observations of the components and the weights are equal to the mean of the factor shares of the components in the corresponding pair of years.

[2] Considering that studies in the literature specify their model for few crops instead of all major crops, Tornqvist index is an index of the returns of crops which have been omitted from the model. In our study, the equation omitted from the system is summerfallow acreage which is affected by the return and variance of all major crops (included in the model) as well as expected total wealth and its variance. Therefore, we have constructed Tornqvist index based on the net return of the nine major crops included in the model.

[3] Theoretically, this can be done when all regressors are identical across equations. Considering that summerfallow acreage is affected by the same factors as other crops (Clark and Klein, 1992), this condition holds in our system.

The estimation of aggregate acreage response equations involves the use of cross section (three provinces) data, therefore it is important to control for persistent provincial economic (dis)advantages, including institutional differences and economic conditions. To solve this problem, fixed effects of individual provinces are used in the model, thus we can be more confident that our independent variable coefficients reflect their marginal impacts rather than long-term structural effects related to economic endowments.

Different specifications have been employed[1]. We have estimated both acreage level and acreage share equations specified in the equations 5.1 and 5.2 using data sets which contain adaptive expectation procedure for the expected price and yield (See tables E.1 and E.2 in the Appendix D). In the acreage level equation, the coefficient for the mean of own-profit has the significant positive sign in all equations except for durum wheat and peas acreage equations (but insignificant). The mean of own-profit has the expected positive sign for all crops in the acreage share equations. The coefficient for the variance of own-profit has a negative sign in spring wheat, barley, flax, canola and hay equations (only statistically significant in spring wheat, canola and hay) in the acreage level equation. In acreage share equation, the variance of own-profit is negative in spring wheat, oats, barley, flax, canola and hay equations although it is statistically significant only in the canola and hay equations. In the acreage level (share) equation, the wealth effect has a significant positive impact on spring wheat (and durum wheat) and a significant negative impact on peas, flax and canola acres. The insurance effect has positive impact on spring wheat and hay acres and it has negative impact on all other crops although it is statistically significant only in the durum wheat and hay equations. In the acreage share equation, the insurance effect has a significant positive impact on the spring wheat and hay equations while it has a significant negative impact on the durum wheat and canola equations. The null hypothesis of all beta coefficients for expected total wealth (wealth effect) and variance of total wealth (insurance effect) being jointly zero are rejected.

We have estimated the acreage share equation using futures prices as the expected price and trend yield as the expected yield (See table E.3 in the Appendix D). The results are, in general, the same as the acreage level equation, base model, that will be discussed later.

Assuming separability, we have estimated a model (specified in the equation 5.1) of two

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[1] The results of different specifications are provided in the Appendix D. Due to the space limitations, the coefficients of covariance terms in each model have not been reported. To increase the degrees of freedom and to avoid the high collinearity between covariance terms, we omitted insignificant covariance terms in each equation. Although the adding-up restrictions require that all regressors are identical across equations, omitting insignificant covariance terms maybe reasonable considering that there are many regressors that suffer from high degree of collinearity.

sub-systems, cereal crops (spring wheat, durum wheat, oats, barley, rye and hay) and non-cereal crops (peas, flax and canola), in order to reduce the number of covariance terms in each equation (See tables E.4 and E.5 in the Appendix D). The coefficients for the mean of own profit and its variance have the expected signs in all equations except for durum wheat (both mean and variance of profit coefficients), barley (mean of profit coefficient) and rye (variance of profit coefficient) in the cereal system and canola (both mean and variance of profit coefficients) in the non-cereal system. In the cereal system, the wealth effect has a positive impact for the spring wheat, rye and hay acres and a negative impact for the durum wheat, oats and barley acres, although it is only statistically significant in the spring wheat and oats equations. In the non-cereal system, the wealth effect is negative for all three crops. Although the insurance effect positively influences the spring wheat, barley and rye acres and negatively affects the durum wheat, oats and hay acres in the cereal system, it is only statistically significant in the durum wheat and hay equations. While the insurance effect negatively affects the acreage allocated to all non-cereal crops, it is not statistically significant. The null hypothesis of all beta coefficients of expected total wealth (wealth effect) and variance of total wealth (insurance effect) being jointly zero are rejected for the sub-system of cereal crops while they are not rejected for the non-cereal crops[1]. However, when cereal and non-cereal crops acreage equations are estimated in one system of equations, wealth and insurance effects are statistically significant in the non-cereal crops.

In another specification, we have estimated the system of acreage equations (specified in the equation 5.1) as a function of the lagged total acreage[2] (instead of the lagged dependent variable), among other variables, as employed by Coyle (1993) and Coyle, Wei and Rude (2008) (See table E.6 in the Appendix D). The coefficient for the mean of own-profit has the expected positive sign in the spring wheat, oats, rye, flax and canola equations and it is statistically significant only in the canola equation. Although the variance of own-profit coefficient has the expected negative sign in the spring wheat, durum wheat, oats, peas, flax and hay equations, it is only statistically significant in the spring wheat and flax equations. The wealth effect leads to a increase in acreage for spring wheat, rye, peas and canola but a decrease for oats and barley acres. The insurance effect positively influences the acreage allocated to spring wheat while it negatively affects oats, barley and canola acres. The null

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[1] Note that we did this test in a model based on the future prices and trend yield as the expected price and yield respectively.

[2] Given that some crops may be substituted into rotations more easily than other crops, lagged total crop acreage may have different impacts on different crop acreage allocations, the specification that contains the lagged total acreage is employed.

hypothesis of all beta coefficients of expected total wealth (wealth effect) and variance of total wealth (insurance effect) being jointly zero are rejected. Since the previous studies in the literature specify their model for few crops instead of all major crops, the lagged total acreage shows variability over time. However, in our study, we have considered all major crops in the model, therefore the lagged total acreage does not vary considerably over time and therefore, in almost all equations, is not statistically significant. As a result, one can not rely on the system of acreage equations conditional on lagged total acreage.

After the estimation of several potential models specified in the equations 5.1 and 5.2 (each of the acreage level and share equations with the adaptive expectations and the futures price-trend yield), results from the acreage level model based on the futures price[1]-trend yield are regarded as the base model due to their consistency with theoretical expectations, more statistically significant coefficients and lower mean square errors. Note that the coefficients related to the wealth and insurance effects are statistically significant in terms of adaptive expectations and share acreage equations in all specifications.

McElroy (1977) suggested a system-wide measure of goodness of fit which has a similar interpretation to the single-equation measure. Bewley (1985), however, has shown that this system measure is biased towards unity when there are few degrees of freedom. An alternative measure would be, $1-\frac{1}{1+LR/[T(n-1)]}$, where T is the number of observations, n is the number of crops and the likelihood ratio, LR, is twice the difference between the log likelihood of the base model and the log likelihood of the same dependent variables on a constant term only[2]. For the base model the system-wide R-squared is 0.95.

According to the results of the base model, we should not worry about the heteroskedasticity problem that potentially arises from the use of cross section data[3]. The system of acreage equations is estimated by seemingly unrelated regression (SUR), which estimates the

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[1] Researchers generally agree that the most efficient way to predict prices is to use futures prices (Gardner, 1976; Choi and Helmberger, 1993). In particular, Gardner suggested the idea of using the futures price as a measure of expected price, arguing that the price of a futures contract for next year's crop reflects the market's estimate of next year's cash price. Moreover, to address for the endogeneity of the expected prices, Choi and Helmberger have estimated a simultaneous equations of futures price (as a proxy for the expected prices), consumption demand and acreage response for soybeans. In future price equation, exchange rate, fishmeal exports by the rest-of-world and lagged three-year moving average of soybean yields are exogenous variables, among other variables. The results show that the ordinary and three-stage least squares estimates of the acreage response function are essentially the same. In other words, little empirical support is found for the view that in estimating acreage response functions, the expected price (as measured by the futures price) should be viewed as an endogenous rather than an exogenous variable.

[2] The log likelihood for the base model is -8884.46 and for the model with the same dependent variables on a constant term (i.e. a system of nine equations in which acreage for each crop has been regressed on a constant term) is -14529.13.

[3] The seemingly unrelated regression estimator in Stata computes robust standard errors of residuals.

equations initially by least square and then incorporates the estimated variance and covariance matrix of residuals in the estimation of generalized least square (GLS). Nevertheless, we have conducted a heteroskedasticity test in individual equations. According to the Breusch-Pagan test, the null hypothesis of homoskedasticity is not rejected for all crops. P-values of computed Lagrange Multiplier (LM) statistics in the spring wheat, durum wheat, oats, barley, rye, peas, flax, canola, and hay equations are 0.99, 0.28, 0.33, 0.24, 0.73, 0.20, 0.14, 0.94, and 0.64, respectively. Hence, the null hypothesis of homoskedasticity cannot be rejected. Also, on the basis of the Durbin h statistics, it might be concluded that there is no evidence of serial correlation in the estimated model. The p-values for the null hypothesis of no serial correlation in the spring wheat, durum wheat, oats, barley, rye, peas, flax, canola and hay equations are 0.11, 0.47, 0.72, 0.76, 0.80, 0.54, 0.63, 0.43 and 0.76, respectively. However, when the estimated model comprises a consistent system of equations, single equation Durbin h statistics can be misleading and alternative tests for autocorrelation should be sought. An alternative test for autocorrelation could be based on a comparison of the likelihoods of the static model with that of the autoregressive processes[1]. Such a likelihood ratio (LR) test (i.e., twice the difference in the log-likelihoods) is asymptotically distributed as chi-squared. With the alternative hypothesis being autoregressive disturbances, the value of the LR statistic is 296.2, which is to be compared with the critical value, at the 5 percent level and with nine degrees of freedom, of 16.92. It implies that the null of no serial correlation is rejected and; therefore, lagged dependent variables are appropriate regressors.

The results of the acreage response model incorporating wealth and insurance effects are given in table 5.1. Table 5.2 provides the estimated elasticities for expected crop profits and variance of crop profits, expected total wealth, variance of total wealth and dependent lagged variable. The overall fit of the resulting model is good, as indicated by the high R-squared (0.95). In addition, the signs on the various variables are generally consistent with theory. As anticipated, expected own profits in the spring wheat, oats, rye, peas, flax, canola and hay equations have the expected positive signs and are statistically significant except for rye and peas. As table 5.2 shows the acreage elasticity with respect to expected own-profit for these crops are 0.18, 0.20, 0.06, 0.09, 0.60, 0.40 and 0.03, respectively. Durum wheat and barley do not have the expected signs for expected own profits, but they are insignificant. Although the variance of own profit variables have all the expected negative signs (except for rye with a positive sign but insignificant), few of them for barley, flax and hay are statistically

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[1] The log likelihood for the static model is -9032.56 and the autoregressive model is -8884.46.

significant. As the variance of own profit elasticities in table 5.2 shows, elasticities are -0.02 for barley, -0.14 for flax and -0.05 for hay.

Table 5.1: Acreage Level Model Results

	ep swh	**ep dwh**	**ep oats**	**ep barl**	**ep rye**	**ep peas**	**ep flax**	**ep cano**	**ep hay**
swh acre									
Coeff.	17203.35	-114.19	-2420.19	2673.32	-1613.20	1271.63	-15.06	-8638.04	667.21
St. Err.	5480.42	2551.18	1648.58	2532.12	1294.09	1093.98	1517.01	2455.72	1272.44
dwh acre									
Coeff.	-114.19	-1228.41	-1618.16	2684.22	-313.66	-208.40	-736.40	496.28	-73.01
St. Err.	2551.18	2432.40	917.77	1610.97	741.45	710.40	954.41	1530.93	705.08
oats acre									
Coeff.	-2420.19	-1618.16	3686.41	2517.66	1642.66	-408.91	74.97	-986.79	-380.26
St. Err.	1648.58	917.77	1152.17	1133.64	779.99	504.01	831.41	918.28	727.11
barl acre									
Coeff.	2673.32	2684.22	2517.66	-1430.60	-689.52	228.16	307.54	-2113.29	1872.22
St. Err.	2532.12	1610.97	1133.64	2280.56	904.55	712.88	1042.11	1346.13	938.70
rye acre									
Coeff.	-1613.20	-313.66	1642.66	-689.52	273.17	-157.67	-428.93	573.13	-115.46
St. Err.	1294.09	741.45	779.99	904.55	1099.34	424.35	722.04	669.39	635.66
peas acre									
Coeff.	1271.63	-208.40	-408.91	228.16	-157.67	390.59	699.04	-984.07	-738.29
St. Err.	1093.98	710.40	504.01	712.88	424.35	456.47	475.01	643.40	443.37
flax acre									
Coeff.	-15.06	-736.40	74.97	307.54	-428.93	699.04	2805.06	-1789.37	-2799.33
St. Err.	1517.01	954.41	831.41	1042.11	722.04	475.01	1048.86	917.72	681.18
cano acre									
Coeff.	-8638.04	496.28	-986.79	-2113.29	573.13	-984.07	-1789.37	8815.63	-218.90
St. Err.	2455.72	1530.93	918.28	1346.13	669.39	643.40	917.72	2072.28	719.82
hay acre									
Coeff.	667.21	-73.01	-380.26	1872.22	-115.46	-738.29	-2799.33	-218.90	1812.15
St. Err.	1272.44	705.08	727.11	938.70	635.66	443.37	681.18	719.82	893.09

Table 5.1: Continued

	varp swh	**varp dwh**	**varp oats**	**varp barl**	**varp rye**	**varp peas**	**varp flax**	**varp cano**	**varp hay**
swh acre									
Coeff.	-100.40	124.68	279.32	-102.58	22.34	-78.03	197.10	-73.39	-129.71
St. Err.	213.21	116.64	101.85	119.68	175.30	56.64	87.87	81.60	182.37
dwh acre									
Coeff.	51.36	-90.64	59.71	144.12	66.79	-27.60	-186.67	226.21	-138.67
St. Err.	159.99	82.42	80.20	85.50	130.73	39.21	63.05	60.51	118.05
oats acre									
Coeff.	-73.25	10.04	-46.21	13.47	144.00	-7.78	3.89	9.14	-102.95
St. Err.	66.34	37.79	34.29	40.30	54.68	18.99	25.72	27.20	59.79
barl acre									
Coeff.	187.52	-42.03	-80.75	-119.10	-68.51	4.19	8.89	27.54	107.64
St. Err.	124.27	65.23	57.70	64.73	108.63	28.46	50.42	49.57	94.39
rye acre									
Coeff.	8.23	-7.00	-6.86	-11.56	65.74	-6.70	10.66	8.43	-12.01
St. Err.	53.24	28.23	22.41	25.83	42.59	14.41	16.65	17.60	43.53
peas acre									
Coeff.	15.17	4.34	-8.39	-79.38	-15.73	-22.52	-23.28	16.07	61.73
St. Err.	58.33	29.14	23.99	32.81	39.13	15.70	23.29	20.56	41.59
flax acre									
Coeff.	60.63	-31.09	-44.09	-32.21	85.64	-33.53	-56.11	65.61	144.16
St. Err.	75.70	39.85	34.01	42.87	51.98	18.11	28.90	27.78	60.68
cano acre									
Coeff.	300.02	-272.55	30.01	341.51	119.01	19.20	-223.37	-50.76	-140.47
St. Err.	180.56	86.85	73.23	88.23	142.34	47.02	55.35	62.14	128.94
hay acre									
Coeff.	-23.01	-58.60	-31.28	107.63	-12.50	21.01	-18.98	23.77	-211.14
St. Err.	44.98	23.93	23.52	31.28	46.07	12.44	19.59	19.92	47.21

Table 5.1: Continued

	covp swh,dwh	**covp swh,oats**	**covp swh,barl**	**covp swh,rye**	**covp swh,peas**	**covp swh,flax**	**covp swh,cano**	**covp swh,hay**
swh acre								
Coeff.	168.94					76.43	-66.98	-186.25
St. Err.	54.34					42.43	39.00	51.23
dwh acre								
Coeff.							37.32	39.22
St. Err.							25.08	27.88
oats acre								
Coeff.						-26.39	-9.79	37.13
St. Err.						17.07	15.23	18.20
barl acre								
Coeff.			15.36	-5.01		17.33		
St. Err.			25.12	16.10		22.30		
rye acre								
Coeff.	-8.49	1.42	0.95	-2.51	4.86			17.30
St. Err.	9.24	4.51	6.30	4.11	4.21			12.62
peas acre								
Coeff.			4.64		-7.15		6.14	18.39
St. Err.			5.84		5.04		10.26	11.72
flax acre								
Coeff.	-9.02	28.25						
St. Err.	9.40	9.07						
cano acre								
Coeff.	127.51	108.06		-51.30	-91.56			133.23
St. Err.	44.02	36.83		20.75	17.90			39.37
hay acre								
Coeff.							0.21	13.20
St. Err.							6.25	9.78

Table 5.1: Continued

	covp dwh,oats	**covp dwh,barl**	**covp dwh,rye**	**covp dwh,peas**	**covp dwh,flax**	**covp dwh,cano**	**covp dwh,hay**	**covp oats,barl**
swh acre								
Coeff.	-107.47		-27.42	41.76		-147.63		
St. Err.	33.64		20.32	23.82		35.70		
dwh acre								
Coeff.		15.06				-13.55		-31.26
St. Err.		20.37				14.42		12.82
oats acre								
Coeff.				7.80	-6.61	17.40	-5.09	
St. Err.				9.09	11.60	15.04	14.11	
barl acre								
Coeff.		5.58		1.05				5.89
St. Err.		17.21		10.52				17.13
rye acre								
Coeff.		12.13		-3.02			-1.77	
St. Err.		12.13		3.37			7.01	
peas acre								
Coeff.								
St. Err.								
flax acre								
Coeff.	5.85							-28.27
St. Err.	6.69							10.79
cano acre								
Coeff.		-247.85				54.22		-44.77
St. Err.		81.48				21.40		26.64
hay acre								
Coeff.				6.83	-5.09	14.53	-6.04	
St. Err.				5.30	7.95	8.19	8.03	

Table 5.1: Continued

	covp oats,rye	**covp oats,peas**	**covp oats,flax**	**covp oats,cano**	**covp oats,hay**	**covp barl,rye**	**covp barl,peas**	**covp barl,flax**
swh acre								
Coeff.	90.34	3.46				-132.63		35.76
St. Err.	34.50	13.35				48.93		47.19
dwh acre								
Coeff.	-2.89	-10.79					38.89	
St. Err.	10.69	5.69					17.22	
oats acre								
Coeff.					-5.42			-0.22
St. Err.					9.94			11.46
barl acre								
Coeff.					-14.74	-13.53	9.46	-17.40
St. Err.					15.76	16.64	17.32	30.79
rye acre								
Coeff.								
St. Err.								
peas acre								
Coeff.								
St. Err.								
flax acre								
Coeff.			-18.92	16.34				
St. Err.			10.06	8.12				
cano acre								
Coeff.	-61.85	-18.09	-107.06	27.20		102.11	87.27	111.48
St. Err.	22.82	8.38	28.11	13.00		39.73	26.61	49.00
hay acre								
Coeff.		3.35				3.88		-13.45
St. Err.		3.04				5.81		11.03

Table 5.1: Continued

	covp barl,cano	**covp barl,hay**	**covp rye,peas**	**covp rye,flax**	**covp rye,cano**	**covp rye,hay**	**covp peas,flax**	**covp peas,cano**
swh acre								
Coeff.		190.63	-69.99		148.65		-34.63	45.54
St. Err.		64.20	18.43		32.66		29.36	22.56
dwh acre								
Coeff.			-17.59	17.17				
St. Err.			9.72	14.25				
oats acre								
Coeff.		-16.31	4.58	3.20	-17.56		7.26	-6.15
St. Err.		25.30	7.36	11.62	16.15		8.35	5.36
barl acre								
Coeff.	-34.46	-15.14						
St. Err.	29.06	32.37						
rye acre								
Coeff.		-6.02						
St. Err.		14.21						
peas acre								
Coeff.			4.83	1.28		-11.15		
St. Err.			3.01	4.66		8.33		
flax acre								
Coeff.	23.35						19.67	-18.15
St. Err.	12.69						7.84	6.61
cano acre								
Coeff.		-226.79						
St. Err.		50.79						
hay acre								
Coeff.				-1.94	-1.88		3.08	-9.18
St. Err.				6.38	5.57		7.40	5.16

Table 5.1: Continued

	covp peas,hay	**covp flax,cano**	**covp flax,hay**	**covp cano,hay**	**exp. tot. w.**	**var. tot. w.**	**acrelag**
swh acre							
Coeff.	114.48	29.26	-84.62		98.80	-1141.80	0.51
St. Err.	29.58	23.92	38.92		47.00	484.60	0.05
dwh acre							
Coeff.	-15.22	-16.43			-4.64	168.20	0.12
St. Err.	15.35	12.94			29.90	347.80	0.10
oats acre							
Coeff.	-20.74		21.34	14.56	-19.10	202.20	0.65
St. Err.	12.30		18.47	8.37	14.70	188.30	0.09
barl acre							
Coeff.	11.40	5.16	-32.03		-56.40	-25.00	0.36
St. Err.	19.71	8.98	22.69		24.80	266.10	0.11
rye acre							
Coeff.					18.00	-33.10	0.43
St. Err.					11.84	95.20	0.19
peas acre							
Coeff.		-1.41		4.55	-27.00	-228.30	0.48
St. Err.		4.26		4.82	10.60	125.30	0.08
flax acre							
Coeff.		-7.47			-6.68	13.90	0.70
St. Err.		6.08			14.40	116.90	0.10
cano acre							
Coeff.			47.42		10.40	990.90	0.47
St. Err.			24.37		30.60	312.20	0.06
hay acre							
Coeff.	-3.80			-2.87	8.73	217.40	1.04
St. Err.	7.04			4.95	10.20	110.70	0.07

Notes: Coef.=Coefficient; St. Err.=Standard Error; swh=spring wheat; dwh=durum wheat; barl=barley; cano=canola; ep=expected profit; varp=variance of profit; covp i,j=covariance between crop i and j profits; exp. tot. w=expected total wealth; var. tot. w=variance of total wealth; The unit of expected total wealth is in million dollars and its variance is in thousand billion.

The results in this study suggest that the individual effects of risk (individual crop's profit's variance and covariance variables) on acreage response for major crops are not strong and vary across commodities. In the spring wheat, durum wheat, oats, barley, rye, peas, flax, canola, and hay equations approximately 65, 37, 20, 10, 5, 17, 70, 87, and 26 percent of risk variables respectively are statistically significant. In a multi-output framework, one has to judge the impact of risk on output as the impact of the variance-covariance matrix as a whole. A Wald test to see if beta coefficients of all individual risk variables in each equation are jointly statistically significant suggests that risk does matter in farmers' spring wheat, durum wheat, oats, peas, flax, canola, and hay planting decisions[1]. However, in the cases of barley and rye, the p-values are 0.45 for the former and 0.75 for the latter. Furthermore, the null hypothesis that beta coefficients of all individual risk variables in the system of nine acreage equations are jointly zero is strongly rejected, which shows the importance of capturing the impact of individual risk through the variance and covariance matrix of individual crop's profit in a system framework.

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[1] The null hypothesis that beta coefficients of all risk variables are zero in the spring wheat, durum wheat, oats, peas, flax, canola, and hay acreage equations have p-values as follows: 0.00, 0.05, 0.00, 0.02, 0.01, 0.00, and 0.00 respectively.

Table 5.2: Estimated Elasticities-Base Model

	ep swh	**ep dwh**	**ep oats**	**ep barley**	**ep rye**	**ep peas**	**ep flax**	**ep canola**	**ep hay**	**varp swh**	**varp dwh**
swh acre											
Coeff.	0.1867**	-0.0015	-0.0224	0.0298	-0.0107	0.0207	-0.0002	-0.1596**	0.0057	-0.0100	0.0293
dwh acre											
Coeff.	-0.0057	-0.0741	-0.0685*	0.1373*	-0.0095	-0.0156	-0.0504	0.0420	-0.0028	0.0233	-0.0976
oats acre											
Coeff.	-0.1577	-0.1279*	0.2044**	0.1686**	0.0653**	-0.0400	0.0067	-0.1095	-0.0194	-0.0436	0.0141
barley acre											
Coeff.	0.0634	0.0772*	0.0508**	-0.0349	-0.0100	0.0081	0.0100	-0.0853*	0.0347**	0.0406	-0.0216
rye acre											
Coeff.	-0.6438	-0.1519	0.5580**	-0.2829	0.0665	-0.0944	-0.2355	0.3894	-0.0360	0.0300	-0.0605
peas acre											
Coeff.	0.2026	-0.0403	-0.0555	0.0374	-0.0153	0.0934	0.1533	-0.2670	-0.0920*	0.0221	0.0150
flax acre											
Coeff.	-0.0024	-0.1397	0.0100	0.0494	-0.0409	0.1641	0.6035**	-0.4764*	-0.3425**	0.0867	-0.1052
canola acre											
Coeff.	-0.2307**	0.0161	-0.0224	-0.0580*	0.0093	-0.0394	-0.0657*	0.4008**	-0.0046	0.0732*	-0.1575**
hay acre											
Coeff.	0.0171	-0.0023	-0.0083	0.0494**	-0.0018	-0.0284*	-0.0988**	-0.0096	0.0364**	-0.0054	-0.0325**

Table 5.2: Continued

	varp oats	varp barley	varp rye	varp peas	varp flax	varp canola	varp hay	exp. tot. w.	var. tot. w	acrelag
swh acre										
Coeff.	0.0468**	-0.0103	0.0024	-0.0263	0.0362**	-0.0185	-0.0130	0.1813**	-0.0839**	0.5168**
dwh acre										
Coeff.	0.0458	0.0661*	0.0328	-0.0426	-0.1570**	0.2618**	-0.0638	-0.0391	0.0566	0.1219
oats acre										
Coeff.	-0.0464	0.0081	0.0927**	-0.0157	0.0043	0.0139	-0.0620*	-0.2101	0.0892	0.6485**
barley acre										
Coeff.	-0.0295	-0.0260**	-0.0160	0.0031	0.0036	0.0152	0.0236	-0.2261**	-0.0040	0.3650**
rye acre										
Coeff.	-0.0422	-0.0425	0.2592	-0.0830	0.0720	0.0783	-0.0443	1.2118	-0.0894	0.4431**
peas acre										
Coeff.	-0.0206	-0.1166**	-0.0248	-0.1115	-0.0627	0.0596	0.0910	-0.7267**	-0.2463*	0.4435**
flax acre										
Coeff.	-0.1064	-0.0464	0.1323*	-0.1628*	-0.1484*	0.2387**	0.2086**	-0.1767	0.0147	0.6903**
canola acre										
Coeff.	0.0124	0.0841**	0.0314	0.0159	-0.1009**	-0.0315	-0.0347	0.0470	0.1791**	0.4518**
hay acre										
Coeff.	-0.0124	0.0255**	-0.0032	0.0167*	-0.0082	0.0142	-0.0501**	0.0379	0.0378**	1.0035**

Notes: * is significant at 10 percent and ** is significant at 5 percent.

The expected total wealth (initial wealth plus market return) variable is statistically significant in the spring wheat, barley and peas equations (as can be seen in table 5.2, acreage elasticity with respect to the expected total wealth are 0.18 in spring wheat, -0.22 in barley and -0.72 in peas). However, all beta coefficients of the wealth variable in the system are jointly statistically significant with a p-value of 0.00. This means that the wealth effect (income-supporting effect) is one of the factors that significantly affects the allocation of acres among different crops. The weighted average of wealth variables for individual crops, is estimated to be 0.01[1]. A positive overall wealth effect is consistent with decreasing absolute risk aversion (DARA) preferences[2]. In other words, an increase in wealth leads to a decline in profit risk (including both yield and price risks) aversion and an increase in the acreage planted to major field crops (note that the total acreage is constant). Regarding the insurance effect, although the insurance variable is only statistically significant in the spring wheat, peas, canola and hay equations (as illustrated in table 5.2, the acreage elasticities with respect to variance of total profit are -0.08 in spring wheat, -0.24 in peas, 0.18 in canola and 0.03 in hay), all beta coefficients of the variance of total wealth variable in the system are jointly statistically significant with a p-value of 0.00, which indicates the importance of considering this insurance effect (income-stabilizing effect) in the model. More importantly, the results reveal that coefficients of expected total wealth (wealth effect) and variance of total wealth (insurance effect) are statistically significant in the whole system, which implies the whole-farm programs are production and therefore trade distorting and are not actually decoupled, even if they satisfied the WTO criteria.

Dynamic Model: Short-Run Elasticities The need for a dynamic specification of the supply function arises because in most cases farmers will not be able or willing to adjust their production activities instantaneously in response to market conditions. Firstly, there may be a psychological resistance to change, particularly if the change involves the adoption of new techniques or the production of commodities which lie outside the scope of their traditional practices. Even when farmers are innovative, the process of acquiring and assessing new

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[1] Weights are the share of each crop acres in total acres during the period of study in the three provinces.

[2] Sandmo (1971) has examined the relationship between wealth effects and the nature of risk preferences. In particular, a zero wealth effect corresponds to constant absolute risk aversion. In contrast, a non-zero wealth effect corresponds to nonconstant absolute risk aversion. In the single-product case, Sandmo has shown that a positive wealth effect in supply response implies decreasing absolute risk aversion. To the extent that Sandmo's result holds in the multiproduct case, this study indicates that farmers are decreasingly absolute risk averse. This is also a maintained hypothesis in much of the economic literature (e.g., Arrow, 1965).

information has costs and takes time and this will give rise to delayed responses. Secondly, partial adjustment to market forces may be due to institutional factors. For example, short run responses may be hampered by farm tenure or other contractual arrangements, by the market infrastructure, by the availability of farm credit, and so forth.

Finally, the technical characteristics of agricultural production may constrain the process of adjustment in the short run. As with industrial firms, farmers in the short run have a fixed capacity in terms of land, buildings and capital equipment and this will impede expansion in response to rising product prices. Another feature of agricultural production which hampers supply responses in the short run is crop rotation. An arable farmer, who is locked into a specific rotational pattern of production in order to reduce the incidence of pests and disease or to replenish soil nutrients, cannot immediately take advantage of market opportunities as they arise.

Therefore, due to inertia, institutional factors or technical considerations, the full adjustment which producers would seek to make in their production activities in response to changing market conditions, will not be instantaneous but will be spread over several periods. Given a set of prices and other signals, the farmer will determine the equilibrium or long run level of output and although this desired position cannot be attained at once, he will strive towards that goal in each production period. However, because market conditions continually change, the producer must continually revise the long run position and may in fact never attain it. Consequently, framers are reacting not just to current levels of the explanatory variables in the supply function but also to their levels in past periods; the supply function is dynamic (Colman and Young, 1989).

To make a dynamic model which controls for the cost of adjustment in switching from one crop to another, the lagged dependent variable was included in the acreage response model as an explanatory variable. Beta coefficients for the lagged dependent variable suggest that producers in the prairie responded to market signals and government programs fairly slowly and differently across crops. In the case of flax, producers completed their response at a rate of 31 percent within a year, while for barley producers completed their response at a rate of nearly 64 percent within a year. In this setting we are able to calculate the short run acreage elasticities with respect to wealth and insurance effects in addition to the contemporaneous elasticities reported in table 5.2. In fact, the short run acreage elasticities represent farmers' reaction to wealth and insurance effects after accounting for adjustments over time to constraints (psychological, institutional and technical) which limit the ability

Table 5.3: Contemporaneous and Short-Run Elasticities

	con. elas. exp. tot. w.	sr elas. exp. tot. w.	con. elas. var. tot. w	sr elas. var. tot. w
swh acre	0.1813	0.3703	-0.0839	-0.1713
dwh acre	-0.0391	-0.0445	0.0566	0.0645
oats acre	-0.2101	-0.6020	0.0892	0.2555
barley acre	-0.2261	-0.3529	-0.0040	-0.0063
rye acre	1.2118	2.1312	-0.0894	-0.1573
peas acre	-0.7267	-1.3959	-0.2463	-0.4731
flax acre	-0.1767	-0.5986	0.0147	0.0500
canola acre	0.0470	0.0886	0.1791	0.3379
hay acre	0.0379	-1.0802	0.0378	-1.0768

Notes: con.=contemporaneous; sr=short-run and elas.=elasticity

to immediately respond. Table 5.3 shows the short-run elasticities of acreage responce with respect to expected total wealth and its variability[1]. As expected the short run elasticities are larger than the contemporaneous ones. For example, in the case of spring wheat, the acreage elasticity with respect to the expected total wealth (variance of total wealth) has increased from 0.18 (-0.08) to 0.37 (-0.17).

5.2.2 Simulations and the Risk Effects of Government Whole-Farm Programs

The estimated acreage response results reported above provide a basis for analyzing the effects of government direct payments on acreage planted to major field crops in the prairies. In this study, the effects of government direct payments on acreage decisions are determined by finding the difference in total profit distribution parameters without government direct payments, and total profit distribution parameters with government direct payments. Then, using the estimated significant coefficients for expected total wealth and variance of total wealth one is able to calculate the acreage effects of direct payments. Specifically, one wants to determine the effects of whole-farm programs, WGSA (1977-1990), NISA (1991-2002) and CAIS (2003-2006), on the plantings of major field crops in the prairie provinces.

Tables D.1, D.2 and D.3 in the Appendix C show values of parameters used in the simulation analysis of the effects of WGSA for 1977-1990, NISA for 1991-2002 and CAIS for 2003-2006 on acreage allocation, in Manitoba, Saskatchewan and Alberta. Specifically, these tables present the parameters of the total profit distribution with (truncated distribution) and without (untruncated distribution) the WGSA, NISA and CAIS as the whole farm programs[2]. Table 5.4 shows the truncation effect of government payments on the mean and

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[1] Note that short run elasticity=contemporaneous elasticity/(1-lagged dependent variable coefficient).

[2] Note that under the WGSA a farmer should pay two percent of gross sales (Freeman, 2005) to the stabilization fund (an amount that was matched by the federal government). Therefore, for simulation the truncated expected total wealth presented in table D.1 over 1977-1990 has been adjusted. The adjusted

Table 5.4: Truncation Effect on the Mean and Variance of Total Wealth

	Without Program (Untruncated)			With Program (Truncated)	
	exp. tot. w.	**var tot. w.**		**exp. tot. w.**	**var tot. w.**
(avg 1977-1990)			**Trun. Point via WGSA**		
MN	687.39	168490.96	426.76	763.16	94813.38
SK	1987.36	727828.83	1446.77	2130.18	468735.47
AB	1584.90	772365.78	990.47	1735.16	441247.74
(avg 1991-2002)			**Trun. Point via NISA**		
MN	871.12	197668.42	626.77	961.07	108737.55
SK	2711.22	886608.53	1876.73	2823.98	563886.55
AB	2088.04	988304.02	1395.88	2228.03	573596.24
(avg 2003-2006)			**Trun. Point via CAIS**		
MN	878.68	135576.35	857.25	969.88	80847.42
SK	1883.70	1014397.39	2133.86	2237.90	595643.61
AB	2068.66	312511.06	1930.01	2305.55	172506.64

Notes: exp. tot. w=expected total wealth; var tot. w=variance of total wealth; Trun.=Truncation; MN=Manitoba; SK=Saskatchewan; AB=Alberta; Expected total wealth and the truncation point are in million dollars and variance of total wealth is in thousand billion.

variance of total wealth in average during the years that the WGSA, NISA and CAIS programs have been implemented. For example, the truncation of CAIS on total (farm) profit distribution raises the expected farm profit in Saskatchewan to 2237.90 million dollar (on average over 2003-2006), up from 1883.70 million dollar in the absence of CAIS. Meanwhile, the truncation of CAIS lowers the variance of farm profit to 595643.61 thousand billion, down from 1014397.39.

Tables 5.5 (in million acre), 5.6, 5.7 and 5.8 (in percentage) present the simulation results for crops in which the coefficients of the expected total wealth (wealth effect) and total profit variability (insurance effect) are statistically significant (spring wheat, barley, peas, canola and hay). As it can be seen, the source of effects of the WGSA, NISA and CAIS on farmers' planting decisions in the prairie vary among crops, they affect spring wheat and peas acres through both wealth and insurance effects, barley through the wealth effect and canola and hay through the insurance effect. Table 5.5 shows the average of changes in acreage (in million acre) due to the implementation of the WGSA, NISA and CAIS programs. For example,

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truncated mean of total profit is initial truncated mean minus two percent of untruncated mean and two percent of total cost. Moreover, under the NISA a farmer should pay up to three percent of eligible net sales to a NISA account (and the federal and provincial governments generally make a matching contribution to a NISA account for the individual). Therefore, for simulation the truncated expected total wealth presented in table D.2 over 1991-2002 has been adjusted. The adjusted truncated mean of total profit is initial truncated mean minus three percent of untruncated mean. Under the AIDA/CFIP no premium was paid by the farmer. However, participation in NISA maximized benefits from the AIDA/CFIP. The current year's government contribution to NISA was deducted from the AIDA/CFIP Program payment for all NISA-eligible AIDA/CFIP participants. NISA participants received the government payment and then had it deducted. AIDA/CFIP participants who were eligible but did not participate in NISA only had the deduction. Therefore, for the truncation, the AIDA/CFIP program is considered as the government program over 1998-2002, although we called the NISA as government program over 1991-2002.

under the the CAIS (2003-2006), spring wheat acreage increased as a result of insurance effect on average by 243,133.5, 708,997.4, 369,040.3 acres in Manitoba, Saskatchewan and Alberta respectively, while canola acreage decreased by 211,001, 615,296.5, 320,268. In this case, the different signs for insurance effect across equations can be interpreted as follows. The producer, who uses diversification to reduce his portfolio risk, is diversifying less as a result of government programs which stabilize producer's farm profit. After stabilizing farm profit through government programs, the producer decides to allocate more acres to spring wheat, which is a more agronomically suitable crop for dryland cultivation than canola, which was normally planted as an option to reduce the risk associated with the crop portfolio. In other words, the risk-reducing effect of government payments tend to offset the risk-reducing effect of diversification.

Table 5.5: Simulation of Acreage Changes due to WGSA, NISA and CAIS (in million acre)

	Spring wheat	**Barley**	**Peas**	**Canola**	**Hay**
MN (avg 1977-1990)					
Acreage planted	4.5783	1.6981	0.1313	1.1026	1.5213
WGSA wealth effect	0.0050	-0.0029	-0.0014	-	-
WGSA insurance effect	0.2386	-	0.0477	-0.2071	-0.0454
SK (avg 1977-1990)					
Acreage planted	15.9145	3.7099	0.1863	3.0017	1.9860
WGSA wealth effect	0.0077	-0.0044	-0.0021	-	-
WGSA insurance effect	0.5193	-	0.1038	-0.4507	-0.0989
AB (avg 1977-1990)					
Acreage planted	6.3688	5.6547	0.0568	2.8916	4.2195
WGSA wealth effect	0.0096	-0.0055	-0.0026	-	-
WGSA insurance effect	0.5472	-	0.1094	-0.4749	-0.1042
MN (avg 1991-2002)					
Acreage planted	3.9403	1.2287	0.1717	2.1020	2.0301
NISA wealth effect	0.0063	-0.0036	-0.0017	-	-
NISA insurance effect	0.3053	-	0.0610	-0.2649	-0.0581
SK (avg 1991-2002)					
Acreage planted	12.5998	4.2414	1.3924	5.1277	3.1667
NISA wealth effect	0.0031	-0.0018	-0.0008	-	-
NISA insurance effect	0.5128	-	0.1025	-0.4450	-0.0976
AB (avg 1991-2002)					
Acreage planted	6.1825	5.1982	0.4254	3.7011	5.4399
NISA wealth effect	0.0076	-0.0044	-0.0021	-	-
NISA insurance effect	0.5823	-	0.1164	-0.5053	-0.1109
MN (avg 2003-2006)					
Acreage planted	2.9636	0.9765	0.1239	2.5273	2.4222
CAIS wealth effect	0.0090	-0.0051	-0.0025	-	-
CAIS insurance effect	0.2431	-	0.0486	-0.2110	-0.0463
SK (avg 2003-2006)					
Acreage planted	9.5896	4.5537	2.5341	6.1042	4.9470
CAIS wealth effect	0.0350	-0.0200	-0.0096	-	-
CAIS insurance effect	0.7090	-	0.1418	-0.6153	-0.1350
AB (avg 2003-2006)					
Acreage planted	5.5285	4.7217	0.6190	3.9279	6.4013
CAIS wealth effect	0.0234	-0.0134	-0.0064	-	-
CAIS insurance effect	0.3690	-	0.0738	-0.3203	-0.0703

As the table 5.6 shows, WGSA has considerably increased the acreage allocated to spring wheat through both the wealth and insurance effects in the prairie provinces. The insurance effect, however, appears to dominate. Spring wheat acres expanded during 1977-1990, on average by 5.32 percent in Manitoba, 3.31 percent in Saskatchewan and 8.74 percent in Alberta. An expansion in acreage can also be seen in the case of peas due to both the wealth and the insurance effect. Based on the results, peas acreage has considerably increased by 36.33, 55.72 and 192.72 percent in Manitoba, Saskatchewan and Alberta, respectively due to the insurance effect[1], although it has slightly decreased by 1.04, 1.13, and 4.63 percent due to the wealth effect.

Table 5.6: Simulation Results of WGSA (Whole-Farm Program over 1977-1990)

	Spring Wheat	**Barley**	**Peas**	**Canola**	**Hay**
MN-WGSA Effect %					
Wealth Effect	0.11	-0.17	-1.04	-	-
Insurance Effect	5.21	-	36.33	-18.78	-2.99
Total Effect	5.32	-0.17	35.29	-18.78	-2.99
SK-WGSA Effect %					
Wealth Effect	0.05	-0.12	-1.13	-	-
Insurance Effect	3.26	-	55.72	-15.01	-4.98
Total Effect	3.31	-0.12	54.60	-15.01	-4.98
AB-WGSA Effect %					
Wealth Effect	0.15	-0.10	-4.63	-	-
Insurance Effect	8.59	-	192.72	-16.42	-2.47
Total Effect	8.74	-0.10	188.09	-16.42	-2.47

In contrast, in the period of WGSA implementation—1977-1990— the acreage planted to barley, canola and hay has decreased, the former through the wealth effect and the latter two through the insurance effect. The insurance effect of WGSA led to a considerable decline in canola acreage, on average by 18.78 percent in Manitoba, 15.01 percent in Saskatchewan and 16.42 percent in Alberta.

As table 5.7 shows, NISA has considerably increased the acreage allocated to spring wheat in the prairie provinces [2]. During 1991-2002, spring wheat acres increased on average by 7.91 percent in Manitoba, 4.09 percent in Saskatchewan and 9.54 percent in Alberta.

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[1] Note that peas acreage comprises only one percent of total acreage in the Prairie provinces which allowed for the large percentage increases. Theses large responses are not feasible for wheat given the total acreage constraint.

[2] In our methodology, we have assumed that the 70 percent of the previous three year average net income is guaranteed by the government under the NISA, while the payment mechanism shows that the maximum withdrawal from NISA account is equal to the minimum of the difference between actual income and guaranteed income and the total amount available in the NISA funds. Under this condition, it is clear that there might be some situations under which the money in the NISA funds was not enough to cover the guaranteed income. Due to the lack of the micro data, it has been assumed that there was always enough money in the funds. Therefore, the effects for NISA might be overestimated in this study and should be interpreted cautiously.

Although both the wealth and insurance effects have a statistically significant role in the acreage increase for spring wheat, the insurance effect is the major reason for the acreage response. Our results suggest that barley acres have decreased through the wealth effect as a result of NISA implementation. This effect, however, is small (0.29, 0.04 and 0.08 percent in Manitoba, Saskatchewan and Alberta, respectively). The decrease in acreage can also be seen in the case of canola, however, this reduction is due to the insurance effect. Based on the results, canola acreage has considerably decreased by 12.60, 8.68 and 13.65 percent in Manitoba, Saskatchewan and Alberta, respectively.

Table 5.7: Simulation Results of NISA (Whole-Farm Program over 1991-2002)

	Spring Wheat	**Barley**	**Peas**	**Canola**	**Hay**
MN-NISA Effect %					
Wealth Effect	0.16	-0.29	-1.00	-	-
Insurance Effect	7.75	-	35.55	-12.60	-2.86
Total Effect	7.91	-0.29	34.55	-12.60	-2.86
SK-NISA Effect %					
Wealth Effect	0.02	-0.04	-0.06	-	-
Insurance Effect	4.07	-	7.36	-8.68	-3.08
Total Effect	4.09	-0.04	7.30	-8.68	-3.08
AB-NISA Effect %					
Wealth Effect	0.12	-0.08	-0.49	-	-
Insurance Effect	9.42	-	27.37	-13.65	-2.04
Total Effect	9.54	-0.08	26.88	-13.65	-2.04

In the period of NISA implementation, peas acres have significantly increased through the insurance effect; on average by 35.55 percent in Manitoba, 7.36 percent in Saskatchewan and 27.37 percent in Alberta. The data on acres show that the acreage planted to peas increased in the prairies during the 1991-2002 period, and therefore the insurance effect of NISA could be a reason for this increase—in addition to factors such as its profitability. Note that acreage for peas during 1981-1990 period was on average 119,390, 114,203 and 103,96 acres in Manitoba, Saskatchewan and Alberta respectively. During the NISA implementation, these values increased to 171,697.3, 1,392,411.2, 425,396.7 (See table 5.5). A decrease in acreage due to the insurance effect can be seen in the case of hay. Based on the results, hay acreage has slightly decreased by 2.86, 3.08 and 2.04 percent in Manitoba, Saskatchewan and Alberta, respectively.

As the table 5.8 shows, the effect of CAIS on acreage decisions has a similar pattern to that of NISA, although its magnitude is different. As can be seen, CAIS has considerably increased the acreage allocated to spring wheat through both the wealth and insurance effects in the prairie provinces. Spring wheat acres expanded during 2003-2006, on average by 8.51 percent in Manitoba, 7.76 percent in Saskatchewan and 7.10 percent in Alberta. An expansion in acreage can also be seen in the case of peas. This increase in the acreage for peas is attributed to both the wealth and the insurance effects. Based on the results, the acreage planted with peas has considerably increased; by 37.24, 5.22 and 10.89 percent in Manitoba, Saskatchewan and Alberta, respectively.

Table 5.8: Simulation Results of CAIS (Whole-Farm Program over 2003-2006)

	Spring Wheat	Barley	Peas	Canola	Hay
MN-CAIS Effect %					
Wealth Effect	0.30	-0.53	-1.99	-	-
Insurance Effect	8.20	-	39.23	-8.35	-1.91
Total Effect	8.51	-0.53	37.24	-8.35	-1.91
SK-CAIS Effect %					
Wealth Effect	0.36	-0.44	-0.38	-	-
Insurance Effect	7.39	-	5.59	-10.08	-2.73
Total Effect	7.76	-0.44	5.22	-10.08	-2.73
AB-CAIS Effect %					
Wealth Effect	0.42	-0.28	-1.03	-	-
Insurance Effect	6.68	-	11.92	-8.15	-1.10
Total Effect	7.10	-0.28	10.89	-8.15	-1.10

In contrast, in the period of CAIS implementation—2003-2006—the acreage planted to barley through the wealth effect, canola and hay through the insurance effect have decreased. The insurance effect of CAIS led to a considerable decline in canola acreage, on average by 8.35 percent in Manitoba, 10.08 percent in Saskatchewan and 8.15 percent in Alberta. In general, CAIS has affected spring wheat acres in Manitoba and Saskatchewan more than the NISA and the WGSA, while NISA has increased acreage planted to spring wheat in Alberta more than the CAIS and the WGSA. CAIS has also affected barley acres in all three provinces more than two other programs. Peas, canola and hay acres have been primarily affected by the WGSA followed by the NISA and CAIS (except for peas and canola acres in Manitoba and Saskatchewan, respectively, for which CAIS has a larger effect than NISA).

Chapter 6

Concluding Comments

6.1 Summary and Conclusions

The shift of the farm subsidies toward programs classified as being non-actionable in the WTO's URAA raises the question of their true impact on production and trade—are they decoupled? The main objective of this dissertation is to investigate whether Canadian whole farm programs, which are considered non-actionable based on the WTO criterion, are actually decoupled. To accomplish this objective, a theoretical and empirical framework which consider the risk effects of these types of programs is developed.

The concept of decoupling and a brief history of government direct payments in the U.S., the EU and Canada are presented in chapter two. It first describes the ambiguity surrounding decoupling. The World Trade Organization (WTO) and the Organization for Economic Cooperation and Development (OECD) have provided two prominent operational definitions of decoupled payments. The WTO provides the ex ante definition and defines decoupled support policies as payments that are financed by taxpayers and are not related to current production, factor use, or prices, and for which eligibility criteria are defined by a fixed, historical base period. The OECD defines decoupling in terms of policy effects. A policy is fully decoupled if it does not influence production decisions of farmers receiving payments. The OECD discusses, however, the government payments can affect the production decisions through some indirect channels. Consequently, it is difficult to imagine a fully decoupled agricultural policy and the OECD introduces a degree of decoupling. Thus, programs that are considered decoupled by the WTO criteria could fail to be decoupled on the OECD criteria. In this dissertation, decoupled payments refer to programs that fit the WTO ex ante definition. The major channels through which decoupled payments could affect production are then presented. In general, decoupled payments may indirectly influence farmers' decisions. Therefore, the implementation of decoupled programs calls into question the appropriateness of the current definition of the Green-Box payments in the WTO.

Chapter three provides a review of the literature in two parts. The first part presents studies pertaining to modeling farmers' acreage decisions. The second part reviews the studies concerning measurement of the effects of decoupled payments on acreage decisions. In general, reviewing the literature pertaining to acreage response shows that future prices, or adaptive expectations, and the weighted three-year moving average of variances are the proxies most commonly used for the expected prices and expected variance-covariance of prices, respectively. Moreover, since single commodity studies fail to incorporate all alternative uses of land, the importance of considering risk in a multicrop framework and taking account of cross-commodity risk effects are emphasized.

The literature addresses six major channels through which decoupled payments could affect production. They ease credit constraints faced by farmers (when capital market are imperfect); they affect the labour allocation decisions of farm households (when labour market are imperfect); they alter land values, rents and land prices or influence the entry and exit decisions of farmers; they influence farmers decisions through expectations about future payments; and they may affect the risk faced by farmers. In the latter case, Hennessy (1998) developed a theoretical framework for the analysis of agricultural income support policies under uncertainty. He showed that for decoupled payments which tend to increase expected profit as well as reduce the variability of profit, decreasing absolute risk aversion is sufficient to ensure an increase in production. He introduced two effects of decoupled payments that would not arise in a certain world: the wealth effect and the insurance effect. The former means that the higher average income arising from the support policy may affect producer decisions. The latter refers to the income-stabilizing attribute that may affect optimizing decision. In general, the literature clearly shows that support policies that are decoupled in a deterministic world can affect the decisions of the risk averse producers when there is uncertainty. However, theoretical studies on the impact of decoupled payments on acreage response lack a detailed theoretical model of how acreage decisions will be affected by stabilizing the farm profit as well as the higher expected profit. In particular, since Canadian farm income stabilization and support policy has moved toward a whole farm approach that targets net income and uses a moving average mechanism to temporally smooth income, it possesses income-supporting and income-stabilizing attributes. The existing literature controls for the wealth effect through changes in average total income arising from government supports, however the insurance effect is captured only through an ad hoc measure. Given the nature of Canadian whole farm programs which attempt to stabilize producers' income, to examine empirically the whole farm programs, a model is needed to capture the insurance effect arising from these programs.

In chapter four, this gap in the literature is addressed by modelling the farmers' acreage decisions under uncertainty and deriving a measure inside the theoretical framework to capture the insurance effect of government policies as well as the wealth effect. Based on the theoretical discussions regarding the role of the insurance effect in acreage decisions, by considering the relationship between income stabilization compensated and uncompensated acreage decision functions, the expected utility maximization framework (under the hypothesis that farmers are risk averse) developed by Chavas and Holt (1990) is modified. This modification allows us to include an insurance effect in our theoretical model. In sum, the theoretical framework shows that acreage allocated to each crop can be specified as a function of the expected profits from each individual crop, elements of the profit variance-covariance matrix, as well as expected total wealth and its variance. These latter capture the wealth and insurance effects of support programs. Government payments are incorporated into the model through truncation of the probability distribution of profits. Specifically, the whole-farm programs truncate the total (farm) profit distribution, which affect the expected total wealth and variance of total wealth.

Regrading the expected sign of the variables in the acreage equation, using portfolio theory, it was analytically shown that the expected own-profit and its variance should have positive and negative impacts on acreage in each equation, respectively. The effect of expected cross-profits and other elements of the variance-covariance matrix on acreage decisions are not known *a priori*. Although it is expected that the expected total wealth (wealth effect) and its variance (insurance effect) have positive and negative impacts on acreage allocations with no constraint on total acreage, the sign of these variables are not clear *a priori* when the total acreage is assumed to be fixed.

In chapter five, the theoretical model devised in chapter four is applied to measure the effect of government programs on acreage decisions for major farm crops in the prairie provinces of Canada over the period 1970 to 2006. After estimation of several potential model specifications (each of the acreage level and share equations with the adaptive expectations and the futures price-trend yield), results from the acreage level model based on the futures price-trend yield are regarded as the base model due to their consistency with theoretical expectations, more statistically significant coefficients and lower mean square errors. We should note that the coefficients related to the wealth and insurance effects are statistically significant in all specifications in terms of adaptive expectations and share acreage equations. Within the empirical model, a system of nine crop equations, for spring wheat, durum wheat, oats, barley, rye, peas, flax, canola and hay, over 1982-2006 is provided and all the relevant elasticities of acreage allocation with respect to the exogenous variables are estimated. Based on the estimated results, the coefficients of expected total wealth and variance of total wealth were statistically significant in the whole system, which implies that the whole-farm programs are production and therefore trade distorting and are not actually decoupled even if they satisfy the WTO criteria.

The estimated statistically significant coefficients (for expected total wealth and variance of total wealth variables) were then used to simulate the impact of the WGSA, NISA and CAIS programs. The WGSA, NISA and CAIS programs have increased the acreage allocated to spring wheat and peas while they have decreased the acreage for barley, canola and hay in the prairie provinces. Under the WGSA during 1977-1990, acres allocated to spring wheat increased, mostly through the insurance effect, on average by 5.32, 3.31, and 8.74 percent in Manitoba, Saskatchewan, and Alberta, respectively. During 1991-2002, spring wheat acres increased on average by 7.91 percent in Manitoba, 4.09 percent in Saskatchewan and 9.54 percent in Alberta under the NISA. Under the CAIS, spring wheat acres expanded during 2003-2006 by 8.51 percent on average in Manitoba, 7.76 percent in Saskatchewan and 7.10 percent in Alberta. Under the WGSA program, acres planted to peas considerably increased, through the insurance effect, by 36.33, 55.72, and 192.72 percent in in Manitoba, Saskatchewan, and Alberta, respectively. In the NISA period, peas acres increased on average by 35.55 percent in Manitoba, 7.36 percent in Saskatchewan and 27.37 percent in Alberta. Based on the results, under CAIS the acreage associated with peas production increased by 39.23, 5.59 and 11.92 percent in Manitoba, Saskatchewan and Alberta, respectively. The results suggest that canola acreage considerably decreased—by 18.78 percent in Manitoba, 15.01 percent in Saskatchewan, and 16.42 percent in Alberta—under the WGSA implementation. Acres planted for canola decreased by 12.60, 8.68 and 13.65 percent in Manitoba, Saskatchewan and Alberta, respectively under the NISA, while the reductions are 8.35, 10.08 and 8.15 percent under the CAIS. In general, our estimates confirm that the size and the direction of the acreage effect of direct payments are strongly influenced by the insurance effect. Therefore, for the whole farm programs, the total impact of the effects related to risk is important.

6.2 Lessons Learned, Policy Implications and Caveats of the Study

This study has endeavoured to answer the following questions:

1. Have Canadian whole farm programs, which are considered as decoupled based on the ex ante WTO definition, actually been decoupled from production?
2. What impacts have government programs had on cropping patterns in the Canadian Prairies?

The theoretical model developed in this thesis and empirical evidence enable us to learn some important lessons related to decoupled payments in general, and Canadian agricultural programs in particular.

The theoretical model developed in this dissertation has shown that it is essential to capture the insurance effect of payments assumed to be decoupled as well as the wealth effect. In an expected utility maximization framework, when the relationship between income stabilization compensated and uncompensated acreage decision functions as well as average income compensated and uncompensated acreage decision functions is considered, the variability of farm profit as well as the average of farm profit will also play a role in acreage decisions by the farmer. This leads to the conclusion that policies that are assumed to be decoupled (which tend to reduce the variability of profit as well as to increase expected profit) are not, in fact, decoupled. The underlying reasons are wealth and insurance effects[1].

In this work, an effort has also been made to shed some light on the expected sign of variables in acreage equation. Using the portfolio theory, it was analytically shown that we can have an expectation only for the sign of the expected own-profit and its variance, the former has positive impact and the latter has negative impact on acreage in each equation. The effect of other variables on acreage decisions are not known *a priori*.

The empirical model estimated in this dissertation has shown that the size and the direction of the acreage effect arising from the Canadian whole-farm programs are strongly

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[1] Note that when contingent markets are easy and cheap to use and sufficiently rich, then separability in the manner of Holthausen (1979) will omit insurance and wealth effects.

influenced by the insurance effect which supports the evidence available in the literature; for example in Hennessy (1998) and Sckokai and Moro (2006). As our results are derived from a more general representation of the acreage decisions, the parameters are estimated based on panel data observations and their statistical significance is quite satisfactory (particularly for the insurance effect), this general result seems quite robust. In general, the size of the wealth effect is quite small, while the insurance effect is always significant. Thus, the empirical results reveal that for the Canadian whole-farm programs the impact of the effects related to risk is important. Particularly, the results show the inherent difficulty in divorcing the stabilization effect received by Canadian whole-farm programs from farmers' production decisions.

Another important lesson relates to the impact of cross-crop effects. Our results show that cross effects can be important not just for market effects, but also for expected wealth and wealth variability. For example, since the risk-averse producer uses diversification to reduce his portfolio risk, she/he is diversifying less as a result of government programs which stabilize producer's farm profit. In fact, after stabilizing producer's farm profit by government programs, the producer decides to allocate more acres to wheat—agronomically the crop most suited to dryland farming in the Canadian Prairies—at the expense of canola which was planted as means to reduce the risk associated with a farmer's portfolio of crops. The conclusion is that the government programs have affected the cropping patterns in the Prairie provinces.

In addition, the results may have an important lesson for the WTO negotiations regarding the current definition of the Green Box payments. The current Green Box provisions have no doubt promoted the agricultural reform process. These measures have been of great assistance to highly-subsidizing countries in shifting from mechanisms that support prices to mechanisms that are expected to be more transparent and less trade-distorting. By providing relatively comprehensive theoretical and empirical frameworks, the results of this dissertation, however, indicate that the supposedly decoupled payments (as a part of Green Box subsidies) could have significant impact on acreage decisions through wealth and insurance effects and, consequently they may distort production and trade. It is clear that further research, using the same theoretical and empirical frameworks, needs to be done on the effect of decoupled payments and other elements of the Green Box subsidies (safety net programs, structural adjustment assistance, regional assistance and environmental aids) on production and investment across different countries. Nevertheless, the results of this dissertation can be considered as a hint that as a result of risk effects of government programs, programs that qualify as non-actionable cannot ensure that there are no or at most minimal distorting effects on production and trade.

Indeed, the major WTO Members have shifted their domestic support from restricted Amber Box to non-restricted Green Box measures, so as to avoid further reduction of their agricultural support. Trade, however, is likely to remain considerably distorted. If further studies also confirm the results of this thesis regarding the risk effect of the Green Box subsidies including the decoupled payments, there is a need to reevaluate the eligibility criteria of the current definition of the Green Box subsidies. Current eligibility criteria do not take into account the farmer's response under uncertainty and are typically based on the market effects of policies. When defining the domestic policy measures that are exempted from the reduction commitments, the risk components of different measures should be taken into account since the size of the risk effects, especially the insurance effect, is relevant.

Obviously, as the analysis indicates, there is no fully decoupled agricultural support measure in theory or in practice. However, the WTO Members can present their proposals about the criteria and mechanism of the Green Box payments including decoupled programs based on their experience and then choose the one with greatest degree of decoupling. This could limit the supports to payments based on the new criteria, or at least limit the Green Box payments to a specific percentage of the value of total agricultural production.

The empirical model employed to study the acreage effect of government programs has a number of caveats. Assuming that aggregate behavior can be represented by a representative farm household making decisions, the acreage function is specified to use aggregate data. Due to the unavailability of data, this study used provincial level data in measuring farmers' acreage decisions. If panel data at the farm level including production costs data were available, it would possibly estimate acreage effect of government programs more accurately, because actual decisions are made at the farm level. The analysis could also be expanded to include a richer set of risk responses than acreage adjustments alone. For example, input use and output supply response under risk may be incorporated with acreage response.

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Appendices

Appendix A

The Expected Utility Theory

Here, decision making under uncertainty in a general case is presented as a background and starting point. This section outlines the main concepts in the literature pertaining to risk and uncertainty to inform the analysis in the remainder of chapter four. Expected utility theory and risk aversion are the two main concepts that are discussed. The expected utility hypothesis states that the individual assigns a utility value to each mutually exclusive activity with an associated probability distribution that is an outcome of a decision. Therefore, maximizing the expected utility of consequences is equivalent to the problem of selecting the action that induces the most preferred probability distribution. Risk aversion is a fundamental feature of the problem of choice under uncertainty and the expected utility model allows us to capture it by assuming concavity of the utility function.

Consider a representative firm that wants to make future investment plans. Let A represent the set of all possible actions available to the firm, and let S represent the set of all possible states of nature. The specific action chosen by the firm and the particular state of nature that is realized determine the outcomes that the firm cares about. In other words, consequences are random variables as given by the function $c : S \times A \rightarrow C$, where C is the set of all possible consequences. For example, C could be the set of all possible commodity bundles as in standard consumer theory, in which case $C = \mathrm{R}^n_+$. Alternatively, if it is monetary outcomes that are of interest to the decision makers, then one can put $C = \mathrm{R}$. Suppose for simplicity that the set C is finite, and that there are N possible consequences. Given an objectively known probability for each state of nature, then choosing a particular action will result in a probability distribution (a lottery) over outcomes. Formally, one can define a lottery as a probability list $L \equiv (p_1, p_2, ..., p_N)$ such that p_i is the probability that outcome $c_i \in C$ will arise. If an outcome is certainly going to happen, then the probability is one, and when an outcome cannot happen at all, the probability is zero ($p_i \in [0, 1]$ and $\sum_i p_i = 1$).

In this setting, primitive preferences are represented by a preference relation $\succeq$ (preferred to or indifferent to) defined over the set of all possible lotteries L . Assuming that this relation is rational (complete and transitive) and satisfies a specific continuity assumption, then all lotteries can be ranked by a function $V : L \rightarrow \mathrm{R}$ in the sense that, for any two lotteries L

and L', we have $L \succeq L' \Leftrightarrow V(L) \geq V(L')$. As the underlying assumption is that the decision maker is concerned only with the ultimate consequences, in this setting compound lotteries are always equivalent to the corresponding reduced lottery. Thus, a gamble that gives lottery L with probability α and lottery L' with probability $(1-\alpha)$ is equivalent to a simple lottery whose probabilities are given by the mixture $\alpha L + (1-\alpha)L'$.

To get the expected utility model, a further assumption is required, namely the independence axiom (Samuelson, 1952). This condition requires that, if we consider the mixture of each of any two lotteries L and L' with another lottery L'', the preference ordering on the two resulting lotteries is independent of the particular common lottery L''. That is, for any L, L' and L'', and any $\alpha \in (0,1)$, $L \succeq L' \Leftrightarrow \alpha L + (1-\alpha)L'' \succeq \alpha L' + (1-\alpha)L''$. In other words, what does not happen or is impossible has no effect on the level of preferences between two possible states of nature. One may note that an equivalent assumption in the standard choice problem of consumer theory would be very restrictive (there is no reason to assume that a consumer's preferences over various bundles of goods one and two should be independent of the quantities of the other goods she/he will consume), which is why it is seldom made in that context. However, the independence assumption is quite natural because of a fundamental feature of decision problems under uncertainty i.e. consequences are mutually exclusive[1].

The independence axiom, coupled with the other standard rational choice assumptions, has the remarkable implication that there exists a utility function defined over consequences, $U : C \rightarrow \mathrm{R}$, such that $L \succeq L' \Leftrightarrow \sum_{i=1}^{N} p_i U(c_i) \geq \sum_{i=1}^{N} p'_i U(c_i)$ where again, p_i is the probability that consequence c_i will attain under L and p'_i is the probability that consequence c_i will attain under L'. In other words, with the independence axiom, the utility function over lotteries can always be represented as the mathematical expectation of a utility function defined over consequences, that is $V(L) = E[U(c)]$ where $E[.]$ is the mathematical expectation operator[2]. Note that, the utility function $V(L)$ is linear in probabilities. The function $U(c)$ is usually called the von Neumann-Morgenstern (v.N-M) utility function. This v.N-M utility function $U(c)$ is monotonically increasing and is cardinal in a way that it is defined up to an increasing linear transformation (that is, if $U(c)$ represents the preference relation $\succeq$, then any, $\widehat{U}(c) \sim \alpha + gU(c)$ with $g > 0$, provides an equivalent representation of this relation). When

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[1] Despite its theoretical appeal, the empirical validity of the independence axiom has been questioned. Some examples are the Allais Paradox (Allais, 1953) and Machina's Paradox (Machina, 1987). These paradoxes limit expected utility as a model of preferences. They may look analogous to the Giffen Paradox in the aggregate investigation of markets, but expected utility is still pervasive in economics.

[2] The strength of the expected utility representation is that it preserves the very useful expectation form while making the utility of monetary lotteries sensitive not only to the mean but also to the higher moments of the distribution of the monetary payoffs.

the consequences of interest are defined by continuous random variables with joint cumulative distribution function $F(c)$, the expected utility theorem implies that $V(F) = \int U(c)dF(c)$. In conclusion, in the expected utility model the problem of selecting the action that induces the most preferred probability distribution reduces to that of maximizing the expected utility of consequences.

Risk Aversion

In many economic settings (including decision making under uncertainty), individuals seem to display aversion to risk. The expected utility model allows us to capture the notion of risk aversion, which is a fundamental feature of the problem of choice under uncertainty. This notion is made precise when the consequences that matter to the decision maker are monetary consequences, such that the v.N-M utility function is defined over wealth, $U(W)$ where $W \in \mathrm{R}$ is realized wealth. The choice problem under uncertainty can be thought of as a choice among distributions (lotteries), with risk-averse firms preferring distributions that are less risky. Specifically, a decision maker is said to be risk averse if, for every lottery $F(W)$, he/she will always prefer (at least weakly) the certain amount $E[W]$ to the lottery $F(W)$ itself, i.e., $U[\int WdF(W)] \geq \int U(W)dF(W)$ (Arrow, 1965; Pratt, 1964). By Jensen's inequality, however, this condition is equivalent to $U(W)$ being concave. Thus, concavity of the v.N-M utility function provides the fundamental feature of risk aversion.

Given the representation of risk aversion in terms of the concavity of $U(.)$, one can then say that firm 2 is unambiguously more risk averse than firm 1 if there exists an increasing concave function $\psi(.)$ such that $U_2(W) = \psi(U_1(W))$, where U_i denotes the utility function of firm i, $i = 1, 2$ (in other words, if $U_2(.)$ is more concave than $U_1(.)$). For measuring changes in the degree of risk aversion of a given firm with the level of wealth, two standard measures of risk aversion are used: the Arrow-Pratt coefficient of absolute risk aversion $A(W)$ and the Arrow-Pratt coefficient of relative risk aversion $R(W)$ (Arrow, 1965; Pratt, 1964). As concavity of $U(W)$ is equivalent to risk aversion, the degree of concavity of $U(W)$, as captured by $U''(W)$, is used to measure the degree of risk aversion. Given that $U(W)$ is defined only up to an increasing linear transformation, we need to normalize by $U'(W) > 0$ to obtain a measure that is unique for a given preference ordering. Thus, the coefficient of absolute risk aversion is defined as $A(W) \equiv -U''(W)/U'(W)$. Absolute risk aversion is useful for comparing the attitude of a firm towards a given gamble at different levels of wealth. It seems natural to assume that firms will become less averse to a given gamble as their wealth increases i.e., $A(W)$ is a decreasing function of W which is called decreasing absolute risk aversion (DARA).

However, sometimes it is interesting to inquire about the attitude of risk-averse decision makers towards gambles that are expressed as a fraction of their wealth. This type of risk preference is captured by the coefficient of relative risk aversion $R(W) \equiv WA(W)$. Unlike the case of absolute risk aversion, there are no a priori reasons for any particular behavior of $R(W)$ with respect to W. Sometimes non-increasing relative risk aversion (NIRRA) is assumed, implying that a firm should not become more averse to a gamble expressed as a fixed percentage of its wealth as the level of wealth increases. Utility functions for which $A(W)$ and $R(W)$ are constant are also interesting in applied analysis. The constant absolute risk aversion (CARA) utility function is given by $U(W) = -e^{-\alpha W}$, where α is the (constant) coefficient of absolute risk aversion. The constant relative risk aversion (CRRA) utility function is given by $U(W) = (W^{1-g})/(1-g)$ if $g \neq 1$, and by $U(W) = log(W)$ if $g = 1$, where g is the (constant) coefficient of relative risk aversion.

Appendix B

The Expected Sign for Own Return and Variance in the Two-Crop Case

Consider a risk-averse farmer with two crops, crop 1 and crop 2, from equation (4.20) or the first-order conditions we can write,

$$\bar{U}_W\bar{\pi}_1 + \bar{U}_{WW}\big(A_1\sigma_1 + A_2Cov(\pi_2,\pi_1)\big) + \mu f_{A_1} = 0 \tag{B-1}$$

and

$$\bar{U}_W\bar{\pi}_2 + \bar{U}_{WW}\big(A_2\sigma_2 + A_1Cov(\pi_1,\pi_2)\big) + \mu f_{A_2} = 0 \tag{B-2}$$

For the case of two crops, from equation (4.15) or acreage constraints, there is another first-order condition for optimization in (4.17) as $\frac{\partial L}{\partial \mu} = f(\mathbf{A}) = 0$. By totally differentiating, we have,

$$f_{A_1}dA_1 + f_{A_2}dA_2 = 0 \tag{B-3}$$

then, by substituting $f_{A_2} = -f_{A_1}dA_1/dA_2$ into (B-2) one has,

$$\bar{U}_W\bar{\pi}_2 + \bar{U}_{WW}\big(A_2\sigma_2 + A_1Cov(\pi_1,\pi_2)\big) - \mu f_{A_1}dA_1/dA_2 = 0 \tag{B-4}$$

which gives $f_{A_1} = dA_2/dA_1\big(\bar{U}_W\bar{\pi}_2 + \bar{U}_{WW}(A_2\sigma_2 + A_1Cov(\pi_1,\pi_2))\big)/\mu$ and by substituting it into (B-1) we have

$$\bar{U}_W\bar{\pi}_1 + \bar{U}_{WW}(A_1\sigma_1 + A_2Cov(\pi_2,\pi_1)) + dA_2/dA_1\big(\bar{U}_W\bar{\pi}_2 + \bar{U}_{WW}(A_2\sigma_2 + A_1Cov(\pi_1,\pi_2))\big) = 0 \tag{B-5}$$

then,

$$\frac{dA_2}{dA_1} = -\frac{\bar{\pi}_1 + \frac{\bar{U}_{WW}}{\bar{U}_W}\big(A_1\sigma_1 + A_2Cov(\pi_2,\pi_1)\big)}{\bar{\pi}_2 + \frac{\bar{U}_{WW}}{\bar{U}_W}\big(A_2\sigma_2 + A_1Cov(\pi_1,\pi_2)\big)} \tag{B-6}$$

$$\begin{aligned}\frac{d^2A_2}{dA_1^2} &= \frac{\big[-\frac{\bar{U}_{WW}}{\bar{U}_W}(\sigma_1+\frac{dA_2}{dA_1}Cov(\pi_2,\pi_1))\big]\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]}{\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]^2}+\\ &\frac{\big[\frac{\bar{U}_{WW}}{\bar{U}_W}(\frac{dA_2}{dA_1}\sigma_2+Cov(\pi_1,\pi_2))\big]\big[\bar{\pi}_1+\frac{\bar{U}_{WW}}{\bar{U}_W}\big(A_1\sigma_1+A_2Cov(\pi_2,\pi_1)\big)\big]}{\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]^2}=\\ &\frac{-\frac{\bar{U}_{WW}}{\bar{U}_W}\sigma_1\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]+2\frac{\bar{U}_{WW}}{\bar{U}_W}Cov(\pi_1,\pi_2)}{\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]^2}\\ &\frac{\big[\bar{\pi}_1+\frac{\bar{U}_{WW}}{U_W}\big(A_1\sigma_1+A_2Cov(\pi_2,\pi_1)\big)\big]-\frac{\bar{U}_{WW}}{\bar{U}_W}\sigma_2\frac{\big[\bar{\pi}_1+\frac{\bar{U}_{WW}}{U_W}\big(A_1\sigma_1+A_2Cov(\pi_2,\pi_1)\big)\big]^2}{\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]}}{\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]^2}\end{aligned} \tag{B-7}$$

then,

$$\begin{aligned}\frac{d^2A_2}{dA_1^2} =&\frac{-\frac{\bar{U}_{WW}}{\bar{U}_W}}{\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]^3}\cdot\\ &\Bigg(\sigma_1\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]^2+\sigma_2\big[\bar{\pi}_1+\frac{\bar{U}_{WW}}{U_W}\big(A_1\sigma_1+A_2Cov(\pi_2,\pi_1)\big)\big]^2\\ &-2Cov(\pi_1,\pi_2)\big[\bar{\pi}_1+\frac{\bar{U}_{WW}}{U_W}\big(A_1\sigma_1+A_2Cov(\pi_2,\pi_1)\big)\big]\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]\Bigg)\end{aligned} \tag{B-8}$$

$$\begin{aligned}\frac{d^2A_2}{dA_1^2} =&\frac{-\frac{\bar{U}_{WW}}{\bar{U}_W}}{\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]^3}\cdot\\ &\Bigg(\sigma_1^{.5}\big[\bar{\pi}_2+\frac{\bar{U}_{WW}}{U_W}\big(A_2\sigma_2+A_1Cov(\pi_1,\pi_2)\big)\big]-\sigma_2^{.5}\big[\bar{\pi}_1+\frac{\bar{U}_{WW}}{U_W}\big(A_1\sigma_1+A_2Cov(\pi_2,\pi_1)\big)\big]\Bigg)^2\end{aligned} \tag{B-9}$$

The second-order condition for the expected utility to be maximized requires that the acreage possibility frontier, $f(\mathbf{A})$, to be concave ($f_{AA} < 0$). Therefore, for having a general solution, the isoutility curve (combination of two acreage crops that maximise expected utility of profit) in $A_2 - A_1$ space must be convex which requires that $\frac{d^2A_2}{dA_1^2} > 0$. Since for a risk-averse farmer $\frac{\bar{U}_{WW}}{\bar{U}_W} < 0$, positivity of $\frac{d^2A_2}{dA_1^2}$ requires that denominator, $\bar{\pi}_2 + \frac{\bar{U}_{WW}}{\bar{U}_W}(A_2\sigma_2 + A_1Cov(\pi_1, \pi_2))$, in (B-9) or in (B-6) to be positive which implies to $\frac{dA_2}{dA_1} < 0$[1] and therefore

---

[1] Because of symmetry the positivity of $\bar{\pi}_2 + \frac{\bar{U}_{WW}}{\bar{U}_W}(A_2\sigma_2 + A_1Cov(\pi_1, \pi_2))$ implies to the positivity of $\bar{\pi}_1 + \frac{\bar{U}_{WW}}{\bar{U}_W}(A_1\sigma_1 + A_2Cov(\pi_2, \pi_1))$ and therefore numerator and denominator in (B-6) are positive, i.e. $\frac{dA_2}{dA_1} < 0$.

isoutility curves in $A_2 - A_1$ space are decreasing and convex.

Considering equation (B-6), when own crop expected profit (variance) increases, the slope of isoutility curve increases (decreases) in each point and therefore A_1 increase (decreases) and A_2 decreases (increases). When competing or substitute crop 2's expected profit increases ($\bar{\pi}_2$), the slope of isoutility curve decreases in each point and therefore, A_1 decreases and A_2 increases. When profit variability for substitute crop 2 increases, the slope of isoutility curve increases in each point and, therefore, A_1 increases and A_2 decreases.

Appendix C

Descriptive Statistics

Table C.1: 1979-2006 Descriptive Statistics

	Mean			**Std. Dev.**		
	MN	**SK**	**AB**	**MN**	**SK**	**AB**
swh acre	3891413	13600000	6068779	769779	3043714	617859
dwh acre	181572	4011186	742761	107616	913717	222995
oats acre	724486	1615364	1567506	199070	490948	210666
barley acre	1438710	3981066	5345905	386015	669760	567444
rye acre	118172	340671	198585	65133	150597	70805
peas acre	140689	1013013	286750	46348	1002321	254686
flax acre	666228	890505	79987	235666	408888	47532
canola acre	1699940	4185984	3282571	705446	1703722	856371
hay acre	1828038	2885723	4937379	405295	1105993	1053451
tonne/acre						
swh yield	0.908	0.763	0.958	0.172	0.138	0.161
dwh yield	0.864	0.754	0.872	0.171	0.171	0.210
oats yield	0.954	0.837	1.002	0.197	0.142	0.109
barley yield	1.172	0.998	1.189	0.199	0.156	0.156
rye yield	0.841	0.691	0.834	0.155	0.152	0.155
peas yield	0.818	0.736	0.964	0.173	0.160	0.156
flax yield	0.477	0.452	0.545	0.094	0.077	0.081
canola yield	0.570	0.510	0.564	0.112	0.076	0.104
hay yield	1.525	1.113	1.476	0.340	0.296	0.383
$/tonne						
swh price	147.393	150.772	146.606	29.401	30.956	30.165
dwh price	163.572	172.513	172.209	37.321	38.809	38.732
oats price	112.553	108.564	109.582	27.365	27.150	30.867
barley price	106.080	113.884	107.425	23.279	22.508	23.186
rye price	105.299	101.192	102.624	33.373	31.430	28.474
peas price	187.732	177.711	183.660	29.985	26.596	33.810
flax price	279.772	280.362	281.101	67.323	68.494	62.372
canola price	299.117	299.391	300.944	54.258	53.713	51.728
hay price	58.268	71.962	73.863	9.935	15.390	15.785
swh exp. price	134.666	137.249	133.161	29.524	28.127	26.207
dwh exp. Price	149.410	157.688	157.399	39.217	41.459	41.364
oats exp. Price	117.494	112.968	113.810	31.206	28.000	27.977
barley exp. Price	111.365	119.425	113.910	24.091	22.550	30.530
rye exp. Price	112.593	109.105	110.639	37.699	37.340	33.897
peas exp. Price	207.536	196.295	203.169	52.087	47.966	55.175
flax exp. Price	304.350	303.622	304.123	65.664	60.981	51.877
canola exp. Price	334.744	335.034	337.554	43.835	42.890	46.425
hay exp. Price	62.881	77.059	79.153	19.503	22.064	22.433
$/acre						
swh cost	57.202	49.669	62.903	6.925	12.809	13.723
dwh cost	66.426	51.240	36.963	8.632	17.026	8.181
oats cost	50.624	49.507	51.450	4.777	14.951	11.393
barley cost	53.694	55.783	62.475	5.137	24.662	13.876
rye cost	53.969	47.791	45.195	4.789	9.759	10.631
peas cost	66.745	60.543	76.113	6.479	15.511	15.585
flax cost	47.703	46.838	66.466	6.471	16.517	13.986
canola cost	75.947	61.263	77.107	23.752	21.095	16.808
hay cost	60.866	54.025	29.474	5.341	6.028	7.010
$						
initial wealth	4850000000	11100000000	13200000000	1120000000	1950000000	4200000000

Appendix D

Parameters used for Simulation

Table D.1: Parameters used for Simulation of the WGSA Effect

	Without Program (Untruncated)		With Program (Truncated)	
	exp. tot. w.	**var tot. w.**	**exp. tot. w.**	**var tot. w.**
MN				
1984	900738895.6	8.24457E+16	906586728.3	7.56028E+16
1985	886811400.9	1.14728E+16	886813524.9	1.1471E+16
1986	640983403.7	8.48395E+15	644286492.5	7.37207E+15
1987	302838033.4	9.23049E+16	516723403.3	1.55106E+16
1988	603287689.7	7.92075E+16	646650994.4	4.90425E+16
1989	795223808.4	4.55789E+17	910597417.5	2.70165E+17
1990	681820641.2	4.49733E+17	830426795.4	2.3453E+17
SK				
1984	2450827698	1.53725E+17	2467566550	1.30621E+17
1985	2327371709	6.69814E+17	2467541337	3.96644E+17
1986	1997395224	7.71041E+17	2147584379	4.56855E+17
1987	1106076268	1.91624E+17	1480511094	2.26037E+16
1988	1711507640	1.17078E+17	1727862753	9.78695E+16
1989	2306533807	1.42423E+18	2392312239	1.10614E+18
1990	2011823857	1.76729E+18	2227896738	1.07042E+18
AB				
1984	1925082365	1.02737E+17	1927415566	9.91571E+16
1985	2016479405	2.61642E+17	2030081142	2.34649E+17
1986	1497560737	2.14438E+18	1843166660	1.07909E+18
1987	849346971.1	6.13754E+17	1200610429	1.86409E+17
1988	1176240700	2.45917E+17	1268773846	1.40027E+17
1989	1824504808	6.34748E+17	1884667310	4.87731E+17
1990	1805108865	1.40338E+18	1991437701	8.61676E+17

Table D.2: Parameters used for Simulation of the NISA Effect

	Without Program (Untruncated)		With Program (Truncated)	
	exp. tot. w.	**var tot. w.**	**exp. tot. w.**	**var tot. w.**
MN				
1991	741519305.1	5.31182E+17	940768159.8	2.43978E+17
1992	771410293.2	2.74185E+17	895500297.3	1.37644E+17
1993	813526975.3	2.60064E+17	918809310.1	1.40844E+17
1994	823931212.5	2.63123E+17	889913642.1	1.74277E+17
1995	980639380.4	3.04908E+17	1064041599	1.90295E+17
1996	1425503051	1.13558E+17	1427013340	1.10962E+17
1997	1130267944	7.60226E+16	1166527152	4.9966E+16
1998	1008048940	1.88175E+17	1104711277	9.78299E+16
1999	674749689.7	1.08237E+17	867612697.2	2.38895E+16
2000	724780396.7	1.6287E+17	815815221.1	8.40999E+16
2001	599593273.9	6.17659E+16	679656568.3	2.52351E+16
2002	759426752.6	2.793E+16	762445273.7	2.58305E+16
SK				
1991	2208020801	1.81198E+18	2440486484	1.06907E+18
1992	2171680741	1.2725E+18	2446787314	6.28069E+17
1993	2167936409	4.90186E+17	2236252576	3.53559E+17
1994	2502182206	4.87152E+17	2525775613	4.2623E+17
1995	2995732579	2.37246E+17	2996882447	2.34167E+17
1996	4300902887	5.63412E+17	4302068183	5.58386E+17
1997	3686124343	6.91479E+17	3736442371	5.55666E+17
1998	3192252267	3.16269E+18	3572633741	1.68124E+18
1999	2485352690	9.74568E+17	2703894942	5.085E+17
2000	2499969517	3.50522E+17	2524293139	2.99397E+17
2001	2164067181	8.63996E+16	2181381612	6.9771E+16
2002	2160371898	5.11164E+17	2220832000	3.82581E+17
AB				
1991	1771121907	2.34612E+18	2196229291	1.06682E+18
1992	1751442586	2.52285E+18	2126738128	1.26869E+18
1993	1704314391	1.03256E+18	1840845340	6.73491E+17
1994	1750689776	6.63659E+17	1866518147	4.23972E+17
1995	1943826114	3.00897E+17	1980443601	2.37283E+17
1996	2938445770	7.86216E+17	2987742233	6.41389E+17
1997	2442267772	2.35346E+18	2776303622	1.23912E+18
1998	2461164477	1.1368E+18	2611223812	7.2901E+17
1999	2153600839	4.759E+17	2201058193	3.7301E+17
2000	2076976804	5.95834E+16	2077313142	5.9106E+16
2001	1804542362	8.69642E+16	1813794771	7.6716E+16
2002	2258146082	9.46287E+16	2258183259	9.45474E+16

Table D.3: Parameters used for Simulation of the CAIS Effect

	Without Program (Untruncated)		With Program (Truncated)	
	exp. tot. w.	**var tot. w.**	**exp. tot. w.**	**var tot. w.**
MN				
2003	805583935.4	4.96862E+16	868945383.3	2.3305E+16
2004	1045004161	4.89117E+16	1055070316	4.14797E+16
2005	695705724.4	1.0157E+17	870766146.4	3.32329E+16
2006	968443139.1	3.42138E+17	1084750406	2.25372E+17
SK				
2003	2169324714	1.78273E+18	2464470913	1.04098E+18
2004	2317663861	1.54337E+18	2572602566	1.00949E+18
2005	1014741009	4.03575E+17	1708525774	1.78104E+17
2006	2033085133	3.27909E+17	2205996059	1.53994E+17
AB				
2003	2164334019	5.06479E+17	2222388056	3.62756E+17
2004	3146658844	2.49629E+17	3151843809	2.51028E+17
2005	1483725809	2.68791E+17	1859095904	4.98831E+16
2006	1479905355	2.25145E+17	1988876533	2.63592E+16

Appendix E

Some Model Results

Table E.1: Acreage Level Model Results based on the Adaptive Expectations

	ep swh	**ep dwh**	**ep oats**	**ep barley**	**ep rye**	**ep peas**	**ep flax**	**ep canola**	**ep hay**	**varp swh**	**varp dwh**
swh acre											
Coeff.	21945.55	-7703.34	472.42	4486.38	-1279.73	3408.35	2126.04	-6880.64	-3101.28	-349.01	-63.78
St. Err.	5346.40	2715.04	1211.01	1935.66	679.32	1060.46	1032.38	1945.64	1327.67	154.14	84.96
dwh acre											
Coeff.	-7703.34	-88.08	1255.06	-288.58	-274.10	271.35	-826.71	474.12	-1489.55	63.83	34.15
St. Err.	2715.04	2398.83	831.88	1309.30	470.46	791.45	705.01	1228.70	951.07	85.66	52.08
oats acre											
Coeff.	472.42	1255.06	3585.04	-1734.07	206.20	-490.17	-1829.19	-1105.66	111.61	63.30	-39.45
St. Err.	1211.01	831.88	1139.32	1275.12	559.44	539.55	591.94	582.20	742.41	32.07	18.58
barley acre											
Coeff.	4486.38	-288.58	-1734.07	3893.91	821.81	-1007.04	-1559.80	-5623.67	782.22	83.59	16.38
St. Err.	1935.66	1309.30	1275.12	2227.43	740.43	787.10	819.63	883.92	1070.43	54.66	30.53
rye acre											
Coeff.	-1279.73	-274.10	206.20	821.81	699.79	172.89	-731.45	318.92	261.99	6.67	-6.35
St. Err.	679.32	470.46	559.44	740.43	546.16	340.31	374.96	322.30	431.96	17.79	10.24
peas acre											
Coeff.	3408.35	271.35	-490.17	-1007.04	172.89	-152.27	-750.01	-1117.07	-1071.82	-14.31	-0.15
St. Err.	1060.46	791.45	539.55	787.10	340.31	627.04	426.08	589.97	630.38	37.20	21.28
flax acre											
Coeff.	2126.04	-826.71	-1829.19	-1559.80	-731.45	-750.01	1518.83	936.10	548.07	24.57	7.49
St. Err.	1032.38	705.01	591.94	819.63	374.96	426.08	608.56	544.96	562.56	32.92	18.55
canola acre											
Coeff.	-6880.64	474.12	-1105.66	-5623.67	318.92	-1117.07	936.10	9586.08	-2422.14	-23.31	127.74
St. Err.	1945.64	1228.70	582.20	883.92	322.30	589.97	544.96	1237.61	635.23	78.21	43.42
hay acre											
Coeff.	-3101.28	-1489.55	111.61	782.22	261.99	-1071.82	548.07	-2422.14	3229.11	-23.61	42.33
St. Err.	1327.67	951.07	742.41	1070.43	431.96	630.38	562.56	635.23	1126.06	37.21	21.42

Table E.1: Continued

	varp oats	**varp barley**	**varp rye**	**varp peas**	**varp flax**	**varp canola**	**varp hay**	**exp. tot. w.**	**var. tot. w**	**acrelag**
swh acre										
Coeff.	-1375.12	786.29	-370.18	-29.55	-6.86	18.55	266.05	0.000085	-0.000397	0.27
St. Err.	304.27	208.46	228.72	49.69	113.07	72.10	170.43	0.000044	0.000442	0.08
dwh acre										
Coeff.	189.58	-71.67	63.40	34.81	-11.96	-15.02	-94.47	0.000031	0.000615	0.19
St. Err.	166.75	113.22	124.89	27.48	64.01	39.55	93.15	0.000025	0.000248	0.09
oats acre										
Coeff.	36.79	-61.36	80.62	-6.79	31.45	11.07	-74.82	-0.000012	0.000112	0.59
St. Err.	60.45	43.29	46.40	9.90	22.99	14.69	33.31	0.000009	0.000090	0.06
barley acre										
Coeff.	70.05	-57.26	-18.75	-0.49	30.24	65.63	-64.77	-0.000024	0.000194	0.46
St. Err.	98.71	73.72	78.14	16.75	40.91	24.90	56.36	0.000015	0.000155	0.07
rye acre										
Coeff.	-37.32	7.46	12.55	-1.00	16.26	-0.94	30.10	0.000007	0.000011	0.40
St. Err.	32.89	23.61	27.06	5.65	13.23	8.35	19.22	0.000005	0.000049	0.13
peas acre										
Coeff.	-14.77	7.86	-25.38	4.49	18.24	-2.00	-20.41	-0.000026	0.000047	0.47
St. Err.	71.75	49.11	54.62	12.16	27.45	17.66	41.11	0.000011	0.000109	0.08
flax acre										
Coeff.	53.27	-27.59	62.61	-4.57	-37.07	-10.80	-14.51	-0.000027	0.000010	0.58
St. Err.	61.22	42.54	47.33	10.37	24.23	15.24	34.98	0.000009	0.000094	0.07
canola acre										
Coeff.	386.45	-141.65	176.23	-14.73	-145.67	-111.11	56.84	-0.000068	0.000003	0.47
St. Err.	152.92	99.92	115.22	25.41	57.62	37.46	86.02	0.000022	0.000229	0.05
hay acre										
Coeff.	-87.71	6.97	-81.68	9.85	21.32	5.66	-130.94	-0.000017	-0.000434	0.51
St. Err.	73.84	49.30	53.70	11.48	27.27	16.99	39.18	0.000011	0.000116	0.13

Notes: Coef.=Coefficient; St. Err.=Standard Error; ep=expected profit; varp=variance of profit; swh=spring wheat; dwh=durum wheat; exp. tot. w=expected total wealth; var. tot. w=variance of total wealth.

Table E.2: Acreage Share Model Results based on the Adaptive Expectations

	ep swh	**ep dwh**	**ep oats**	**ep barley**	**ep rye**	**ep peas**	**ep flax**	**ep canola**	**ep hay**	**varp swh**	**varp dwh**
swh acre share											
Coeff.	3.542	-0.751	-0.142	0.835	-0.200	0.046	0.326	-1.758	-0.839	-0.212	-0.128
St. Err.	0.498	0.229	0.166	0.234	0.131	0.092	0.171	0.214	0.142	0.155	0.083
dwh acre share											
Coeff.	-5.053	0.945	0.953	0.402	0.111	0.687	-1.050	0.448	-0.664	0.090	0.064
St. Err.	1.540	1.360	0.771	1.015	0.561	0.438	0.743	0.817	0.633	0.515	0.305
oats acre share											
Coeff.	-0.640	0.640	3.840	-1.141	0.225	-0.182	-1.758	-0.291	-0.427	0.700	0.030
St. Err.	0.750	0.518	0.779	0.766	0.439	0.298	0.468	0.396	0.425	0.222	0.124
barley acre share											
Coeff.	1.593	0.114	-0.482	1.033	0.243	-0.592	-0.645	-1.539	0.718	0.333	-0.035
St. Err.	0.447	0.288	0.323	0.523	0.235	0.159	0.251	0.217	0.228	0.132	0.072
rye acre share											
Coeff.	-6.368	0.525	1.589	4.051	6.247	-0.848	-5.677	2.535	0.643	0.552	-0.529
St. Err.	4.160	2.656	3.093	3.930	3.602	1.722	2.559	1.989	2.341	1.090	0.614
peas acre share											
Coeff.	1.060	2.348	-0.929	-7.131	-0.612	2.935	-0.783	-1.095	-2.059	-0.513	0.063
St. Err.	2.120	1.498	1.516	1.919	1.244	1.253	1.279	1.148	1.305	0.655	0.366
flax acre share											
Coeff.	3.304	-1.584	-3.949	-3.432	-1.808	-0.345	2.937	3.223	1.159	-0.356	0.242
St. Err.	1.739	1.121	1.051	1.333	0.815	0.564	1.337	0.962	0.854	0.556	0.304
canola acre share											
Coeff.	-4.626	0.175	-0.169	-2.122	0.209	-0.125	0.836	4.457	-0.279	-0.673	0.381
St. Err.	0.563	0.320	0.231	0.300	0.164	0.131	0.250	0.397	0.184	0.224	0.124
hay acre share											
Coeff.	-1.808	-0.213	-0.204	0.811	0.044	-0.193	0.246	-0.228	0.695	-0.117	0.093
St. Err.	0.305	0.203	0.203	0.258	0.158	0.122	0.181	0.151	0.259	0.087	0.048

Table E.2: Continued

	varp oats	**varp barley**	**varp rye**	**varp peas**	**varp flax**	**varp canola**	**varp hay**	**exp. tot. w.**	**var. tot. w**	**acrelag**
swh acre share										
Coeff.	-1.062	0.583	-0.529	-0.011	0.218	0.040	0.491	-0.00045	-0.00735	0.687
St. Err.	0.291	0.197	0.236	0.049	0.113	0.073	0.166	0.00044	0.00438	0.079
dwh acre share										
Coeff.	1.102	-0.297	-0.277	0.203	0.292	-0.098	-0.423	0.00295	0.02022	0.444
St. Err.	0.981	0.679	0.748	0.163	0.382	0.236	0.553	0.00144	0.01466	0.093
oats acre share										
Coeff.	-0.224	-0.539	0.258	-0.040	0.256	0.020	-0.244	0.00077	0.00232	0.506
St. Err.	0.406	0.291	0.323	0.068	0.160	0.100	0.227	0.00061	0.00607	0.059
barley acre share										
Coeff.	0.018	-0.186	-0.209	-0.003	0.156	0.217	-0.137	-0.00053	0.00063	0.652
St. Err.	0.234	0.180	0.192	0.040	0.097	0.060	0.134	0.00036	0.00363	0.055
rye acre share										
Coeff.	-0.801	-0.303	1.274	0.041	0.748	0.131	1.358	0.00014	0.01166	0.559
St. Err.	1.989	1.431	1.722	0.340	0.816	0.505	1.140	0.00301	0.02960	0.224
peas acre share										
Coeff.	-0.405	1.060	-1.183	0.019	0.563	-0.132	-0.328	0.00129	0.00069	0.698
St. Err.	1.253	0.873	0.972	0.210	0.485	0.305	0.724	0.00189	0.01884	0.105
flax acre share										
Coeff.	1.159	0.161	1.202	0.035	-0.618	-0.448	-0.279	-0.00297	0.00174	0.657
St. Err.	1.001	0.707	0.788	0.170	0.410	0.256	0.576	0.00152	0.01538	0.074
canola acre share										
Coeff.	1.563	-0.008	0.732	-0.018	-0.477	-0.515	-0.138	-0.00038	0.01042	0.551
St. Err.	0.428	0.285	0.335	0.072	0.166	0.108	0.250	0.00062	0.00645	0.040
hay acre share										
Coeff.	-0.173	0.089	-0.198	0.071	0.097	-0.085	-0.257	0.00037	-0.01059	0.720
St. Err.	0.164	0.117	0.127	0.027	0.064	0.039	0.093	0.00025	0.00254	0.112

The dependent variable in each equation is the percentage change in acre share. The unit of the expected crop profits (ep) are in ten dollars.

The unit of crop profit variances (varp) are in one-hundred dollars. The unit of expected total wealth is in million dollars and its variance is in thousand billion.

For example, if spring wheat's expected profit per acre increases by ten dollar, the percentage change in the share of spring wheat in total acre will be 3.54.

Table E.3: Acreage Share Model Results based on Future Prices and Trend Yield

	ep swh	**ep dwh**	**ep oats**	**ep barley**	**ep rye**	**ep peas**	**ep flax**	**ep canola**	**ep hay**	**varp swh**	**varp dwh**
swh acre share											
Coeff.	2.165	-0.113	0.021	-0.158	-0.073	0.393	-0.034	-1.218	-0.017	-0.260	0.258
St. Err.	0.757	0.281	0.253	0.305	0.135	0.134	0.182	0.383	0.179	0.292	0.148
dwh acre share											
Coeff.	-0.764	-0.894	-2.675	1.735	0.087	-0.510	-0.213	1.606	0.297	0.479	-0.405
St. Err.	1.888	1.460	0.817	1.143	0.494	0.564	0.664	1.112	0.646	0.984	0.518
oats acre share											
Coeff.	0.097	-1.796	2.799	2.780	-0.069	-0.461	0.645	-1.679	0.088	-0.699	0.066
St. Err.	1.144	0.549	0.774	0.690	0.385	0.329	0.492	0.573	0.489	0.415	0.232
barley acre share											
Coeff.	-0.302	0.492	1.174	0.078	-0.099	0.121	0.040	-0.555	0.248	0.567	-0.103
St. Err.	0.581	0.324	0.291	0.500	0.180	0.173	0.225	0.322	0.237	0.258	0.138
rye acre share											
Coeff.	-2.329	0.412	-0.486	-1.650	4.621	-1.965	-2.438	5.761	0.630	1.225	-1.189
St. Err.	4.294	2.341	2.717	2.996	3.809	1.577	2.535	2.280	2.790	1.795	0.932
peas acre share											
Coeff.	9.041	-1.743	-2.348	1.454	-1.419	0.937	1.121	-4.775	-2.190	0.273	-0.163
St. Err.	3.092	1.927	1.673	2.085	1.139	1.507	1.463	2.111	1.454	1.743	0.911
flax acre share											
Coeff.	-0.341	-0.321	1.449	0.213	-0.777	0.495	1.673	0.260	0.788	1.932	-1.322
St. Err.	1.851	1.001	1.105	1.198	0.808	0.645	1.302	1.055	0.931	0.924	0.491
canola acre share											
Coeff.	-3.205	0.628	-0.978	-0.766	0.476	-0.546	0.067	2.285	-1.297	0.099	-0.437
St. Err.	1.008	0.435	0.334	0.444	0.188	0.242	0.274	0.843	0.284	0.613	0.282
hay acre share											
Coeff.	-0.037	0.095	0.042	0.280	0.043	-0.205	0.167	-1.062	-0.589	-0.046	-0.129
St. Err.	0.387	0.207	0.233	0.268	0.189	0.136	0.198	0.232	0.304	0.155	0.087

Table E.3: Continued

	varp oats	**varp barley**	**varp rye**	**varp peas**	**varp flax**	**varp canola**	**varp hay**	**exp. tot. w.**	**var. tot. w**	**acrelag**
swh acre share										
Coeff.	0.326	0.166	-0.359	-0.016	0.045	0.037	-0.196	0.00117	-0.01306	0.676
St. Err.	0.133	0.161	0.229	0.083	0.116	0.112	0.223	0.00060	0.00579	0.078
dwh acre share										
Coeff.	0.658	0.794	-0.139	-0.126	-1.086	1.291	-0.830	0.00073	0.00228	0.208
St. Err.	0.507	0.523	0.830	0.239	0.387	0.382	0.746	0.00188	0.02129	0.096
oats acre share										
Coeff.	0.030	0.172	1.419	-0.094	0.062	-0.172	-1.413	-0.00155	0.01559	0.405
St. Err.	0.212	0.224	0.396	0.133	0.154	0.168	0.406	0.00089	0.01044	0.083
barley acre share										
Coeff.	-0.181	-0.150	-0.243	0.052	0.008	0.061	0.031	-0.00092	0.00211	0.436
St. Err.	0.115	0.132	0.225	0.058	0.089	0.104	0.207	0.00054	0.00555	0.094
rye acre share										
Coeff.	0.443	0.787	-0.543	0.549	-0.121	0.463	-1.061	0.00360	0.00408	0.484
St. Err.	0.855	0.904	1.310	0.427	0.597	0.653	1.528	0.00321	0.02899	0.225
peas acre share										
Coeff.	-0.058	-1.349	-0.061	-0.668	-0.759	0.592	1.875	-0.00676	-0.03933	0.604
St. Err.	0.695	0.981	1.375	0.474	0.595	0.628	1.428	0.00320	0.03714	0.140
flax acre share										
Coeff.	-1.484	-0.140	1.472	-0.773	0.386	-0.048	0.549	-0.00104	0.01766	0.784
St. Err.	0.441	0.487	0.634	0.241	0.376	0.359	0.719	0.00172	0.01646	0.072
canola acre share										
Coeff.	0.157	0.267	1.243	0.008	-0.560	-0.289	0.796	0.00002	0.02726	0.617
St. Err.	0.291	0.303	0.558	0.168	0.208	0.253	0.440	0.00110	0.01213	0.066
hay acre share										
Coeff.	-0.204	0.080	0.152	0.010	-0.176	0.135	-0.094	0.00017	0.00286	0.786
St. Err.	0.085	0.086	0.119	0.039	0.061	0.067	0.142	0.00031	0.00242	0.117

The dependent variable in each equation is the percentage change in acre share. The unit of the expected crop profits (ep) are in ten dollars.

The unit of crop profit variances (varp) are in one-hundred dollars. The unit of expected total wealth is in million dollars and its variance is in thousand billion.

For example, if spring wheat's expected profit per acre increases by ten dollar, the percentage change in the share of spring wheat in total acre will be 2.16.

Table E.4: Acreage Level Cereal Crops Results based on Future Prices and Trend Yield

	ep swh	**ep dwh**	**ep oats**	**ep barley**	**ep rye**	**ep hay**	**varp swh**	**varp dwh**
swh acre								
Coeff.	14248.31	-5131.22	9.88	-327.89	-85.26	-1037.87	-197.00	81.00
St. Err.	6182.07	2748.31	1574.03	2088.00	489.71	1161.20	285.57	141.08
dwh acre								
Coeff.	-5131.22	-688.15	-873.62	1353.07	-535.94	141.65	74.61	18.99
St. Err.	2748.31	2138.38	964.27	1508.87	325.97	736.55	158.47	82.79
oats acre								
Coeff.	9.88	-873.62	2403.46	1678.88	400.53	-25.22	-126.87	34.20
St. Err.	1574.03	964.27	1187.79	1199.07	390.90	670.93	70.41	37.35
barley acre								
Coeff.	-327.89	1353.07	1678.88	-1070.71	60.95	201.99	224.54	-39.04
St. Err.	2088.00	1508.87	1199.07	2133.68	432.13	922.32	123.73	61.89
rye acre								
Coeff.	-85.26	-535.94	400.53	60.95	1178.11	-836.25	32.67	-22.85
St. Err.	489.71	325.97	390.90	432.13	479.96	286.28	22.39	11.73
hay acre								
Coeff.	-1037.87	141.65	-25.22	201.99	-836.25	1619.79	-98.74	-11.67
St. Err.	1161.20	736.55	670.93	922.32	286.28	732.12	53.42	25.54

Table E.4: Continued

	varp oats	**varp barley**	**varp rye**	**varp hay**	**exp. tot. w.**	**var. tot. w**	**acrelag**
swh acre							
Coeff.	228.03	89.04	127.89	-572.71	0.000155	-0.000674	0.65
St. Err.	116.43	140.50	178.27	220.37	0.000054	0.000506	0.05
dwh acre							
Coeff.	32.68	-9.50	31.13	39.72	-0.000008	0.000768	0.29
St. Err.	67.60	72.92	96.85	122.58	0.000029	0.000286	0.09
oats acre							
Coeff.	-31.69	32.57	74.46	-23.74	-0.000033	0.000050	0.67
St. Err.	32.97	34.85	46.34	61.48	0.000014	0.000134	0.07
barley acre							
Coeff.	-14.64	-115.57	-14.73	131.12	-0.000028	-0.000012	0.62
St. Err.	50.64	58.06	77.32	94.71	0.000023	0.000206	0.08
rye acre							
Coeff.	-3.46	-7.88	41.59	-7.11	0.000006	-0.000006	0.45
St. Err.	9.24	10.19	14.19	19.01	0.000004	0.000038	0.08
hay acre							
Coeff.	-26.98	29.49	47.76	-155.22	0.000005	0.000169	0.98
St. Err.	19.47	28.21	41.18	40.86	0.000010	0.000086	0.04

Notes: Coef.=Coefficient; St. Err.=Standard Error; ep=expected profit; varp=variance of profit; swh=spring wheat; dwh=durum wheat; exp. tot. w=expected total wealth; var. tot. w=variance of total wealth.

Table E.5: Acreage Level Non-Cereal Crops Results based on Future Prices and Trend Yield

	ep peas	**ep flax**	**ep canola**	**varp peas**	**varp flax**	**varp canola**	**exp. tot. w.**	**var. tot. w**	**acrelag**
peas acre									
Coeff.	79.58	255.97	-1765.93	-10.16	-26.80	42.27	-0.000010	0.000025	0.84
St. Err.	437.36	411.92	646.46	14.32	18.24	23.54	0.000009	0.000081	0.04
flax acre									
Coeff.	255.97	1293.26	-1295.43	-21.14	-21.67	62.79	-0.000003	0.000051	0.71
St. Err.	411.92	793.53	735.16	15.21	19.91	25.88	0.000010	0.000087	0.09
canola acre									
Coeff.	-1765.93	-1295.43	-1227.79	-41.28	-38.04	53.59	-0.000060	0.000264	0.50
St. Err.	646.46	735.16	1820.33	43.54	56.23	70.59	0.000029	0.000257	0.07

Notes: Coef.=Coefficient; St. Err.=Standard Error; ep=expected profit; varp=variance of profit; swh=spring wheat; dwh=durum wheat; exp. tot. w=expected total wealth; var. tot. w=variance of total wealth.

Table E.6: Acreage Level Model Results conditional on Lagged Total Acreage, based on Future Prices and Trend Yield

	ep swh	**ep dwh**	**ep oats**	**ep barley**	**ep rye**	**ep peas**	**ep flax**	**ep canola**	**ep hay**	**varp swh**	**varp dwh**
swh acre											
Coeff.	2628.30	-1996.96	-3047.22	1267.28	-178.43	4488.85	3051.08	6851.98	-1626.14	-549.33	579.63
St. Err.	7484.12	2968.36	1559.35	2525.86	1276.04	1946.16	1486.12	3522.65	2407.36	366.69	188.32
dwh acre											
Coeff.	-1996.96	-828.30	314.51	588.71	-643.77	-411.04	-78.80	-187.10	-2125.35	38.82	-78.64
St. Err.	2968.36	2202.78	947.55	1490.50	834.35	995.58	854.69	1590.43	1351.07	165.56	90.18
oats acre											
Coeff.	-3047.22	314.51	4899.06	1409.20	243.62	-51.92	454.45	-3499.58	1754.25	-143.71	12.20
St. Err.	1559.35	947.55	1102.97	1052.16	892.66	607.20	753.49	954.63	1015.20	84.34	45.97
barley acre											
Coeff.	1267.28	588.71	1409.20	-1701.55	34.01	946.63	-162.13	-3166.83	6086.28	-14.89	8.33
St. Err.	2525.86	1490.50	1052.16	1842.53	1024.27	796.18	914.81	1396.86	1248.87	133.11	68.21
rye acre											
Coeff.	-178.43	-643.77	243.62	34.01	470.93	133.02	-1362.50	1023.09	34.89	-1.57	-8.87
St. Err.	1276.04	834.35	892.66	1024.27	1182.18	497.56	815.23	789.01	812.56	55.07	28.34
peas acre											
Coeff.	4488.85	-411.04	-51.92	946.63	133.02	-499.97	1697.17	-7174.07	-1751.18	101.83	-132.46
St. Err.	1946.16	995.58	607.20	796.18	497.56	861.99	583.97	1076.77	814.94	135.83	69.80
flax acre											
Coeff.	3051.08	-78.80	454.45	-162.13	-1362.50	1697.17	84.45	-2336.63	100.10	18.13	-54.97
St. Err.	1486.12	854.69	753.49	914.81	815.23	583.97	933.03	877.47	851.24	91.92	47.75
canola acre											
Coeff.	6851.98	-187.10	-3499.58	-3166.83	1023.09	-7174.07	-2336.63	5413.81	-7319.16	699.02	-552.22
St. Err.	3522.65	1590.43	954.63	1396.86	789.01	1076.77	877.47	2593.50	1411.37	198.12	104.58
hay acre											
Coeff.	-1626.14	-2125.35	1754.25	6086.28	34.89	-1751.18	100.10	-7319.16	-1369.68	-28.16	-103.43
St. Err.	2407.36	1351.07	1015.20	1248.87	812.56	814.94	851.24	1411.37	1486.57	126.27	67.28

Table E.6: Continued

	varp oats	varp barley	varp rye	varp peas	varp flax	varp canola	varp hay	exp. tot. w.	var. tot. w	total acrelag
swh acre										
Coeff.	561.82	-668.64	-262.78	-138.27	537.24	-479.52	-54.88	0.000267	-0.001809	0.25
St. Err.	159.23	191.41	226.96	90.54	130.97	123.46	278.10	0.000082	0.000648	0.29
dwh acre										
Coeff.	64.55	124.44	-38.03	-29.75	-194.05	333.77	-64.77	0.000038	0.000165	0.16
St. Err.	82.62	78.62	129.88	40.52	55.54	57.15	128.66	0.000037	0.000337	0.13
oats acre										
Coeff.	-41.59	55.81	200.86	-21.40	-43.55	50.64	-46.82	-0.000072	0.000332	-0.21
St. Err.	38.60	42.15	58.56	21.64	30.44	29.68	67.66	0.000018	0.000160	0.07
barley acre										
Coeff.	-15.99	44.07	13.91	-23.54	-124.39	214.41	-23.13	-0.000077	0.000275	-0.15
St. Err.	60.01	69.49	88.78	31.65	46.79	46.64	107.68	0.000033	0.000245	0.11
rye acre										
Coeff.	23.53	13.32	35.81	-1.67	18.43	-10.56	-45.51	0.000024	0.000041	0.03
St. Err.	20.85	29.68	37.25	15.86	18.09	16.83	44.50	0.000014	0.000101	0.05
peas acre										
Coeff.	-139.73	198.72	17.12	-26.14	-216.02	251.36	66.84	-0.000100	0.000196	-0.22
St. Err.	61.87	68.88	88.12	33.33	45.87	44.30	100.71	0.000029	0.000243	0.10
flax acre										
Coeff.	-47.99	145.89	-12.89	-40.16	-95.83	171.90	45.92	-0.000029	-0.000008	-0.02
St. Err.	40.90	48.96	62.85	23.45	32.48	30.27	72.65	0.000020	0.000141	0.07
canola acre										
Coeff.	-326.53	494.66	379.59	32.16	-515.84	95.04	91.62	-0.000078	0.001568	0.10
St. Err.	98.17	96.74	164.07	63.82	82.20	78.77	148.79	0.000047	0.000427	0.15
hay acre										
Coeff.	-57.20	354.92	-236.59	-44.70	-273.13	220.18	-123.50	-0.000022	0.000128	-0.12
St. Err.	55.95	63.88	96.21	30.99	42.19	39.69	105.55	0.000030	0.000223	0.10

Notes: Coef.=Coefficient; St. Err.=Standard Error; ep=expected profit; varp=variance of profit; swh=spring wheat; dwh=durum wheat; exp. tot. w=expected total wealth; var. tot. w=variance of total wealth.