A Methodological Aggregation-consistent Individual Level Supply Response Model

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ABSTRACT

Government interventions in agricultural markets in order to stabilize commodity prices and producer incomes have had a long tradition. Intervention has been at both the state and country levels and has been for the most part in the form of commodity-based schemes. This study represents an attempt to develop an appropriate methodology for analyzing the aggregate effects of a particular type of policy rule. This type of policy rule is one for which the unit of observation is the individual farm unit rather than the individual unit of commodity. The methodology developed in this paper represents an initial attempt to provide the necessary micro-macro modeling with supply response which is required for analyzing the aggregate effects of whole-farm income support programs. The methodology will be illustrated by an empirical application of the aggregate impacts of the whole-farm program in Saskatchewan, Canada.

Keywords: Aggregation, Methodology, Micro-macro Modeling, Policy rule, Supply response.

INTRODUCTION

Government intervention in agricultural markets in order to stabilize commodity prices and producer incomes has had a long tradition. Intervention has been, for the most part, in the form of commodity-based schemes that have provided support as well as stabilization and have tended to distort markets (Spriggs and van Kooten, 1988; Spriggs and Nelson, 1997; and Hosseini and Binazir, 2000 and 2002). More recently, there has been some interest expressed in whole-farm income support programs. Such programs would not be commodity-based, rather they would include all farm incomes in the income stabilization and support calculations. Such a program already exists in one Canadian province (Saskatchewan), in the form of the whole-farm Net Income Stabilization Account (NISA) program. NISA also existed in other Canadian provinces but for a more limited basket of commodities. It can be regarded as a whole-farm scheme to stabilize income which would include all commodities under a single program. The NISA scheme is multi-commodity in nature but it is different in that the policy rule for income stabilization applies to the individual farm rather than the aggregate situation. NISA differs from other support programs such as price supports in that the unit of measurement is the individual farm income rather than units of the commodity income.

From a methodological perspective, purely aggregate approaches to policy analysis of such programs along the lines of Houck and Ryan (1972) are no longer appropriate. Such approaches were appropriate for commodity-based price supports which involve policy rules that operate at the level of individual units of a particular commodity. However, they are not appropriate for whole-farm income supports which involve policy rules that operate on a basket of commodities (Spriggs

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and Nelson, 1997; and Hosseini and Binazir, 2000 and 2002). These policy rules concern producer contributions and payouts (or with-drawals) which operate at the individual farm level and are not commodity-specific.

There have been previous attempts at assessing aggregate policy effects based on an analysis of individual representative farm models (Spriggs *et al.*, 1995; Hosseini and Binazir, 2000 and 2002). Individual-level supply responses to a particular policy were summed over all farms represented by these models to achieve the aggregate policy effects. Such modeling attempts were popular in the 1950s and 1960s and have previously been discussed and evaluated (Sharpies, 1969). According to Sharpies, these modeling attempts did not prove satisfactory for analyzing the aggregate effects of farm income supports because of the existence of aggregation bias. Hence, an aggregate supply response function derived from individual firm-level relationships tended not to approximate well to the aggregate functions based on aggregate data. Ultimately, researchers moved away from this approach to aggregate policy analysis. Since the income support programs tended to be commodity-specific, the purely aggregate approach based on an analysis of aggregate demand and supply curves gained currency.

Stoker (1993) suggested an alternative approach that starts with a directly estimated aggregate function, from which individual-level functions are derived that are consistent with the aggregate level function. The policy analysis proceeds at the representative individual level, based on these derived aggregation-consistent individual-level functions. The estimated individual effects are then aggregated up to obtain an estimated aggregate effect. Stoker (1993) points out that there have been only a few empirical attempts at using this general methodological approach. He provides a list of such studies, but none relates to agricultural income support programs. The present paper attempts to adapt this general methodological approach to the case of Canadian NISA-type agricultural income support programs. The methodology will be illustrated by an empirical application of the aggregate impacts of whole-farm NISA in Saskatchewan, Canada.

MATERIALS AND METHODS

The purpose of this paper is to build upon the methodology for generating estimates of the aggregate level effects of the NISA program for Saskatchewan as a whole. The necessary work can be divided into two categories: (1) farm-level analysis, to develop farm-level results for representative farms differentiated by income class and geographical location (soil type); (2) aggregation, to develop the methodology and estimate results for the aggregation at the provincial level, assuming homogeneity of operation within each income class, farm type and geographical location (soil type). The layout of the methodology is as follows:

There are three specific methodological steps to be followed:

(1) Derivation of representative farm supply functions that are consistent with an estimated aggregate supply function.

(2) Simulation of the policy effects at the individual level.

(3) Aggregation of these estimated representative farm policy effects to the aggregate level.

These problems are discussed in the following main sections.

Derivation of Farm-Level Supply Functions

The purpose of this section is to develop a methodology for deriving a system of individual-level supply functions consistent with an estimated aggregate supply function. In undertaking this exercise there are three issues to be considered: consistency, aggregation bias, and recoverability.

Consistency

The problem here is one of ensuring consistency between the estimated aggregate supply function and the empirical individual (representative farm) supply functions used in the analysis of the policy. Green (1964: 35) poses the problem as follows:

Consistency means that a knowledge of the "macro-relation"... and of the values of the aggregate independent variables would lead to the same value of the aggregate dependent variable as a knowledge of the micro relations and the values of the individual independent variables.

With respect to Green's definition, consider two alternative methods for generating predicted values of a dependent macro variable. The first method is direct estimation of the macro function. Suppose we denote a resulting predicted value as Y_1. The second method involves estimation of the micro functions for each micro-unit, prediction of the dependent micro variable for each representative farm (y_i) and, then, aggregation to a predicted macro value which we denote as Y_2. Following Green's definition, aggregation is consistent if, and only if, $Y_1 = Y_2$. Consistency generally requires the following conditions: (a) that the same arguments appear in the micro-relations as appear in the macro relation, and (b) that account be taken of aggregation bias in the parameter estimates. In addition, following Stoker (1993), Pesaran and Smith, (1995), and Imbs *et al.* (2005), we assume limited heterogeneity. That is, we can represent the aggregate function by a finite set of micro-level functions each of which is for a particular representative farm.

Recoverability in a Two-Moment Supply Model

Following Miranda *et al.* (1994), and based on *ex ante* rational expectations, supply is specified as a function of the first two moments of the probability distribution of revenue per acre. This model is attractive for analyzing the effects of NISA-type income stabilization programs because such programs tend to increase average revenue and reduce the variance of revenue. The aggregate equation can be specified as:

$$Y_t = a + b\,E(M_t) + c\,var(M_t) + u_t \qquad (1$$

Where Y_t is the aggregate area (acreage)

planted by farms at time t (e.g. in the country, state or province), M_t is the aggregate revenue per acre from operating these farms, and t is the time subscript.

Following Stoker (1993), we assume limited heterogeneity. That is, we assume homogeneous production within a given farm type and given region. However, we allow for heterogeneity among farm types and regions. Following Spriggs *et al.* (1995), Spriggs and Nelson (1997) and Hosseini and Binazir (2000), assume there are three different farm types ($i = 1,2,3$) corresponding, say, to 'small', 'medium' and 'large'. Assume also there are R different regions ($r = 1,2,...R$). Hence, the micro-level supply functions may be represented as:

$$y_{irt} = a_{ir} + b_{ir}\,E(m_{irt}) + c_{ir}\,var(m_{irt}) + u_{irt} \qquad (2$$

Where y_{irt} is the area planted by farm type i in region r ($r = 1,2,...R$) during year t and this is assumed to be a function of the average revenue from the whole-farm operation, $E(m_{irt})$ and the variance of revenue, $var(m_{irt})$.

Suppose, the following simplistic relationships exist:

$$Y_{rt} = \lambda_r Y_t \qquad (3$$

$$Y_{rt} = y_{1rt} N_{1r} + y_{2rt} N_{2r} + y_{3rt} N_{3r} \qquad (4$$

Where Y_{rt} is the area planted in region r in year t, N_{ir} (not a function of y_{irt}) is the number of farms of types i in region r, and λ_r is the crop area proportion. More complex and perhaps more realistic relationships are left for further study. Similarly, we make the simplistic assumption:

$$M_{rt} = s_r M_t \qquad (5$$

Where M_{rt} is the revenue per acre for all farm types in region r during year t, M_t is the revenue per acre in year t of the aggregate area being considered and s_r is a constant multiplier.

Thus,

$$E(M_{rt}) = s_r\,E(M_t) \qquad (6$$

$$var(M_{rt}) = s_r^2 var(M_t) \qquad (7$$

By substituting (1) and (4) through (7) into

(3), the following equation can be derived.

$$y_{1rt}N_{1r} + y_{2rt}N_{2r} + y_{3rt}N_{3r} = \lambda_r[a + bE(M_t)$$

$$+ c\,var(M_t) + u_t] = \lambda_r[a + bE(M_{rt})$$

$$/s_r + c\,var(M_{rt})/s_r^2 + u_t] \tag{8}$$

Substituting (2) into (8) and taking expected values, yields the aggregate equation in terms of micro and macro variables and coefficients:

$$\sum_{i=1}^{3}[a_{ir} + b_{ir}E(m_{irt}) + u_{irt}]N_{ir} = \lambda_r[a + bE(M_{rt})$$
$$/s_r + c\,var(M_{rt})/s_r^2 + u_t] \tag{9}$$

In deriving estimates of the left hand side (LHS) coefficients that are consistent with the right hand side (RHS) coefficients, it may be tempting to make the simplifying assumption that $E(m_{irt}) = E(M_{rt})$ for all i. However, following Theil (1954) and Pesaran and Zhao (1999), this is recognized as a likely source of aggregation bias which may, given the data, be taken into account as follows. If one has access to cross-section and time series data on representative tax-filer records, it may be possible to estimate the relationships between m_{irt} and M_{rt}:

$$m_{irt} = \alpha_i + \beta_i M_{rt} + \varepsilon_{irt} \text{ for all } i. \tag{10}$$

The coefficients α_i and β_i as well as var (ε_{irt}) can be estimated using regression methods. Taking expectations from these relationships, we have:

$$E(m_{irt}) = \alpha_i + \beta_i E(M_{rt}), \text{ and} \tag{11}$$

$$var(m_{irt}) = \beta_i^2 var(M_{rt}) + var(\varepsilon_{irt}) \tag{12}$$

Substituting these results into aggregate equation (9) yields an equation involving macro variables with the macro coefficients on the RHS and the consistent micro coefficients on the LHS:

$$\sum_{i=1}^{3}[a_{ir} + b_{ir}\{\alpha_i + \beta_i E(M_{rt})\} + c_{ir}\{\beta_i^2 var(M_{rt}) + var(\varepsilon_{irt})\}$$

$$+ u_{irt}]N_{ir} = \lambda_r[a + bE(M_{rt})/s_r + c\,var(M_{rt})/s_r^2 + u_t] \tag{13}$$

From (13), we can impose the following relationships between the micro and macro coefficients.

$$\sum_{i=1}^{3} b_{ir}\beta_i N_{ir} = \lambda_r b/s_r \tag{14}$$

$$\sum_{i=1}^{3} c_{ir}\beta_i^2 N_{ir} = \lambda_r c/s_r^2 \tag{15}$$

$$\sum_{i=1}^{3}[a_{ir} + b_{ir}\alpha_i + c_{ir}var(\varepsilon_{irt})]N_{ir} = \lambda_r a \tag{16}$$

These equations cannot uniquely identify the micro coefficients (b_{ir}, c_{ir} and a_{ir}) given the other coefficients (a, b, c, s_r, λ_r, β_i, N_{ir}, α_i, and var(ε_{irt}). To obtain unique micro coefficients, we suggest estimating side conditions based on extraneous farm-level analysis. With three farm types, we require two side conditions for each of (14), (15) and (16) above. For example, suppose it is calculated that 'small' farms are on average only 70 percent as supply responsive with respect to a change in average (expected) revenue as 'medium' farms and are only 40 percent as responsive as 'large' farms. Then, the side conditions for (14) are:

$$b_{1r} = 0.7\,b_{2r} = 0.4\,b_{3r} \tag{17}$$

Similarly, side conditions can be calculated for (15) by involving c_{1r}, c_{2r} and c_{3r}. The side conditions for (16) involve the intercept terms (a_{1r}, a_{2r} and a_{3r}) and may be obtained as:

$$a_{1r} = \theta_2 a_{2r} = \theta_3 a_{3r} \tag{18}$$

Where, for example, θ_2 can be calculated as the ratio:

$$[y_{1r} - b_{1r}E(m_{1r}) - c_{1r}var(m_{1r})]/[y_{2r} - b_{2r}E(m_{2r}) - c_{2r}var(m_{2r})] \tag{19}$$

Evaluated at the average values, $E(M_{1r})$ and $var(m_{1r})$.

Micro Simulation Methodology

This paper uses dynamic stochastic simulation of the stabilization account for representative farms over a 10-year period. Dynamic stochastic simulation is the most appropriate approach to use because the proposed program is dynamic (withdrawals are based on a moving average of past gross

margins) and it operate on the basis of fluctuations in random variables (prices and yields). Revenues are generated using randomly chosen prices and yields from specified multivariate normal distributions. Since prices and yields are distributed under a multivariate probability distribution, in any given year, crop yields are correlated with each other as are price yields.

Once an individual-level supply function has been estimated, it is superimposed on the corresponding representative farm simulation model along with the stabilization policy rules. The micro-level (representative farm) effects are then simulated. A description of this simulation methodology is provided immediately below.

Crop area for the representative farm is estimated on the basis of the micro-level supply function which is a function of the first two moments of net income per acre. However, these two moments are themselves a function of the policy rules. For example, whole-farm NISA tends to raise expected income per acre and lower the variance of income. These first two moments of income are obtained from a stochastic simulation of the representative farm model.

The stochastic nature of the simulation is expected to arise from random yields and prices. An example of such a simulation model developed for representative grain farms in Saskatchewan is found in Spriggs *et al*. (1995), Spriggs and Taylor (1994) and Spriggs and Nelson (1997). Spriggs and Taylor examine the effects of a NISA-type whole-farm income stabilization program on the first two moments of farm income, but with no supply response component.

For the present paper, initial values are chosen for the producer's expectations of the first two moments and inserted on the RHS of the individual-level supply function. A stochastic simulation is performed and the first and second order mathematical expectations of the policy-adjusted revenue per acre are calculated. These values become the second-round estimates of the producer's expectations, inserted into the

supply function and a second stochastic simulation is then conducted. The process continues until convergence is attained. The final iteration crop areas are used to generate values for the desired output variables (such as farm income and government cost) for each representative farm which are to be aggregated.

Aggregation Methodology

Once the micro simulation analysis has been completed, all the replicates on the desired output variables (such as crop area, farm income and government cost) on each representative farm in each region for each year of the simulation period will be available. Aggregate values for the desired output variable may be calculated over the various farm types and regions. For example, aggregate farm revenue (M_{jt}) for each replicate j may be estimated as:

$$M_{jt} = \sum_{i=1}^{3} \sum_{r=1}^{R} M_{ijrt} N_{ir} \qquad (20$$

M_{jt} may be calculated under alternative policy rules (e.g. with or without NISA) and, given a large number of replicates, may be arranged in a histogram to approximate the probability distribution of farm income under the alternative policy scenarios. In our experience, in addition to farm income there is particular interest in estimating a probability distribution for government cost. In these days of tight government budgets, governments are interested not only in the expected cost of government programs, but also the uncertainty of such costs.

An Empirical Illustration

In this illustration, supply functions are derived for 24 representative grain (and oilseed) farms in Saskatchewan, Canada, from a single estimated aggregate supply function. The aggregate effects of a whole-farm NISA-type stabilization program are estimated and compared with the aggregate effects estimated in a previous study which did

not take supply response into account. These earlier studies were by Spriggs *et al*. (1995) and Spriggs and Nelson (1997). Much of the data and basic modeling framework are taken from their studies in order to facilitate the empirical comparisons. Various policy alternatives assessed at the aggregate level by examining: (1) the policy-affected income, which we hereafter refer to as adjusted gross margin (this is equal to annual gross margin from market receipts plus total withdrawals from the NISA account minus producer contributions); and (2) government cost.

This section is divided into three main sub-sections. In the first sub-section is the derivation of individual representative farm supply functions that are consistent with a directly estimated aggregate supply function. In the second, there is a discussion of the micro-simulation analysis and a summary of the policy effects at the individual representative farm level. In the third, are placed the aggregation analysis and results.

Derivation of the Representative Farm Supply Functions

The 24 representative farms (RFs) used in this analysis are characterized as farms with gross farm receipts of at least $10,000 and which earn at least 75 percent of their farm revenue from grains and oilseeds. The data

are from Statistics Canada (1993). These 24 RFs include three farm types (small, medium, and large) in each of eight regions of the province. The small farm is defined as one earning $10,000 to $50.000 in gross farm revenue in 1991, a medium farm is defined as one earning $50,000 to $100,000 in 1991 and a large farm is defined as one earning $100,000 to $250,000 in 1991. The eight regions comprise all 20 crop districts as indicated in Table 1. The estimated numbers of farms of each type as in 1991 are presented in the three rightmost columns of this Table.

The 24 micro-level supply functions are obtained from a directly-estimated aggregate supply of the grains function. We envisage that the aggregate supply function would be estimated with the mean and variance of income as arguments. Such a function has been previously estimated for Western Canada by Miranda, Novak and Lerohl (1994), hereafter referred to as MNL. Since our empirical example is for illustrative purposes only we have chosen to simply adapt the MNL supply equation for Saskatchewan. We assume a linear functional relationship and use MNL's elasticities along with Saskatchewan price-quantity points to estimate the parameters of a linear aggregate supply equation.

MNL estimated the short-run elasticity of acreage supply with respect to expected per acre revenue (ε_m) at 0.28 and the short-run

Table 1. Number of grain and oilseed farms, eight regions of Saskatchewan, 1991.

Region	Soil Zone	Crop Districts[a]	N_{1r}	N_{2r}	N_{3r}	N_r
1	Brown	3AN,3AS,<u>3BN</u>,3BS,4A,4B	2120	2405	780	5305
2	Brown	<u>7A</u>	575	595	240	1410
3	Dark Brown	1A,<u>2A</u>,2B	1945	1755	980	4680
4	Dark Brown	<u>6A</u>,6B	1665	1475	775	3915
5	Dark Brown	<u>7B</u>	445	525	260	1230
6	Black	1B,<u>5A</u>,5B	2160	2265	1170	5595
7	Black	<u>8A</u>,8B	1115	1255	840	3210
8	Black	<u>9A</u>,9B	1040	1090	915	3045

[a] The representative farm for a given region is located in the highlighted crop districts.
Source: Statistics Canada (1993).

elasticity of acreage supply with respect to revenue variance (ε_{var}) at -0.08.

The Saskatchewan price-quantity points for Y, E(M) and var(M) are obtained from Spriggs *et al*. (1995) as 23.4 (million acres planted in Saskatchewan to the four major grain crops: wheat, barley, canola, and durum), 35 (dollars per acre expected revenue from operating grain farms in Saskatchewan), and 532 (per acre revenue variance from operating grain farms in Saskatchewan). Thus, the estimated aggregate supply function for the grain sector for Saskatchewan used in the analysis is:

$$Y = 18726000 + 187800\,E(M) - 3519\,var(M) \quad (21$$

To derive the coefficients of the individual supply functions consistent with Equation (13), we first calculate λ_r (regional crop area proportions), s_r (regional per-acre revenue coefficients), α_i, β_i and var(ε_{ir}) (statistics indicating the degree of aggregation bias) and the side-conditions. These steps are discussed in the following four parts:

Regional Crop Area Proportions (λ_r)

Crop area of grain farms in each region (r = 1,...8) is calculated from representative farm data as Y_r , where:

$$Y_r = y_{1r} * N_{1r} + y_{2r} * N_{2r} + y_{3r} N_{3r} \quad (22$$

and where y_{1r}, y_{2r}, y_{3r} are the crop areas on each RF. These are presented in Table 2. The crop area proportions (λ_r) are calculated as:

$$\lambda_r = Y_r / \sum_{i=1}^{8} Y_r \quad (23$$

Regional Per-acre Net Revenue Coefficients (s_r)

At this step, the relationship between revenue per-acre at the regional level and the provincial level is calculated. This relationship is assumed to be as follows:

$$s_r = M_r / M$$

where,

$$M_r = \frac{y_{1r}*N_{1r}*m_{1r} + y_{2r}*N_{2r}*m_{2r} + y_{3r}*N_{3r}*m_{3r}}{y_{1r}*N_{1r} + y_{2r}*N_{2r} + y_{3r}*N_{3r}} \quad (24$$

$$M = \frac{\sum_{r=1}^{8} M_r * \sum_{i=1}^{3} y_{ir} N_{ir}}{\sum_{i=1}^{3} \sum_{r=1}^{8} y_{ir}*N_{ir}} \quad (25$$

and where M_r is the weighted average of revenues per-acre on all three farm types in region r and M is the revenue per-acre (weighted average of revenues per-acre of

Table 2. Crop area on representative grain arms, eight regions of Saskatchewan, 1991 plus the crop area proportions λ_r.

Region	y_{1r}	y_{2r}	y_{3r}	y_r	λ_r
1	522	648	1232	2402	.19
2	405	520	1040	1965	.04
3	371	675	1331	2377	.17
4	376	692	1350	2418	.14
5	311	569	1102	1982	.04
6	384	591	994	1969	.17
7	403	805	1328	2536	.13
8	457	623	1178	2258	.12

Source: Statistics Canada (1993) and, in the case of λ_r, calculated estimates.

regions) of the whole province. In Table 3, the revenues per-acre calculated for the different-sized representative farms in each region are presented (Spriggs *et al*., 1995). These representative farms are based in the crop districts highlighted in Table 1.

Coefficients Indicating Aggregation Bias, α_i, β_i and var(ε_{ir})

The per-acre revenues of different representative farms may differ in their relationship to per-acre revenue at the aggregate level. These

relationships were estimated using cross-section and time series data from representative farm taxfiler records (Statistics Canada, 1993). These relationships were estimated as a system of seemingly unrelated regression equations and the results are presented in Table 4.

Side Conditions

For the purposes of our illustrative example, the side conditions for the slope coefficients are assumed to be:

$$b_{1r} = b_{2r} = b_{3r}, \text{ and } c_{1r} = c_{2r} = c_{3r} \quad (26$$

That is, 'small', 'medium', and 'large' farms are assumed to be equally responsive with re-

Table 3. Average net revenue on representative grain farms ($/acre) in eight regions of Saskatchewan, 1991 and S_r values.

Region	m_{1r}	m_{2r}	m_{3r}	s_r
1	27.48	34.61	44.44	0.99
2	9.02	28.27	27.07	0.63
3	16.43	23.36	24.94	0.64
4	34.11	33.64	68.40	1.30
5	38.88	49.10	49.84	1.35
6	29.82	39.85	41.43	1.08
7	26.82	39.22	42.78	1.10
8	22.46	27.06	39.03	0.91

Source: Simulation Model (Spriggs *et al.*, 1995).

spect to a change in $E(m_{ir})$ and $var(m_{ir})$. With respect to the intercept terms in the representative farm supply functions, the side conditions are assumed to be:

$$a_{1r} = \theta_{2r} a_{2r} = \theta_{3r} a_{3r} \quad (27$$

Where

$$\theta_{2r} = [y_{1r} - b_{1r} E(m_{1r}) - c_{1r} var(m_{1r})]$$

$$/[y_{2r} - b_{2r} E(m_{2r}) - c_{2r} var(m_{2r})$$

, and

$$\theta_{3r} = [y_{1r} - b_{1r} E(m_{1r}) - c_{1r} var(m_{1r})]/[y_{3r} - b_{3r} E(m_{3r}) - c_{3r} var(m_{3r})]$$

$E(m_{1r})$ and $var(m_{3r})$ are estimated from stochastic simulations on the 24 representative farm simulation models under the assumption of no supply response. Each simulation run involves 200 replicates and a ten-year simula-

tion period. For further details on the simulation procedure, see the sub-section below and Spriggs *et al.* (1995). The values of $E(m_{1r})$ and $var(m_{3r})$ used to calculate θ_{2r} and θ_{3r} are respectively, the averages over the ten-year simulation period of the first two estimated moments. These values are presented in Table 5.

By recovering these aggregation-consistent coefficients, the individual supply functions on the 24 representative grains and oilseeds farms are determined. The coefficients for these equations are presented in Table 6.

Policy Simulation at the Representative Farm Level

The simulation is carried out for a 10-year prospective simulation period from 1994 to 2003. This section is in two parts. One section describes the input variables used in the simulations, while in the other section the empirical results on gross margin, adjusted gross margin, and government cost are presented.

Input Variables

The basic data source for the representative farm simulation models is the Extraction System of Agricultural Statistics (ESAS) of Statistics Canada. Further details on the data used are given in Spriggs *et al.* (1995). There are two types of variables used in the micro simulation analysis (i) random (stochastic) variables and (ii) deterministic (non-stochastic) variables. The sources and derivation of the values for these variables are discussed in the following section.

(i) Stochastic variables

The study used dynamic stochastic simulation of the stabilization account for representative farms over a prospective 10-year period. Revenue was generated using randomly chosen prices and yield from specified multivari-

Table 4. Estimated coefficients and estimated error variances farm size.

Statistics	Rearm Size		
	Small	Medium	Large
α_i	-17.198	9.136	8.062
	(-7.80)	(3.37)	(4.43)
β_i	1.44	0.8	0.93
	(13.34)	(7.38)	(8.10)
$Var(\varepsilon_{j1})$	0.57	1.01	1.12
$Var(\varepsilon_{j2})$	12.34	22.99	25.56
$Var(\varepsilon_{j3})$	0.75	1.40	1.56
$Var(\varepsilon_{j4})$	1.07	1.99	2.21
$Var(\varepsilon_{j5})$	14.77	27.52	30.61
$Var(\varepsilon_{j6})$	0.70	1.30	1.45
$Var(\varepsilon_{j7})$	1.17	2.17	2.42
$Var(\varepsilon_{j8})$	1.55	2.89	3.22

Source: Estimates. Numbers in parentheses are t-values.

Table 5. Expected per-acre revenue, revenue variance on representative grain farms in Saskatchewan and on-values.

Region	E(m1r)	E(m2r)	E(m3r)	var(m1r)	var(m2r)	var(m3r)	θ_{2r}	θ_{3r}
1	28.5	35.9	45.6	389	564	510	0.86	0.41
2	10.4	29.2	28.0	227	216	211	1.12	0.43
3	17.6	24.5	26.1	541	531	522	0.58	0.27
4	35.4	34.9	40.1	677	645	598	0.44	0.21
5	40.0	50.4	51.1	731	6888	646	0.46	0.20
6	31.3	41.3	42.8	720	700	684	0.64	0.34
7	28.3	40.8	44.3	701	751	739	0.47	0.26
8	23.7	28.4	40.3	551	589	588	0.72	0.37

Source: Simulation Model.

ate probability distributions. In any given year, crop yields are assumed to be correlated with each other as are prices. However, crop yields are not assumed to be correlated with prices.

The rationale for allowing cross-commodity correlation of prices is that these prices are basically determined in international markets which are related. The rationale for allowing cross-commodity correlation of yields is that weather variables may affect all crop yields in a particular crop district. The rationale for not allowing correlations between prices and yields is that Saskatchewan production variability is not sufficiently large to influence the world price and Saskatchewan yields are though to be primarily affected by weather and only marginally affected by prices. The random (stochastic) exogenous variables assumed in the micro simulation analysis are prices and yields. The price distribution for each commodity over the 10-year prospective simulation period is assumed to be multi-variate log-normal. The means of the log-normal distributions in each year are set equal to the mean price forecasts for that year, obtained from Agriculture Canada (1993). The underlying variance-covariance matrix is estimated using prices from Saskatchewan Agriculture and Food (1992) over a 15-year time period.

Table 6. Estimated aggregation-consistent individual-level supply functions.

Region	Small			Medium			Large		
	a_{1r}	b_{1r}	C_{1r}	a_{2r}	b_{2r}	C_{2r}	a_{3r}	b_{3r}	C_{3r}
1	535.4	6.36	-0.104	622.5	6.36	-0.104	1295	6.36	-0.104
2	477.5	8.00	-0.203	427.6	8.00	-0.203	1113	8.00	-0.203
3	377.9	9.59	-0.24	646.4	9.59	-0.24	1374	9.59	-0.24
4	305.9	4.55	-0.054	691.3	4.55	-0.054	1460	4.55	-0.054
5	246.7	4.02	-0.049	530.7	4.02	-0.049	1231	4.02	-0.049
6	358.6	5.02	-0.075	557.3	5.02	-0.075	1059	5.02	-0.075
7	355.2	6.75	-0102	759.9	6.75	-0.102	1384	6.75	-0.102
8	433.9	7.46	-0.136	600.7	7.46	-0.136	1170	7.46	-0.136

Source: Calculated estimates.

Crop yields are assumed to be distributed multi-variate normal, truncated at zero, and constant over time. The mean forecast yields are determined as the 10-year crop district average (Saskatchewan Agriculture and Food, 1992), and the variance-covariance matrix is calculated from the Saskatchewan Crop Insurance Corporation (SCIC) record of production on individual farms. Farmers with at least 15 years (10-years for canola) of data for each crop were selected and the variance and covariance of yields were calculated over time. The average, across farmers, of the individual farm variances and covariances was used to estimate the variance-covariance matrix of the yields for each representative farm. In some cases, the number of farmers meeting the 15 year criteria was too small to get a reasonable estimate of the covariance; in these cases, adjustments were made to include farmers with at least 10 years of data for each commodity. The random observations on prices and yields are generated using the statistical computer packages, Regression Analysis of Time Series (RATS).

One other stochastic exogenous variable used in the micro simulation analysis is crop insurance premium. This is introduced as a percentage of (stochastic) market price and (stochastic) long-term yield, according to the SCIC rule for setting the premium.

There is one stochastic endogenous variable in the model, namely crop area. Total crop area on a representative farm is determined by the individual-level supply equation derived in the section entitled "Derivation of the Representative Farm Supply Functions". This supply equation is solved for total crop area using the iterative simulation methodology described in Section; Methodology. Once total crop area is determined (for a given replicate), this is apportioned to one of four crops (wheat, durum, barley and canola) assuming an average cropping pattern for the particular region.

(ii) Non-stochastic Variables

The non-stochastic variables appearing in the representative grain farm analysis include the expenses (excluding crop insurance premiums) for the representative farms which are taken from the 1991 taxfiler data from Statistics Canada (1993). These data are used as the 1991 baseline expenses and are inflated using Agriculture Canada (1993) for farm inputs.

Empirical Results

(i) Representative-Farm Level Results

At the representative farm level, the level of financial support provided by the NISA policy options can be partly measured by the difference between the adjusted gross margin (AGM) and the gross margin (GM) under no policy. AGM is equal to GM plus producer withdrawals from his/her NISA account minus producer contributions. The remaining finan-

cial support accrues as additions to the producer's wealth through enhancements to the producer's average account balance. In Table 7, the enhancements to adjusted gross margin per acre resulting from NISA under two alternative modeling assumptions are presented. The first assumption is that there is no supply response permitted to the policy and the second assumption is that supply response is permitted, in line with the individual supply functions estimated above.

As may be seen from Table 7, NISA increases the mean GM under both the Supply Response (SR) at the individual farm-level to the policy rule and No Supply Response (NSR) assumptions. Note that the average enhancement to GM from the policy was higher under the NSR assumption. This implies fewer withdrawals and more wealth accumulation when supply response is assumed. The explanation for this is that the SR assumption tends to lead to a growth in gross margin over time relative to the NSR case and, hence, to fewer withdrawal opportunities. Note that withdrawals are triggered only when the gross margin falls relative to the preceding five-year average.

There are two reasons for the expected relative growth in GM per acre under the SR assumption. They are associated with (a) an increase in average gross margin per acre and (b) an increase in average crop acres per farm. This implies that, by ignoring supply response to the stabilization policy we would likely underestimate the enhancement in GM per acre, and overestimate account withdrawals.

(ii) Aggregate-Level Results

Aggregate agricultural income as measured by gross margin was first obtained from the simulation model assuming no NISA policy. This was used as the benchmark against which to compare the effects of NISA. Aggregate gross margin over the 200 replicates and the ten-year simulation period was calculated for each of the 24 representative farms. These GM values were aggregated using the aggregation methodology developed in the4 section entitled "Methodology". The first moment for each of the distributions of aggregate GM for the three farm types under the Supply Response (SR) and Non Supply Response (NSR) assumptions is presented in Table 8. These results suggest that the average aggregate effect of NISA on disposable income in the grain sector of Saskatchewan is greater under the SR assumption than under the NSR assumption. The average aggregate GM was found to be 19% higher under the SR than under the NSR assumption ($977 million vs. $822 million). This increase is because, under the SR assumption, crop area is permitted to vary in response to adjusted gross margin (AGM) per acre. The NISA program raises AGM and this in turn increases crop area. Aggregate gross margin is the product of crop area and gross margin per acre. Since crop area increases under the SR scenario so does aggregate gross margin.

The average aggregate GM enhancement due to NISA was found to be about $25 mil-

Table 7. Average enhancement to gross margin from NISA ($/acre).

| Farm Type | Region | | | | | | | |
	1	2	3	4	5	6	7	8
No Supply Response (Spriggs *et al.*,1995)								
1	0.99	1.34	1.21	1.30	1.45	1.53	1.62	1.27
2	1.27	0.97	1.47	1.29	1.32	1.41	1.53	1.32
3	1.27	0.97	1.47	1.57	1.26	1.41	1.51	1.28
Supply Response								
1	0.70	1.25	1.17	1.16	1.17	1.31	1.36	1.26
2	0.65	1.15	0.96	1.13	1.03	1.16	1.30	1.28
3	0.45	0.16	1.02	1.02	0.98	1.02	1.28	1.26

Source: Simulation model.

lion under the SR assumption and $32 million under the NSR assumption. The direction of results is consistent with the results at the farm level.

Effects on Aggregate Government Costs

In the present study, the government costs of NISA include only the direct program costs (government contributions and interest bonus). These include government contributions which amount to 2 percent of eligible net sales and an interest bonus on producer contributions of 3 percent. The average aggregate government costs of NISA over the ten-year simulation period are presented in

Table 9 shows that the average annual average aggregate government transfer is estimated to be about $42.9 million under the SR assumption. This is slightly higher than the estimate ($42.4 million) under the NSR assumption.

Government transfers under NISA may show up either as increased annual disposable income or as wealth increases through additions to the program account. Since government transfers were about the same (on average) under the SR and NSR assumptions, and since annual GM enhancement was found to be larger under the NSR assumption, this means that NISA balances will tend to grow larger and faster under the SR assumption.

Effects on Aggregate Crop Area

The total crop area given N1SA was estimated to be 23.4 million acres under the NSR

Table 8. Average annual aggregate gross margin on grain farms in Saskatchewan (million $)

Farm Type	No Supply Response	Supply Response
1	145.3	202.3
2	307.2	378.9
3	369.7	395.4
Total	822.2	9766

Source: Simulation model

assumption and 24.2 million acres under the SR assumption. This represents an increase of 3 percent which is a measure of the supply responsiveness to changes in the first two moments of revenue per acre wrought by the stabilization policy.

Table 9. Aggregate government cost of NISA in Saskatchewan (million $): Provincial level.

Farm Type	No Supply Response	Supply Response
1	9.9	10.5
2	16.1	16.5
3	16.5	15.0
Total	42.4	42.9

Source: Simulation Model.

CONCLUSION

This paper represents an attempt to develop an appropriate methodology for analyzing the aggregate effects of a particular type of policy rule. This type of policy rule is one for which the unit of observation is the individual farm unit rather than the individual unit of a particular commodity. When the unit of observation is for a particular commodity, as in the case of price support policies, the aggregate effects of the policy can generally be analyzed by directly using aggregate supply and demand functions. However, when the unit of observation is the individual farm, this is no longer appropriate. One must explore the impacts of the policy rules on the individual farm unit as a prelude to exploration at the aggregate level. To this end, the present paper attempted to develop a methodology which ensures consistency in the supply relationships between the farm level and the aggregate level. This linkage permits individual behavioral responses to be consistent with the aggregate response.

An important benefit of such a micro-macro simulation approach is that it provides a tool for analyzing the aggregate effects of very specific rule changes which operate at the individual level. For example, one could use this methodology for looking at aggregate effects

of changing NISA contribution levels and withdrawal rules.

Although the methodology was applied to an analysis of NISA, it is envisaged as one that can be widely applicable. The same basic approach could conceivably be used to analyze the aggregate effects of other policy options that may affect supply and operate at the individual farm level. These may include other forms of revenue insurance as have been recently suggested in the United States.

While the main conclusions concern the methodology, some tentative conclusions can also be made from the illustrative analysis. The analysis examines the potential for bias in the analysis of the aggregate effects of NISA arising from a failure to allow for supply response to the program. The present study suggests that ignoring supply response may result in: (1) a downward bias in the estimated aggregate gross margin, (2) an upward bias in the estimated enhancement to gross margin from the program, and (3) an ignorance of the positive effect on crop area.

Micro- and macro-model complementarities can be discussed from several perspectives including model specification, model simulation and model results. In the present study, individual level supply functions were specified which were consistent with the aggregate level supply function. Owing to the difficulties of achieving consistency with non-linear specifications (according to Stoker (1993)), linear supply functions were specified. One can verify that linear individual models are the only models that give recoverability for broad ranges of distributions. Stoker (1993) mentioned that the foundation of the aggregate model rests on its connection to individual behavior parameters which are recoverable from the aggregate model. He pointed out that, without such a recoverability property, the connection between the aggregate level and individual level is not clear. Therefore, in order to recover the micro level parameters from the aggregate level, linear supply functions at both levels were assumed.

From our experience, there are at least six important areas of potential difficulty and weakness which researchers may have to confront if they venture into this type of research methodology. First, one may have to deal with the situation of prices being endogenous at the macro level but exogenous at the micro level. In the present study, such a problem is side-stepped because it is reasonable to assume that prices are exogenous at both levels. Second, in empirical application, the researcher may be faced with poor availability of farm level agricultural data. For example, to estimate aggregation-consistent individual-level supply functions it is necessary to have information on the relative responsiveness of different farm types (farm size) to a change in expected per acre revenue as well as the variance of revenue. This we did not have. Third, there is the assumption of limited heterogeneity which introduces discontinuities into the analysis and hence imprecision into the results. The discontinuities arise from the assumption that all farms of a certain type in a certain geographical region are homogeneous and face identical experiences (with respect to price and yield). The number of farms in each homogeneous group is assumed to be constant. However, it seems likely that some policy options could lead to a change in these numbers and our methodology does not allow for such possibilities. Fourth, a further limitation is the estimated aggregate supply function that was used in the empirical analysis. This study used the Miranda *et al.* (1994) aggregate acreage supply function estimated for western Canada which may or may not be a good approximation of an aggregate supply function for grains and oilseeds in Saskatchewan province. Fifth, another limitation is the choice of representative farms. The representative farms were of crop districts, which may or may not be representative of a region. Sixth, the methodology that was developed is sensitive to the functional form of the aggregate and individual supply functions. In this paper the linear function was assumed. It would be worthwhile exploring the sensitivity of the results to alternative functional forms. More complex and perhaps more realistic relationships are left for further study.

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متدولوژی الگوی سازگاری واکنش سطح عرضه فردی-جمعی

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چکیده

به منظور تثبیت قیمت کالاها و درامد تولیدکنندگان، مداخله دولت در بازارهای کالاهای کشاورزی سابقه طولانی داشته است. مداخله در هر دو سطح استانی و کشوری و به طور عمده در شکل سیاستهای کالایی وجود داشته است. این مقاله کوششی است برای توسعه متدولوژی مناسب برای تحلیل آثار جمعی (کلان) یک ابزار سیاستی خاص. این نوع ابزار سیاستی برای حالتی است که در آن، واحد مورد نظر یک مزرعه فردی است تا یک واحد فردی از کالا. متدولوژیی که در این مطالعه ارائه شد، کوششی اولیه است، در جهت نیاز به الگوی واکنش عرضه فردی-جمعی که برای تحلیل آثار برنامه های حمایت درآمدی whole-farm،ضروری میباشد. کاربست این متدولوژی برای بررسی آثار جمعی برنامه whole-farm در ایالت ساسکاچوان کانادا انجام شده است.