AN ANALYTICAL APPROACH TO THE CONSIDERATION OF AGRICULTURAL INCOME, PRICE, PRODUCTION AND FARM SIZE POLICY ALTERNATIVES*

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Introduction

Concern over adjustments in the agricultural industry and their relationships to adjustments in the rest of the economy is high. National and provincial unemployment rates have been relatively high and there is interest in reducing those rates by decreasing the rate of decline in farm numbers and hence the agricultural labor force. Variation in export demand for agricultural products and the rising cost of farm inputs relative to product prices have generally increased concern with respect to farm income levels and their variation, efficiency of agricultural production, and the price of agricultural products for domestic consumption and sale on international markets. As well, there is growing concern over the social and economic costs of continued urbanization and concentration of population in a few large urban centers. It is concerns such as these[1,2] which prompt demands and/or recommendations for:

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[1]For discussion of these concerns in one provincial context, see Province of Manitoba, Guidelines for the Seventies, Vol. I (Winnipeg, Manitoba: Queen's Printer, March, 1973), pp. 81-94.

[2]For a discussion of Canadian goals concerning agriculture, see Federal Task Force on Agriculture, Canadian Agriculture in the Seventies (Ottawa, Ontario: Queen's Printer, December, 1969), pp. 27-36.

1. Higher and more stable prices for agricultural commodities.

2. Increased farm size and improved efficiency in production.

3. Lower input prices.

4. Higher levels and redistribution of farm income.

5. Market development and improvement.

6. Adjustments in the level, composition and interregional distribution of production.

In response to such demands and/or recommendations, a number of programs for Canadian agriculture have been proposed and in many instances implemented.

Examples include:

1. The Lower Inventories for Tomorrow (LIFT) program[3] implemented to reduce wheat acreage and thereby wheat inventories.

2. The federal Small Farm Development Program[4] now implemented in a number of provinces and designed to facilitate the consolidation of small marginal farms into farm units of viable size.

3. The Prairie Grain Stabilization Act[5] proposed as a means of stabilizing farm income from crop sales through price determination based on a five-year moving average and the composition of production on farms.

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[3]The Honourable O.E. Lang, "Statement to the House of Commons on Lower Inventories for Tomorrow: Wheat Stock Reduction Program," February 27, 1970.

[4]Canada Department of Agriculture, "Canada-Alberta Agreement on the Small Farm Development Program," News Release (Ottawa, Ontario: Canada Department of Agriculture Information Division, July 14, 1972).

[5]House of Commons of Canada, An Act Respecting the Stabilization of Prairie Grain Sale Proceeds and to Repeal or Amend Certain Related Statutes, Bill C-244 (Ottawa, Ontario: Queen's Printer, April, 1971).

4. Manitoba's Farm Diversification Program[6] funded jointly by the federal and provincial governments under the Agricultural Rehabilitation and Development Act and implemented to stimulate increased livestock production on farms with $5,000-$15,000 gross sales operated by younger farmers.

The proposal and/or implementation of such programs is evidence of the growing interest and concern with respect to how the agricultural industry can best serve farmers, rural regions and society at large.

The Problem

As indicated in the introduction, concerns of society respecting agriculture have tended to place increasing emphasis on issues like employment and income, as well as continuing to emphasize efficiencies in production and low food cost. However, corresponding modifications to analytical models constructed for use in analysis of agricultural production have not been made.

Consider the large linear programming models constructed by Heady and Whittlesey,[7] Brokken[8] and Eyvindson[9] in a United States context, and the similar Canadian model constructed by Craddock.[10] Successive generations of such models

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[6] Province of Manitoba, op. cit., p. 92.

[7] E.O. Heady and N.K. Whittlesey, A Programming Analysis of Interregional Competition and Surplus Capacity in American Agriculture, Research Bulletin No. 538 (Ames, Iowa: Agriculture and Home Economics Experiment Station, Iowa State University, July 1965).

[8] R.F. Brokken, "Interregional Competition in Livestock and Crop Production in the United States: An Application of Spatial Linear Programming" (unpublished Doctor's dissertation, Iowa State University, 1965).

[9] R.K. Eyvindson, "A Model of Interregional Competition in Agriculture Incorporating Consuming Regions, Producing Areas, Farm Size Groups and Land Classes" (unpublished Doctor's dissertation, Iowa State University, 1973).

[10] W.J. Craddock, Interregional Competition in Canadian Cereal Production, Special Study No. 12, Economic Council of Canada (Ottawa, Ontario: Queen's Printer, 1970).

were expanded to include a wider range of commodities, farm size considerations and soil type specific production alternatives. The result was, and is, existence of a model (or set of models in the U.S. case) designed to estimate the most efficient distribution of agricultural production among regions and farm sizes for the nation (Canada or U.S.). That distribution maximizes returns to the agricultural industry (minimizes the cost of national food production) subject to available supplies of one or more factors including land. Each of these models is defined on the premise that maximum efficiency in agricultural production is 'the' primary objective of the agricultural industry.

The problem is that efficiency of production is only one of several objectives which society views as important. Others include maintenance of levels of employment and income. Consequently, analytical models like those referred to above require modification to accomodate analysis in the context of the broadened set of policy objectives. Such model modifications can and should be made to further enhance their usefulness and hence gain further benefits from the high levels of professional and financial investment they contain.

Purpose

The purposes of this paper are:

1. To present a linear programming model similar to those developed to date but modified to provide for farm size specific consideration of employment and income objectives, as well as that of production efficiency.

2. To present a simple illustrative example of its application to consideration of an employment objective together with the "traditional" efficiency of the production objective.

The Model

As suggested earlier, the model is an interregional linear programming type model. It provides for explicit consideration of employment and income on a farm size specific basis in the following manner:

1. Labor constraints by farm type are included in the model. The specification of lower bounds on labor requirements by farm size provides the capacity to require that agricultural employment be at or above a given level.

2. Net income[11] constraints by farm type are included in the model.

As a result, it is possible to constrain agricultural production in a context requiring that all costs of production be covered on any one or all farm types.[12]

In addition to these two specific features, the model provides for specification of agricultural commodity demand categories, corresponding production alternatives, regional production constraints and the objective function. The categorization of demand and specification of production alternatives were based on:

1. Analysis of past agricultural production in Manitoba and identification of that set of commodities accounting for 95 percent of total agricultural production.

2. Specification of production activities related to each commodity on the basis of the knowledge of study participants concerning agricultural

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[11]Returns to management plus profit.

[12]Such specification is equivalent to the requirement that pure profits plus returns to management be non-negative.

production in Manitoba. The agricultural commodity set and corresponding production activities identified are indicated in Appendix Table 1.

The production constraints included were regional and farm size specific minimum and maximum production levels for each commodity to be produced, regional farm size specific land bounds, provincial commodity demand levels, and the farm type specific income and labor constraints. The objective function to be maximized was a net revenue function.

Application of the model to analysis of policy impacts on region specific objectives for Manitoba regions required prior specification of provincial regions. The criteria employed in that specification were:

1. The concept of functional economic areas.[13]

2. Compatibility with established administrative regions of the provincial government's Department of Agriculture.[14]

Given the regional analysis research results developed by Maki and MacMillan and the recently specified boundaries for each of the five administrative regions of the Manitoba Department of Agriculture, the study regions illustrated in Figure 1 were specified. Given the intra-regional variability in production practices and soil productivity, subregions corresponding to Statistics Canada census divisions were identified in each region in order to provide for identification of small area differences in costs of production and factor input requirements.

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[13]Prior analysis of regional systems in Manitoba conducted by Maki and MacMillan facilitated satisfaction of that criterion. See Wilbur R. Maki and James A. MacMillan, <u>Regional Systems for Development Planning in Manitoba</u>, Research Bulletin No. 70-1 (Winnipeg, Manitoba: Department of Agricultural Economics, University of Manitoba, September, 1970).

[14]The Manitoba Department of Agriculture is primarily responsible for agriculture and rural development in the province. Therefore, the ultimate usefulness of the study results is dependent on the ability of departmental staff to utilize the results in the context of their administrative regions.

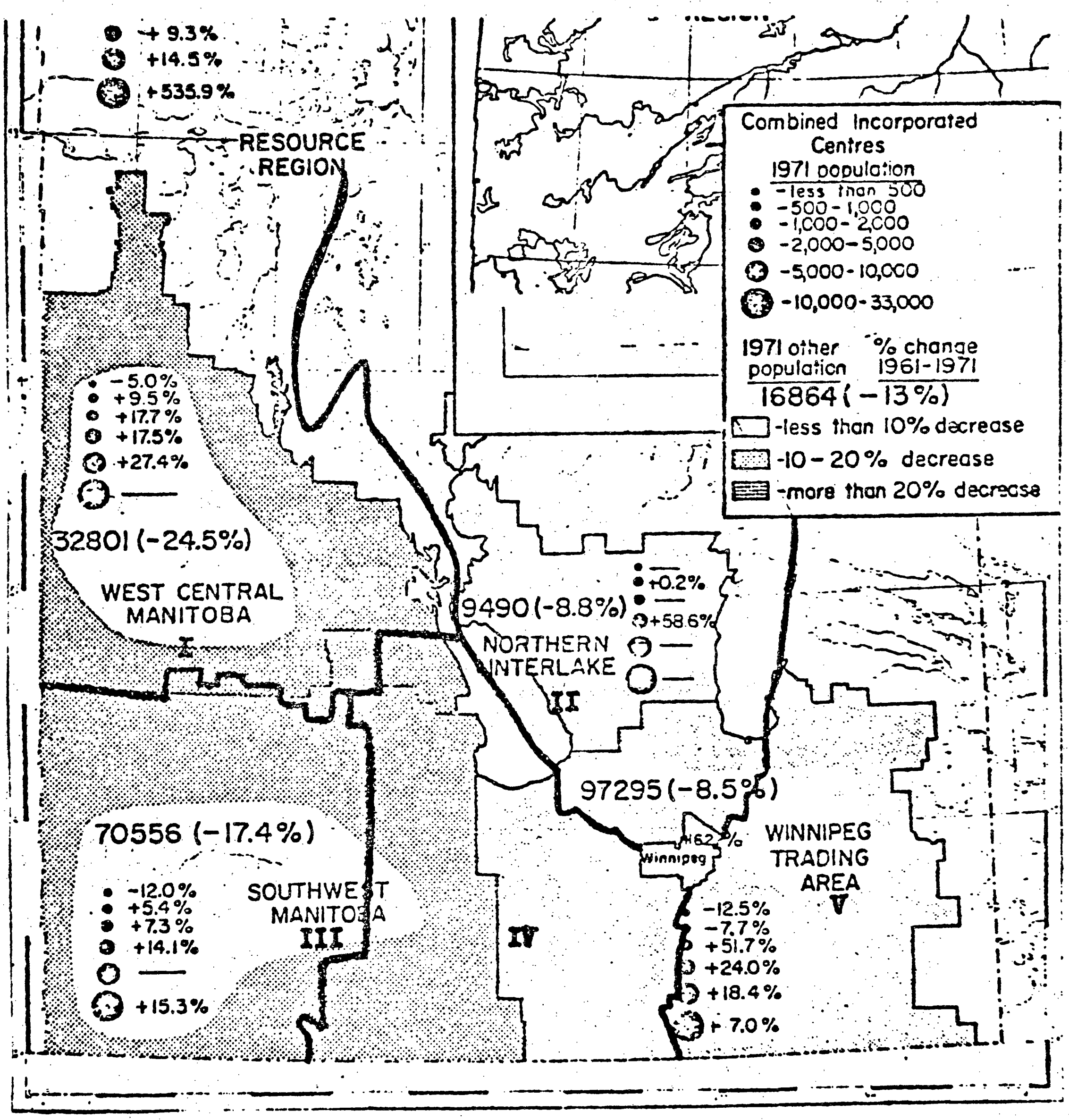

Figure 1

Study Regions and Descriptive Information Indicative of Current Conditions and Trends[a]

[a]The five study regions corresponding to administrative regions of the Manitoba Department of Agriculture are indicated by the wide boundary lines. The other regions and related demographic information are those delineated by Maki and MacMillan and are included to provide the reader with descriptive background information.

An algebraic statement of the agricultural production analysis model is as follows:

Maximize the objective function

$$Y = \sum_{i=1}^{14} \sum_{j=1}^{3} \sum_{k=1}^{3} \sum_{p=1}^{51} r_{ijkp} X_{ijkp} - \sum_{i=1}^{14} \sum_{v=1}^{14} \sum_{p=1}^{3} t_{ivp} T_{ivp} - \sum_{i=1}^{14} \sum_{v=1}^{14} \sum_{p=57}^{62} c_{ivp} A_{ivp} \quad (1)$$

where:

Y = net revenue;

r_{ijkp} = net revenue from the production of one unit of commodity p in region i on farm size j and soil quality k;

X_{ijkp} = the quantity of commodity p produced in region i on farm size j and soil quality k;

t_{ivp} = transportation cost per unit of crop commodity p transported from region i to region v;

T_{ivp} = quantity of crop commodity p transported from region i to region v;

c_{ivp} = transportation cost per unit of livestock of commodity type p produced on farms in region i transported to farms in region v; and

A_{ivp} = number of livestock animals of commodity type p produced on farms in region i transported to farms in region v;

subject to the constraints

$$L_{ik} \leq \sum_{j=1}^{3} \sum_{p=1}^{79} a_{ijkp} X_{ijkp} \qquad \text{for all i and k} \quad (2)$$

$$R'_{ijp} \leq \sum_{k=1}^{2} b_{ijkp} X_{ijkp} \qquad \text{for all i and p and for j = 1, 2, 3} \quad (3)$$

$$R''_{ijp} \geq \sum_{k=1}^{2} b_{ijkp} X_{ijkp} \qquad \text{for all i and p and for j = 1, 2, 3} \quad (4)$$

$$P_p = \sum_{i=1}^{14} \sum_{j=1}^{3} \sum_{k=1}^{2} b_{ijkp} X_{ijkp} \quad \text{for } p = 1,\ldots,9,13,21,32,\ldots,36, 72,73,74 \tag{5}$$

$$Y_{iq} \geq \sum_{k=1}^{2} \sum_{p=1}^{79} y_{iqkp} X_{iqkp} \quad \text{for all } i \text{ and } q \tag{6}$$

$$ME_i = \sum_{k=1}^{2} \sum_{p=1}^{3} f_{ikp} F_{ikp} \quad \text{for all } i \text{ and } p = 1, 2, 3 \tag{7}$$

$$LS_{ip} = \sum_{j=1}^{3} d_{ijkp} X_{ijkp} \quad \text{for all } i, \text{ for } k = 3 \text{ and for } p = 66,\ldots,71 \tag{8}$$

$$FG_{ip} = \sum_{j=1}^{3} \sum_{k=1}^{2} b_{ijkp} X_{ijkp} \quad \text{for all } i \text{ and for } p = 1, 2, 3 \tag{9}$$

$$MG_{i\alpha} = \sum_{j=1}^{3} h_{ijkp} X_{ijkp} \quad \text{for all } i, \text{ for } k = 3, \alpha = 2,3 \text{ and } p = 13,\ldots,36 \tag{10}$$

$$E_{iq} \geq \sum_{k=1}^{2} \sum_{p=1}^{79} e_{iqkp} X_{iqkp} \tag{11}$$

where:

L_{ijk} = land with soil quality k available in region i on farms of size j;

a_{ijkp} = the commodity p per unit requirement for land in region i, farm size j and soil quality k;

R'_{ijp} = the minimum level of production of commodity p allowed in region i on farms with enterprise size j;

R''_{ijp} = the maximum level of production of commodity p allowed in region i on farms with enterprise size j;

b_{ijkp} = per unit yield of commodity p in region i on farms of size j and soil quality k;

P_p = provincial demand for commodity p;

Y_{iq} = minimum income requirement for farms of type q in region i;

y_{iqkp} = net revenue plus labor return from commodity p produced in region i on farms of type q and soil quality k;

ME_i = livestock feed requirements in region i;

f_{ikp} = feed yield per unit of commodity p produced in region i on soil quality k;

F_{ikp} = total commodity p produced for feed on soil type k in region i;

LS_{ip} = livestock supply of commodity type p in region i;

d_{ijkp} = the per unit quantity of livestock commodity p produced in region i on farm size j and soil quality k;

FG_{ip} = feed grain of commodity type p produced in region i;

$MG_{i\alpha}$ = minimum feed of commodity type $p = \alpha$ required in region i;

h_{ijkp} = minimum commodity $p = \alpha$ which must be fed to produce commodity p in region i on farm size j and soil quality k;

E_{iq} = minimum labor hours required for farms of type q in region i; and

e_{iqkp} = hours of labor required to produce commodity p in region i on farms of type q and soil quality k.

Application of the Model--An Illustrative Example

Application of the model is illustrated through its application to analysis of the implications of a policy of: (1) restricting decline of farm numbers (maintenance of employment in agriculture) and, given that constraint, (2) maximizing production efficiency.

The application involved the generation of two linear programming solutions for Region II[15] of the province of Manitoba. The constraints imposed on each solution differed only with respect to labor utilization.

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[15]See Figure 1.

In the first solution (Solution I), the labor row was left free and simply counted labor hours utilized on each farm size. In the second solution (Solution II), livestock labor hours employed on farm types 1 and 2 and crop labor hours employed on farm type 2 were required to be at least 120 percent of those employed in Solution I.[16]

The constraints common to both solutions were maximum land availability constraints and the requirement that commodity production levels on each farm size not be allowed to fall below 80 percent or rise above 120 percent of 1971 levels, and that levels of regional production be similarly constrained to not less than 80 percent and not more than 120 percent of 1971 levels. The 20 percent variation around 1971 levels was selected to represent the extent of change assumed feasible in a five-year time horizon given factors constraining adjustment in agriculture.

The results of the model's application are presented in Table 1. They indicate that without complementary programs to improve production efficiency on smaller farms (farms of types 1 and 2), restriction of out-migration from the agricultural industry generally leads to lower actual returns per hour of labor employed. Examples are the indicated declines of from 0 to -.05¢ and from $1.52 to $1.09 per hour of labor for type 2 farms in subregions 4 and 12 respectively. Further illustrative examples of the types of model modification suggested could be derived through analysis of restrictions placed on the model's income row and elimination of one or more farm sizes from the model.

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[16] The implication is that economic forces would tend toward Solution I and maintenance of employment above that level would require specific policy intervention.

Table 1

The Implications of Restricted Out-Migration Policies for Agriculture Given No Complementary Policy Thrusts and Current Technology Trends and Production Practices[a,b]

Subregion	Farm Type	1971 Farm Nos.	Labor Hours		Wages Per Farm	Net Income		Net Income /Hr. of Labor	Actual Return /Hr. of Labor
			Total Hours	Hours/Farm		Total	Per Farm		
SOLUTION I									
4	1	647	131,050	203	$ 304.50	$-215,023	$- 332.34	$-1.64	$- .14
4	2	361	267,248	740	1,110.00	-401,984	-1,113.53	-1.50	0.00
4	3	221	841,770	3,809	5,713.50	-355,395	-1,608.12	- .42	1.08
12	1	1,658	308,463	186	279.00	- 34,755	- 20.96	- .11	1.39
12	2	777	618,370	796	1,194.00	13,287	17.10	.02	1.52
12	3	205	505,512	2,466	3,699.00	816,975	3,985.24	1.62	3.12
SOLUTION II									
4	1	647	151,010	233	349.50	-250,322	- 386.90	-1.66	- .16
4	2	361	317,817	880	1,320.00	-491,417	-1,361.27	-1.55	- .05
4	3	221	748,132	3,385	5,077.50	- 87,981	- 398.10	- .12	1.38
12	1	1,658	358,370	216	324.00	-153,245	- 92.43	- .43	1.07
12	2	777	766,920	987	1,480.50	-314,243	- 404.43	- .41	1.09
12	3	205	491,890	2,399	3,598.50	798,594	3,895.24	1.62	3.12

[a]The estimates presented in this table are indicative of the magnitude of the implications of restricted out-migration policies for agriculture and further refinement is necessary before these results should be used for other than illustrative purposes.

[b]Corresponding subregion and farm size value of production information for both Solutions I and II is contained in Appendix Table 2.

Conclusion

The usefulness of models developed for analysis of agricultural policy alternatives is dependent on their capability to provide for analysis of a wide range of policy alternatives. While past research and resulting models have indeed been useful, there is an immediate need to increase the scope of their capacity to analyze alternate agricultural development policies. The approach taken in this paper is one example of how to achieve that end.

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APPENDIX

Table 1

Commodity or Production Activity	Identifying Subscript
Wheat	1
Oats	2
Barley	3
Flax	4
Rapeseed	5
Rye	6
Tame Hay	7
Potatoes	8
Sugar Beets	9
Wheat for Feed	10
Oats for Feed	11
Barley for Feed	12
Beef Veal Calf	13
Beef Calf to 500 lbs.	14
Beef Calf to 700 lbs.	15
Beef Calf to 1050 lbs.	16
Beef 500 to 1170 lbs. Grass	17
Beef 500 to 1000 lbs. No Grass	18
Beef Birth to 1170 lbs. Grass	19
Beef 700 to 1050 lbs. No Grass	20
Dairy Veal Calf	21
Dairy Calf to 500 lbs.	22
Dairy Calf to 700 lbs.	23
Dairy Calf to 1050 lbs.	24
Dairy 500 to 1170 lbs. Grass	25
Dairy 500 to 1050 lbs. No Grass	26
Dairy Birth to 1170 lbs. Grass	27
Dairy 700 to 1050 lbs. No Grass	28

Table 1 (continued)

Commodity or Production Activity	Identifying Subscript
Hogs Birth to Weanling	29
Hogs Birth to Market	30
Hogs Weanling to Market	31
Milk Fluid	32
Milk Manufactured	33
Eggs	34
Broilers	35
Turkeys	36
Wheat Produced for Sale as Feed	37
Barley Produced for Sale as Feed	38
Oats Produced for Sale as Feed	39
Wheat Purchase for Feed	40
Barley Purchase for Feed	50
Oats Purchase for Feed	51
Transport Newborn Dairy Calves	57
Transport 500 lb. Dairy Calves	58
Transport 700 lb. Dairy Animal	59
Transport 500 lb. Beef Animal	60
Transport 700 lb. Beef Animal	61
Transport Weanling Hogs	62
Metabolizable Energy	64
Tame Hay Supply	65
Beef Calf Supply	66
Beef Feeder Supply	67
Dairy Calf (Newborn) Supply	68
Dairy Calf 500 lb. Supply	69
Dairy Feeder Supply	70
Weanling Supply	71
Provincial Pork Demand	72
Provincial Fed Beef Demand	73

Table 1 (continued)

Commodity or Production Activity	Identifying Subscript
Farm Income	74
Wheat Supply for Sale as Feed	75
Oats Supply for Sale as Feed	76
Barley Supply for Sale as Feed	77
Minimum Oat Feed in Rations	78
Minimum Barley Feed in Rations	79

Table 2

Value of Production by Producing Subregion, Farm Size and Commodity Class: Solutions I and II[a]

Production Subregion	Farm Size	Number of Farms	Crops: Value of Production	Crops: Value Per Farm	Livestock: Value of Production	Livestock: Value Per Farm	Value of Total Production	Value of Production/Farm
		....	....	....	$	....	....	....
					SOLUTION I			
4	1	647	635,626	982	1,389,872	2,149	2,025,498	3,131
	2	361	1,432,605	3,969	3,520,928	9,753	4,953,533	13,722
	3	221	4,752,508	21,505	11,770,977	53,262	16,523,485	74,767
12	1	1,658	1,262,679	762	4,877,733	2,942	6,140,412	3,704
	2	777	2,586,766	3,329	12,358,503	15,906	14,945,269	19,235
	3	205	2,313,172	11,284	10,660,498	52,002	12,973,670	63,286
					SOLUTION II			
4	1	647	635,626	982	1,509,408	2,333	2,145,034	3,315
	2	361	1,432,605	3,969	3,823,561	10,591	5,256,166	14,560
	3	221	4,451,121	20,141	10,776,632	48,763	15,227,753	68,904
12	1	1,658	1,262,679	762	5,115,036	3,085	6,377,715	3,847
	2	777	2,832,867	3,646	12,959,680	16,679	15,792,547	20,325
	3	205	2,313,172	11,284	10,382,392	50,646	12,695,564	61,930

[a] To be used only for illustrative purposes pending further refinement.