經濟與管理論叢(Journal of Economics and Management), 2009, Vol. 5, No. 2, 305-332

Sufficiency Economy Matrices: Multi-Period Optimization for Local Development Planners

Peter Calkins*

Faculty of Economics, Chiang Mai University, Thailand

and

CREA, Laval University, Canada

Unprecedented resource, economic, and social constraints now require social and economic planners to view 5-year plans as a problem of constrained optimization. Analyses of social accounting matrices have typically been limited to multiplier analyses, which proceed by trial and error and largely ignore such constraints. Lagrangians expressly take constraints into account, but become impracticable as the number of production, sales, consumption, investment, government, and trading activities multiplies; resource and ethical constraints increase; and decision makers become increasingly leery of downside risk. MOTAD programming models are an effective way to analyze complex decisions of this type, but they have not been applied to social accounting matrices in the past, nor have they included such ethical principles as those contained in Thailand's Sufficiency Economy philosophy. This research applies constrained optimization, risk programming, and the sufficiency economy philosophy to a case study of a sub-district in Northern Thailand. A seven-step process takes local decision-makers and planners from their current sub-optimal, unprotected situation to an optimal, "immunized" 5-year plan. Shadow price analyses, sufficiency economy indicators and parametric programming are also integrated into the 7-step procedure.

Keywords: social accounting, linear programming, sufficiency economy, bottom-up planning
JEL classification: B00, C61, O11

Received January 6, 2009, revised April 13, 2009, accepted April 24, 2009.

*Correspondence to: Faculty of Economics, and Associate Director, Institute for Sufficiency Economy Research and Promotion, Chiang Mai University, Chiang Mai, Thailand. Member, CREA, Laval University, Quebec, Canada. E-mail: peter_calkins2004@yahoo.com. The author wishes to thank the National Economic and Social Development Board of Thailand, as well as Chiang Mai University for their financial support of this project; Professors Songsak Sriboonchitta and Aree Wiboonpongse for their invaluable comments and suggestions throughout the research; the staff of the ISERP for their diligence and patience in collecting and organizing the data; and especially the people of the study district for their cooperation.

1 Introduction

Under Thailand's 10th Five-year plan (2007-2011), sub-districts, districts, and provinces have been called upon to formulate their own plans and to send them upwards to be aggregated at the national level. Thailand's unique context of bottom-up planning is made all the more challenging in that local decision-makers must also integrate and implement King Bhumibol's Sufficiency Economy Philosophy (SEP), a social paradigm which bears some similarities to India's Ghandian economics and Bhutan's Gross National Happiness, but which is more tractable in that it relies on a set of six specific conditions. The unprecedented ecological, energy, market, and social constraints of 21st century globalization further complicate the task of sub-national planners.

2 Mathematical Formulation

Constrained optimization models can be of great service in estimating the social optima that must underlie and guide 5-year plans under these very complex conditions. The problem is to maximize utility U , defined as gross domestic happiness per capita, offset by one or more Lagrangian multipliers:

$$Max\, U = U(M, S, C) - \lambda_1(m - b_1 < 0) - \lambda_2(s - b_2 \leq 0) - \lambda_3(c - b_3 \geq 0), \quad \text{Relation [1]}$$

where

M or m = economic/material/environmental happiness or constraints,

S or s = social happiness or constraints,

C or c = cultural and ethical happiness or constraints.

Relation [1] shows that in the absence of any material, social, or ethical constraint (λ_i), or when constraints are not close to binding levels (leaving $\lambda = 0$), potential individual or social utility is limitless. Conversely, the greater the number of constraints, the greater the likelihood that one or more of them will be binding, making the associated λ_i values non-zero, and successively reducing attainable levels of welfare.

The Lagrangian form of relation [1] is convenient for theoretical expositions and applications of simple calculus. However, when data sets are large and

constraints numerous (as in the real world), solutions through calculus become rapidly intractable. This is why mathematical programming has been developed, in the following general form:

$$\underset{j=1}{\overset{n}{\text{Max}}}\, U = \sum P_j X_j \,, \qquad \text{Utility function [Relation 2a]}$$

subject to:

$$\sum_{j=1}^{n} a_{mj} X_j \leq b_m \,, \qquad \text{Resource limits [Relation 2b]}$$

$$\sum_{j=1}^{n} a_{pj} X_j = 0 \,, \qquad \text{Intermediate product balances [Relation 2c]}$$

$$\sum a_{m,s,cj} \overset{n}{\underset{j=1}{X_j}} \geq b_{m,s,c} \,, \qquad \text{Additional minimal targets [Relation 2d]}$$

$$\sum a_{m,s,cj} \overset{n}{\underset{j=1}{X_j}} \leq b_{m,s,c} \,, \qquad \text{Additional maximal tolerances [Relation 2e]}$$

$$\forall X_j \geq 0 \,, \qquad \text{Non-negativity [Relation 2f]}$$

where

$p =$ intermediate products.

Relation [2a] is the utility function part of the Lagrangian, as shown above. Each of the subsequent relations [2b] through [2f] includes a class of constraints for which Lagrangian λ_i values are sought. Logically, relation [2b] lists resource constraints, i.e. the level of land (*space* [1]), labour (*time*), capital (*energy*), management (*knowledge*) and enthusiasm (*spirit*) of the household, firm, region or nation. Relation [2c] traces the flows of intermediate products generated by one production activity and finished by a second through the addition of value added; since all markets and production processes must clear with no surplus, the sum of the row for each intermediate product must be zero.[2] Relation [2d] gives a set of additional objectives (to the maximization of net income [2a]) to be achieved at a minimal target level (e.g., kilometers of paved roads, number of children educated). Relation [2e] does the same for still other objectives expressed as maximal tolerable levels of bads (e.g. public debt, unemployed adults, risk, environmental pollution).

[1]The terms in parentheses, inspired by Boulding (1981) are more general categories for traditional production inputs. We feel these will gain increasing acceptance during the twenty-first century.

[2]The identical structure is also used in MOTAD models to account for dollars of risk generated in any given type of year.

Relation [2f] states that all decision variables must be greater than or equal to zero; i.e., the social unit cannot produce, consume or trade a negative level of a good or service.

In mathematical programming, the values of Lagrangian λ_i at the optimum are called "shadow" or "dual" prices. If non-zero, they show by how much the value of the utility function has been reduced by the last downward turn of the screw on the constraint in question. If that constraint is of the type $\leq$, reducing its b_i or right-hand side further will reduce attainable utility. If $\geq$ or $=$, reducing the constraint level will increase utility. Both [2a] and [2b through 2e] may be non-linear, to reflect the curvilinear nature of indifference curves, production functions, isoquants, and production possibility frontiers.

Traditionally, the multi-dimensional nature of relations [2d] and [2e] has been little explored in Lagrangian or mathematical programming analysis. Instead, those studies that have admitted a secondary objective have aimed at developing a two-dimensional trade-off curve between progressively higher levels of that constraint and the primary objective contained in the utility function of relation [2a]. For example, [2a] has been opposed [2e] in the form of an environmental constraint such as GHG emissions (Loulou and Kanudia, 1999) or chemical dumping in rivers (Loucks *et al.*, 1967) to give planners the choice of minimum environmental sustainability under which they wish then to maximize income. Other trade-offs at the social and macroeconomic levels were left implicitly untouched under the *ceteris paribus* condition. Similarly, Anderson (2008) has plotted the trade-off between efficiency [2a] and equity [2d] by forcing a certain percentage or absolute level of income to be channelled to the poorest in society. Calkins (1981) has traced the trade-offs between income and nutrition in Nepalese subsistence households.

In terms of trade-offs between income [2a] and risk [2e], authors dating back to Porter (1973) and Lin *et al.* (1974) have traced expected income vs. income variance (the so-called "E-V" efficiency frontier) through optimizable MOTAD models to allow managers to select an acceptable level of downside risk in expected income. Following Hazell (1974), most authors have set the minimization of negative deviations (i.e., downside volatility) as the objective function, with the minimum necessary expected income parameterized upward as a constraint. In the present research, we reverse the positions of the these two goals in order to retain the basic

structure of the linear program above, but add a set of negative deviations counters which may not be allowed to surpass a certain level λ (maximum tolerable negative deviations in income) at any given level of risk. Income is optimized for several levels of λ İn order to trace out the E-V frontier:

$$\underset{j=1}{\overset{n}{\text{Max}}}\, U = \sum P_j X_j \,, \qquad \text{Utility function [Relation 2a]}$$

subject to:

$$\sum_{j=1}^{n} a_{mj} X_j \le b_m \,, \qquad \text{Resource limits [Relation 2b]}$$

$$\sum_{j=1}^{n} a_{pj} X_j = 0 \,, \qquad \text{Intermediate product balances [Relation 2c]}$$

$$\sum_{j=1}^{n} a_{pj} X_j - D_g = 0 \,, \qquad \text{Risk in good year [2c}_g\text{]}$$

$$\sum_{j=1}^{n} a_{aj} X_j - D_a = 0 \,, \qquad \text{Risk in an average year [2c}_a\text{]}$$

$$\sum_{j=1}^{n} a_{bj} X_j - D_b = 0 \,, \qquad \text{Risk in bad year [2c}_b\text{]}$$

$$\%pr(D_g) + \%prD_a + \%prD_b - D_{total} = 0 \,, \qquad \text{Weighted probable deviations [2e}_w\text{]}$$

$$D_{total} \le \lambda \,, \qquad \text{Maximum tolerable risk [2e}_t\text{]}$$

$$\forall X_j \ge 0 \,, \qquad \text{Non-negativity [Relation 2f]}$$

where the subscripts

$_g$ = good ; $_a$ = average ; $_b$ = bad ; $_w$ = weighted ; $_t$ = total

The rare studies that have defined a large set of objectives in multiple space within the [2d] block have adopted “goal programming” or “multiple-goal programming,” which minimize deviations from a whole range of desired objective levels rather than maximizing utility directly. To do so, it requires repeated interactions with decision makers at the micro-, community, or macro- levels to determine and refine the weights that they assign to each objective in the case that all objectives cannot be met simultaneously. The objective of such a goal programming model is to minimize the shortfalls in meeting several potentially conflicting objectives, each of which is assigned a unique weight by the decision-makers:

$$\underset{j=1}{\overset{n}{\text{Min}}} -U = \sum (d_{i-} + d_{i+}) , \qquad \text{Relation [3]}$$

where

d_{i-} = negative deviations from the preferred minimum level of each goal i ,

d_{i+} = positive deviations from the preferred minimum level of each goal i .

3 Empirical Implementation

The purpose of this paper is to elaborate, through a case study of a typical sub-district in Northern Thailand, a theoretically consistent set of constraints [2b through 2f] for effective regional planning. In so doing, we shall operationalize the two conditions, three principles and overall concept of balance in the King of Thailand's Sufficiency Economy Philosophy. Thirty cardinal indicators (Table 1) were retained as guidelines to help the sub-district government and economists from the Institute for Sufficiency Economy Research and Promotion (ISERP) to calibrate decisions consistent with the King's Sufficiency Economy (SE) philosophy, measure the current level of progress in meeting those goals, and create a 5-year "Master Plan" for the 2007-2011 period.

Although presented as a table, there exists a *temporal* order linking the six principles of the SE philosophy. Knowledge and ethics serve as preconditions or inputs into sufficiency economy processes, where knowledge is a necessary condition and ethics is a sufficient condition; without knowledge it is not possible to have ethics. Without knowledge and ethics in turn it is not possible to implement the SE processes of moderation, reasonableness and self-immunization. Finally, although listed as separate processes, balance and sustainability are also the overall results of this SE process.[3]

There also exists a *logical* order linking the 6 major divisions of table 1. For other types of analysis a simple strength-weakness-opportunity-threat (SWOT) diagram is adequate; but for sufficiency economy planning, the SWOT must be expanded into an opportunity-strength-weakness-equilibrium-equilibrium-threat (O-

[3]We thank an anonymous reviewer for suggesting the ideas in this paragraph.

Table 1: Indicators of sufficiency economy for the sustainable planning model[4]

S *Strength* *2d*	**W** *Weakness* *2e*	**E** *Internal equilibrium* $\geq 2d, \leq 2e$
		Moderation/sufficiency GDP per capita **Balance/new agr. theory** % land to non-grain, homestead, livestock, water % agricultural industry in total business output value % cottage industry and handicraft output value in total industrial volume
Knowledge % salaried employment in total employment % annual VA spent on schooling	**Reasonableness** % business costs on chemical inputs % pollution costs in agricultural output value activities	**Ethics** % poor hh disposable income total VA income % poor hh disposable income (per capita) other two class per capita Ratio income female- to male-headed hhs **Self-immunization** % poor hh health expenditures in total health expenditures % poor hh food expenditures /food expenditures
Corporate social responsibility % business costs spent on education		% business costs for health care **Corporate social responsibility** % community enterprise in total business volume % business costs to local non-agr. plus salaried employees **Good governance** % salaried employment in total operating costs government
O *Opportunity* *2d*	**T** *Threat* *2e*	**E** *External equilibrium* $\geq 2d, \leq 2e$
	Self-immunization	**Self-immunization**
Positive globalisation Trade balance with the rest World	Debt per capita % interest payments on debt in VA	Savings per capita % income from migration Trade balance with rest Thailand **Good governance** % up transfers from village over down transfers from central government in tambol budget Ratio income rural- to urban-headed hhs

[4]Adapted from Wiboonpongse *et al*., 2009.

SWEET) grid.[5] This innovation in community development analysis results from the key role of internal and external equilibrium in the sufficiency economy philosophy of the King of Thailand. In other words, some key components of community planning should neither be viewed as strengths to be maximised (2d in the mathematical formulation) nor weaknesses to be minimized (2e) but as elements to be kept in delicate balance along a middle path between the two ($\geq 2d$, $\leq 2e$).

Discussions were undertaken with local leaders at the sub-district level to determine what levels of each of these indices were considered acceptable final targets for the 2007-2011 period.[6] The data for the model were collected during a social accounting survey of households and firms in Por-Pieng,[7] a sub-district in Northern Thailand with a diversified range of income-generating possibilities. The sub-district was composed of eight villages, of which two were selected for data collection. A total of 17 poor, medium- and wealthy households and 5 firms were interviewed to generate the basic data to build a social accounting matrix (SAM).

Figure 1 clarifies the seven-step procedure which may take sub-district leaders and economists from an un-optimized non-immune current situation before additional investment to a clear and implementable immunized optimal plan for the next five-year period under the assumption of injecting 30 million baht of new investible capital stock at the beginning of the plan. The arrows in the figure show the direction of the steps.

3.1 Step 1: The Un-Optimized, Non-Immune Money Matrix (UNMM)

To portray the baseline situation for creating a 5-year 2007-2011 Master Plan for Por Pieng, we start with the actual purchase and sales behaviours of the 23 economic sectors of the sub-district economy in 2007 (Table 2). The un-optimized, non-immune money matrix (UNMM) is a snapshot of amounts of payments in cash, and occasionally in kind, when the household retains products for its own consumption.

[5]These letters move counter-clockwise from the lower left-hand side of the table to show how seizing opportunities can eventually offset threats by passing through internal strengths and weaknesses, and establishing internal and external equilibria.

[6]A final round of discussions was conducted to allow the policy makers to re-adjust their weightings once they had observed the results of the initial optimization.

[7]The name has been changed to protect the anonymity of the sub-district. Data were collected in October and November, 2007 by a team from the ISERP, Chiang Mai University.

It provides planners with a complete summary of information they may have known intuitively, but without numerical precision.

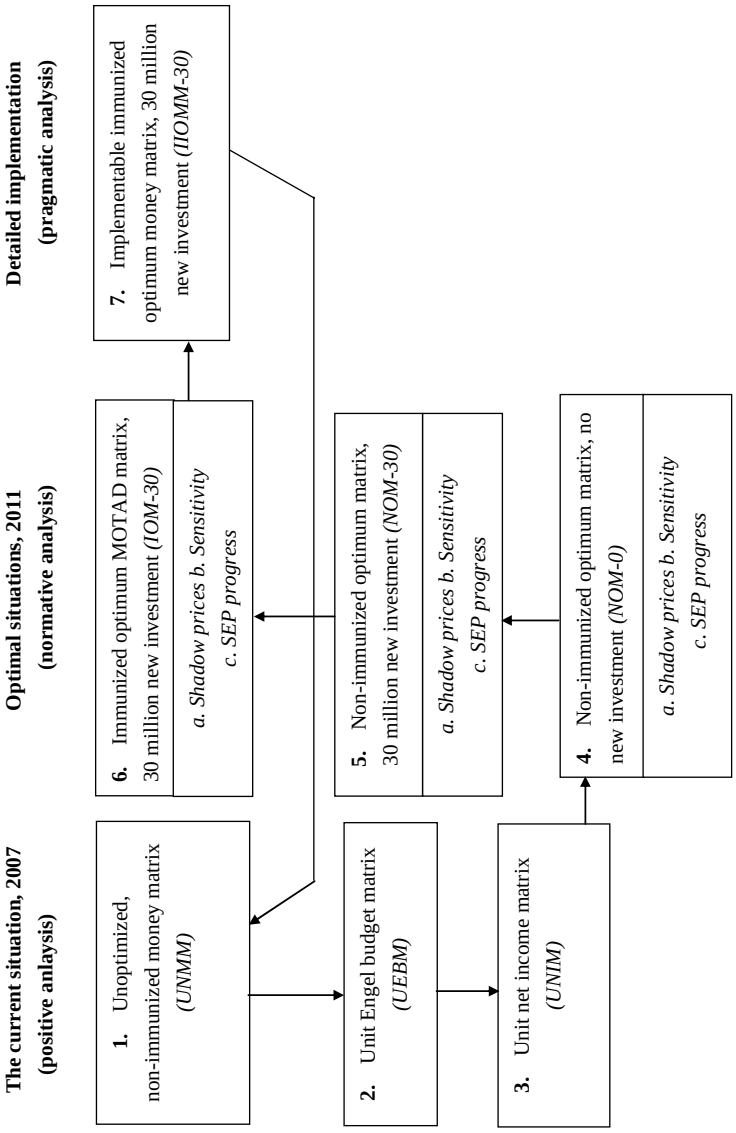

Figure 1: The 7 steps of Sufficiency Economy Optimal Planning

3.1.1 SEM-SAM but Different

The UNMM takes the form of a SAM, but it will be modified and converted into a sufficiency economy matrix (SEM) that explicitly reflects the 30 indicators of Table 1.

Table 2 organizes the aggregate data from the surveys, adjusted through logic and further interviews, to ensure that the total of each row (income for a given sector of the economy) exactly covers all the expenses reported (column total for the same activity). Those expenses include the payments to the factors of production of the sub-district (*tambol*): land rent; wages to hired agricultural, non-agricultural, and salaried workers; and returns to family labour and machinery, which when summed (total of all values in the third-to-last row) equals the "value added for the *tambol*," (VAT) in other words the "Gross *Tambol* Product" (GTP).

The benchmark or baseline level of GTP, calculated from Table 2 to be 127.41 million baht, will be optimized and immunized in the six remaining steps. We may present the definition of each row algebraically as follows:

$$y_i = [P_{ij}] + C + I + G + X \,, \qquad \text{Relation [4]}$$

where P_{ij} = intermediate purchases and the other symbols are as in standard macroeconomic notation.[8] Similarly, the structure of payments within each column is the sum of intermediate purchases + land rental + salaries + capital rental + taxes + imports from the rest of Thailand and the rest of world, or algebraically

$$y_i' = [P_{ij}] + r + w + l + t + m \,. \qquad \text{Relation [6]}^{9}$$

[8]It should be noted that each row of a SAM is *not* equal to the contribution of each sector to aggregate demand, another measure of GTP, defined as:

$$D_i = C + I + G - T + X - M \,, \qquad \text{Relation [5]}$$

because interindustry purchases are included, and there are no negative elements. Although we could convert each row from relation [4] into relations [5], it is much more straightforward to estimate GTP as the sum of value-added payments to the factors.

[9]But this is *not* equivalent to column j's contribution to GTP as estimated by aggregate supply:

$$S_j = r + w + I + (t - tr) + (m - s) \,, \qquad \text{Relation [7]}$$

because there are no interindustry purchases and there are no negative elements, it is one again more convenient to estimate GTP directly through the sum of the values-added paid to factors.

Table 2a: Initial SEM (UNMM) for Por Pieng OBT (m baht), current situation 2007

	Balance with Logic												CSR								
	Irrigated rice	Annual gardens	Unirrigated agriculture	Orchards &perennial flowers	Livestock	Fish and aquaculture	Poultry	Processing of raw products	Textiles/ tailors	Health services	Utilities (water and electricity)	Telephones & communication	Commerce	Massage	Other tourism aned leisure	Roads and transportation	Home stay	Other business and service	Rafting and elephants	Construction	Housing
Irrigated rice	0.02												8,14	0.15							
Unirrigated agriculture								1.14					19.36								
Orchards and perennials													5.42	0.02							
Livestock													14.69	0.04							
Fish and aquaculture													1.15	0.04							
Water and electricity			0.05		1.06								0.39	0.01					0.14		
Telephone & commun.	0.02	0.47												0.01					0.12		
Tobacco and alcohol	0.41			0.77									8.00		4.38		2.00				
Commerce	2.19	0.09	1.45	0.75	0.94	0.23	0.20	1.30						0.00					1.64		
Massage														0.07	3.00		1.00		4.95	4.00	
Roads and transportation		0.01		0.19		0.75								0.09							
Rafting and elephants																					
Construction	0.16				0.58			0.14									0.12		1.00		
Land	0.99										1.00										
Machinery and building											1.00		0.76	0.08					0.91		
Family labor	0.88	0.00	0.00	0.00	0.00		0.00						3.42						2.46		
Hired agricultural labor	17.42	1.94	3.07	3.78	2.07		2.07														
Hired non-agricultural labor									0.85			9.06		13.6				46.6			
Salaried employment										2.04	1.48		4.32		2.00	1.04		2.00	0.59		2.00
Low income			2.15		0.55			5.18													
Middle income		2.30	0.77		4.02	1.15															0.57
High income									1.06				40.36								0.07
Schools													0.02	0.00					0.06		
Village government	0.06			0.07										0.00							
Tambol government													0.03	0.00					0.03		
Central government													0.00						0.03		
Banks and lenders													48.12								
Rest of Thailand	0.34	0.04	14.2	0.54	5.52		0.08		2.00				44.53						13.1		
Rest of world													44.24								
TOTAL VALUE	22.5	4.8	21.7	6.1	14.7	2.1	2.3	7.8	3.9	2.0	3.5	9.1	253.0	14.2	9.4	1.0	3.1	48.6	29.8	4.0	2.6
Value added	19.3	1.9	3.1	3.8	2.1	0.0	2.1	0.0	0.8	2.0	3.5	9.1	8.5	13.7	2.0	1.0	0.0	48.6	4.0	0.0	2.0
Value added as % of column	0.9	0.4	0.1	0.6	0.1	0.0	0.9	0.0	0.2	1.0	1.0	1.0	0.0	1.0	0.2	1.0	0.0	1.0	0.1	0.0	0.8
Value added as % of GTP	15%	2%	2%	3%	2%	0%	2%	0%	1%	2%	3%	7%	7%	11%	2%	1%	0%	38%	3%	0%	2%

Table 2b: Initial SEM (UNMM) for Por Pieng OBT (m baht), current situation 2007

	Ethics							Knowledge			Good governance				Self-immunization		Balance/logic	Positive global'n	GTP:	127,4
	Land	Machine/building	Family labor	Hired ag.labor	Hirenon-ag.labor	Salaried employ	Emigrants	Low income	Middle income	High income	Schools	Village gov't	Tambol gov/t	Central gov't	Banks/ lenders	Immigrant	Rest of Thailand	Rest of world	TOTAL INCOME	TOTAL EXPENSE
Irrigated rice								2.26	11.48	0.44									22.47	22.47
Unirrigated agriculture								0.13	0.08	0.16	0.81								21.68	21.68
Livestock																			14.74	14.74
Processing raw products									2.42	0.16									7.77	7.77
Health services								0.66	1.34	0.03									2.04	2.04
Water and electricity								0.83	0.85	0.07	0.09								3.48	3.48
Telephone & commun.								1.51	2.95	0.14	1.31	0.53	1		0.5		0.5		9.06	9.06
Tobacco and alcohol								1.42	3.53	0.2									20.71	20.71
Commerce								20	33.54	5.9	10	10	25	5	30	11.4	92.4	1	253	253.02
Massage								0.06	1.1										14.18	14.18
Other business & service								0.48	2.33	0.09		5	23.7		5		11	1	48.58	48.58
Rafting and elephants																		29.8	29.75	29.75
Hired agricultural labor																			30.34	30.34
Hired non-agricultural labor																			70.1	70.1
Salaried employment											0.54	1	2.29		4				23.3	23.3
Low income			4	9.28	8.64		0.15								0				30.18	30.15
Middle income	0,6		1.76	19.5	37.9	10									0.56		14.2		93.39	93.39
High income	1,4	2.75	1	1.6	23.5	13.3									0.06		80.8		186.56	186.56
Schools								0.04			0.37		13.3						13.84	13.84
Village government													17.4						17.53	17.53
Tambol government								0.61	21.72	87.5									109.87	109.87
Central government													5						5	5
Banks and lenders								0.06	0.01	11.5									59.71	59.71
Outside Migrants															7.78				12.53	12.53
Rest of Thailand								1.86	7.52	79.5	0.72		21.2		11.8				202.86	202.86
Rest of world																			44.24	44.24
TOTAL VALUE	2	2.75	6.76	30.3	70.1	23.3	0.15	30.15	93.39	187	13.84	17.5	110	5	59.7	12.5	203	44.2		

3.1.2 Sufficiency Economy Philosophy Indicators

The third column of Table 3 reports the current 2007 levels of the quantitative indices of the King's SEP (Table 1) that may be derived directly from the data of the UNMM (as well as all subsequent matrix solutions in this paper). Such a table allows planners to follow the progress[10] of SEP implementation from one scenario to the other.

For example, the King's New Agricultural Theory (NAT) recommends that 30% of land be devoted to grain and subsistence crops, 30% to water and aquaculture, 10% to the homestead, and 30% to non-grain crops and livestock. The current plan would seem very close in terms of land to crops and land to non-grain crops an livestock, but would seem lacking in water surface.

3.2 Step 2: The unit Engel Budget Matrix (UEBM)

The UNMM is easily converted into a unit Engel budget matrix (UEBM), usually called the "A matrix" (table 4), by dividing each monetary value in Table 2 by its column total. Since each column sums to 1.00 (last row), local planners may compare the relative factor-intensity of current technology in various *producing sectors* as a guide to specialization for trade and/or reducing unemployment among labourers of a certain class. For example, unirrigated agriculture hires much less agricultural labour than either irrigated rice or annual gardens, making the latter more interesting for job creation. Similarly in the *household sector*, the three columns "low income," "middle income," and "high income" show the proportions of total receipts that are paid for consumption, taxes, interest, and imports. These are equivalent to the Engel coefficients routinely used by economists to decide which goods may be taxed without unduly hurting the poor.

[10] In most cases, the diversity of environmental situations in Thailand makes it difficult to fix absolute targets for these indicators; relative improvements over the 5-year plan would seem sufficient as long as they move towards the goals set by local leaders during the focus group.

Table 3: Progress indicators of implementing the Sufficiency Economy Philosophy

		Step 1: Current solution	Step 4: Optimum with no new investmt.	Step 5: Optimum with 30 m baht investmt.	Step 6: Immunization with 30 m baht investment
Balance	% agricultural industry output value in total business volume	65.11%	65.45%	65.38%	32.53%
	% cottage industry and handicraft in total industrial value	34.89%	34.55%	34.62%	37.91%
	Trade balance with the rest Thailand	0	0	0	0
Balance and new agriculture theory	% land to crops	24.73%	24.60%	32.03%	36.89%
	% Value added to water-based production (fish)	0.90%	0.85%	0.86%	0.86%
	% land to homestead	n.a.	n.a.	n.a.	n.a.
	% land to non-grain crops	7.21%	7.14%	9.33%	0.00%
	% livestock in agricultural output value	23%	29%	28%	35%
Sufficiency	GTP per capita (baht)	25.416	26.469	33.247	29.672
Reasonableness	% environmental pollution costs in total agricultural output value	2.30%	2.70%	2.70%	0.00%
Self-immunization	% income from migration	0.05%	0.05%	0.05%	0.05%
	% interest payments on debt in VA	46.90%	44.30%	44.80%	44.60%
	Savings per capita	0.0042	0.0036	0.0047	0.0041
	Debt per capita	0.0193	0.019	0.0242	0.0215
Ethics	% poor household disposable income total value added income	16.20%	16.90%	16.80%	16.90%
	% poor household disposable income (per capita) other two classes	20.10%	21.50%	21.20%	21.40%
	% poor household to total health expenditures (per capita)	32.50%	33.10%	32.90%	33.00%
	% poor household food expenditures (per capita) overall food expenditures (per capita)	1.10%	13.70%	13.60%	13.60%
Knowledge	% salaried employment in total employment	17.90%	16.70%	17.00%	16.80%
	% annual value added spent on schooling	10.90%	10.40%	10.50%	10.40%

Table 4: SAM UEBM (A-matrix) for Por Pieng OBT (m baht)

	Production technology budgets									Household consumption		
	Irrigated rice	Annual gardens	Unirrigated agriculture	Orchards & perennial flowers	Livestock	Fish and aquaculture	Poultry	Processing of raw products	Textiles/ tailors	Low income	Middle income	High income
Irrigated rice	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.075	0.123	0.002
Annual gardens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.025	0.000
Unirrigated agriculture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.147	0.000	0.004	0.001	0.001
Fish and aquaculture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004
Poultry	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.011	0.000
Processing raw prod'ts	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.001
Textiles/tailors	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Health services	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.014	0.000
Water and electricity	0.000	0.000	0.002	0.000	0.072	0.000	0.000	0.000	0.000	0.027	0.009	0.000
Telephone & commun.	0.001	0.098	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.032	0.001
Tobacco and alcohol	0.018	0.000	0.000	0.126	0.000	0.000	0.000	0.000	0.000	0.047	0.038	0.001
Commerce	0.097	0.018	0.067	0.124	0.064	0.108	0.086	0.167	0.000	0.663	0.359	0.032
Massage	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.012	0.000
Road /transportation	0.000	0.001	0.000	0.031	0.000	0.352	0.000	0.000	0.000	0.000	0.000	0.000
Other bus. & service	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.025	0.000
Construction	0.007	0.000	0.000	0.000	0.039	0.000	0.000	0.019	0.000	0.000	0.000	0.000
Housing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000
Land	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Family labor	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hired agricultural labor	0.775	0.401	0.142	0.620	0.140	0.000	0.880	0.000	0.000	0.000	0.000	0.000
Hired non-ag labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.217	0.000	0.000	0.000
Low income	0.000	0.000	0.099	0.000	0.038	0.000	0.000	0.668	0.000	0.000	0.000	0.000
Middle income	0.000	0.474	0.035	0.000	0.273	0.540	0.000	0.000	0.000	0.000	0.000	0.000
High income	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.271	0.000	0.000	0.000
Schools	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Village government	0.003	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tambol government	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.233	0.469
Banks and lenders	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.062
Rest of Thailand	0.015	0.007	0.654	0.088	0.375	0.000	0.034	0.000	0.512	0.062	0.081	0.426
TOTAL VALUE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Percentage value added	86%	40%	14%	62%	14%	0%	88%	0%	22%			

In Por Pieng, fish and aquaculture are basically not consumed by the poor and are heavily consumed by the rich, even in relative terms; while the poor pay the highest percentage of their incomes for health care. A luxury tax on fishery commodities could therefore be envisaged. The revenues could then be transferred to poor households in support of health and education.

3.3 Step 3: The Unit Net Income Matrix (UNIM)

Step 3 provides no new information, but is a necessary algebraic step in the final conversion of the initial UNMM into an immunized optimum matrix, as it forms the heart of the linear programming matrix. The UEBM cost matrix is multiplied by -1 (since the cost coefficients above may be considered negative incomes), and a positive 1 is added for each activity along the diagonal to show the corresponding income once costs are paid. The resulting matrix (not shown) is called an I-A matrix or unit net income matrix (UNIM).

3.4 Step 4: The Non-Immunized Optimal Matrix (NOM)

At this point in the analysis, most studies of SAMs invert the I-A matrix to yield multipliers associated with the investment in selected target sectors of the sub-district economy by outside agents (provincial or national level governments, Thai investors, or the rest of the world in terms of both imports and Foreign Direct Investment). Although informative, this process ensures neither that the best possible mix of investments will be found, nor even that an apparently good mix of activities is feasible given the large number of resource, social, and ethical constraints that impinge upon modern society but are ignored in multiplier analysis. We therefore branch away from multiplier analysis to linear programming optimization of the data inherent in the I-A matrix. The UNIM is expanded into an LP model (of which representative rows and columns are shown in Table 5) by adding four rows at the top of the matrix and two columns at the right of the matrix. The first new row is a copy-paste of the value-added row of the UEBM (second to last row of the first page of Table 2), which now becomes row 5 (value added) in Table 5, the non-immunized optimal matrix or NOM. Row 5 is called the social

objective function because it is this row that we shall optimize under resource and Sufficiency Economy constraints.

We then initialize to zero all values in row 4 just above the value added row ("optimal level") because we want a "fresh start" in terms of zero-based planning of the sub-district economy. To better compare this fresh start with the benchmark situation in 2007, we list in row 2 ("current level") the initial values in million baht of the baseline situation. Finally, we use EXCEL to define row 3 ("optimum percentage change"), a line endogenously determined during optimization that shows by how much each activity should optimally increase or decrease as compared with the baseline.

We must add columns as well. At the right of the I-A or UNIM heart of the matrix, we add the row total column. i.e., the sum-products obtained by multiplying each element in row 4 (the optimal level of each production, consumption, investment, spending or export activity) by the corresponding column element for each row in turn. These must be constrained for mathematical, natural resource, and philosophical reasons, however, as shown in three respective blocs. Bloc 1 is the I-A matrix including all rows from "irrigated rice" to the "rest of the world." Mathematically, the LIMIT column forces each row in bloc 1 to be greater than or equal to zero because each sector must produce at least enough income to pay its costs.

Bloc 2 is natural resource constraints, ranging from irrigated land through investible capital. These must be less than or equal to the total amount of each resource available. Bloc 3 is the set of constraints associated with moderation, sustainability, reasonableness, ethics, and knowledge of the King's philosophy (Tables 1 and 3). To save space,[11] a single example of both "reasonableness" and "ethics," the environmental pollution row in Tables 5 and following shows the expenses in m baht incurred by each activity for harmful chemicals used in their production process. The LIMIT column constrains this to be less than or equal to a certain total amount of pollution considered acceptable by sub-district planners, say 4 million baht; but this value can and should be parameterized downward in successive optimizations in their presence.

[11]Tables 5, 7, and 9 had to be simplified to fit on a single page for expositional clarity; certain rows and column sectors have therefore been masked.

Table 5: The linear program for no new investment

	Irrigated rice	Livestock	Textiles/ tailors	Health services	Commerce	Other business & service	Housing	Hired agricultural labor	Salaried employment	Low income	Middle income	High income	Banks and lenders	Rest of world	ROW TOTAL	LIMIT
Current level	22.47	14.74	3.91	2.04	253.03	48.58	2.64	30.34	23.30	30.2	93.39	186.56	59.71	36.87		
Optimum % change	0.02	-0.02	-0.02	0.04	-0.02	-0.02	-0.04	0.21	-0.03	0.06	0.03	-0.01	-0.13	0.18		
Optimal level	22.83	14.51	3.85	2.12	249.06	47.73	2.54	36.69	22.62	31.9	96.30	184.20	51.81	43.55		
Value added	0.86	0.14	0.22	1.00	0.03	1.00	0.76								133	0
BLOC I																
Irrigated rice	1.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	-0.07	-0.12	0.00	0.00	0.00	0	0
Livestock	0.00	1.00	0.00	0.00	-0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0
Poultry	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	7	0
Textiles/tailors	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0
Health services	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.01	0.00	0.00	0.00	0	0
Commerce	-0.10	-0.06	0.00	0.00	1.00	0.00	0.00	0.00	0.00	-0.66	-0.36	-0.03	-0.50	-0.02	0	0
Other tourism aned leisure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.21	0	0
Other business & service	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	-0.02	-0.02	0.00	-0.08	-0.02	0	0
Housing	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0	0
Hired agricultural labor	-0.77	-0.14	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0
Salaried employment	0.00	0.00	0.00	-1.00	-0.02	-0.04	-0.76	0.00	1.00	0.00	0.00	0.00	-0.07	0.00	0	0
Low income	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	-0.31	0.00	1.00	0.00	0.00	0.00	0.00	0	0
Middle income	0.00	-0.27	0.00	0.00	0.00	0.00	-0.22	-0.64	-0.43	0.00	1.00	0.00	-0.01	0.00	0	0
High income	0.00	0.00	-0.27	0.00	-0.16	0.00	-0.03	-0.05	-0.57	0.00	0.00	1.00	0.00	0.00	0	0
Banks and lenders	0.00	0.00	0.00	0.00	-0.19	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	1.00	0.00	0	0
Rest of world	0.00	0.00	0.00	0.00	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0	0
BLOC II																
Irrigated land	25.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	583	968
Unirrigated land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1104	1456
Orchard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	627	6980
Labor	13.96	94.43	17.86	8.84	0.27	8.84	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7702	12005
Investible capital	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.16	0.50	0.00	0.00	112	112
BLOC III																
Environmental pollution	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	4

EXCEL is equipped with a powerful optimizer called Solver, which in addition to the optimized matrix (Table 5) yields a separate sensitivity analysis worksheet (Table 6) listing shadow prices. Even with no new exogenous investment of capital from government, banks or migration, reorganizing the relative importance of the production and sales activities within the matrix increases GTP from 127.41 to 132.60 million baht (Table 5). While many of the activities will go up or down by less than 3%, poultry should quadruple from 2.35 to 9.36 million; health services should increase by 4%, offset by housing decreases of 4%; and exports should increase from 36.87 to 43.55 million baht (up 18%).

The upper half of Table 6 shows the marginal change in the value of the GTP associated with a one-unit reduction in the level of a given constraint cell in the LIMIT column. The only non-zero shadow price (λ_i) is that of investible capital. The sub-district could pay up to 112% interest per year and still make a profit on their investment. If this result holds for neighboring sub-districts, it will show strong evidence of a major capital shortage in Northern Thailand.

Table 6: Shadow prices

	Resource use level	Resource availability	Shadow price (value marginal product)	Market price	Ratio Shadow price to market price
Optimal solution, no new investment					
Irrigated land	583	968	0	n.a.	n.a.
Unirrigated land	1104	1456	0	n.a.	n.a.
Orchard	627	6980	0	n.a.	n.a.
Labor	7702	3801	0	n.a.	n.a.
Investible capital	112	112	1.133	0.1	1133%
Environmental pollution	2	2	0	n.a.	n.a.
Optimal solution, 30 million new investment					
Irrigated land	736	968	0	n.a.	n.a.
Unirrigated land	1402	1456	0	n.a.	n.a.
Orchard	796	6980	0	n.a.	n.a.
Labor	9343	3801	0	n.a.	n.a.
Investible capital	142	142	1.133	0.1	1133%
Environmental pollution	3	2	0	n.a.	n.a.

3.5 Step 5: The Non-Immunized Optimum Matrix, 30 M Baht New Investment (NOM-30)

The constraint level in the LIMIT column cell for investible capital is increased from 112 to 142 million baht, reflecting a foreseeable injection of 30 million baht new capital under the 5-year plan into the target sub-district. This injection may come from the provincial or national governments, outside bankers, and/or investors in Thailand or the rest of the world. After re-optimization not shown, total value added increases by 34 million baht.[12] There are also significant changes in the relative weights of various activities in the final plan as compared with the current situation. For example, poultry increased to 325% of its baseline level and exports to the rest of the world rise by 50%. Hired agricultural laborer will benefit more than other types of labor, with an increased demand of 48%. The shadow price on capital also remains high at 113%.

3.6 Step 6: The Immunized Optimum MOTAD Matrix, 30 M New Investment (IOM-30)

To reflect the principle of self-immunization inherent in the King's philosophy, the optimizable SEM with 30 m baht investment of Table 5 was converted into a MOTAD SEM (Table 7) by adding a block of 5 constraints at the bottom of the matrix. The first such row reflects for each production or service activity the expected income increase or decrease in a "good" rainfall year for agricultural production. Rice, for example, will earn 0.9 million baht more in a good year than an average year, but fish and aquaculture will see incomes go down because of excessive rainfall. Similarly, the extra rainfall will increase the likelihood that poultry will get diseases, causing a drop in income from poultry.

At the end of these rows we include a "1.00" which mathematically will allow the sum of each row to rise to zero in case it is otherwise infeasible for the total

[12]This may sound like a scant improvement, unless we remember to distinguish between the *stock* of new capital (30 m baht) and the annual *flow* it produces. The opportunity cost of a 30 m baht investment is to place it in a long-term deposit in the bank, earning a maximum of 8 to 10 percent interest. Compared to that a 34/30 = 113% increase in value added to local-owned resources is very high indeed!

positive deviations from the activities themselves to completely cancel the negative deviations through what is called in finance the "portfolio" effect. These "1.00s" are associated with new columns called negative deviation counters for each type of year. Similarly, the sum of deviations in an average and a bad year for rainfall are listed in separate rows. These three annual deviation rows are then weighted by their prior probabilities, i.e., the historical frequencies in Por Pieng sub-district of different types of rainfall year: good (14%), average (45%) and poor (41%). Finally, the total weighted deviations in a given year are set less than or equal to the maximum level of risk or non-immunization acceptable to sub-district leaders.

In the case where those leaders are completely immunization-neutral (indifferent to risk), we set the row limit to some arbitrarily large number (say 1 million baht) to render the constraint non-binding. We then progressively reduce the row limit from 1 million to zero to portray the efficient E–V frontier between value added and increasing levels of self-immunization.

Although it is possible to do this by manually changing the permissible sum of negative deviations and re-optimizing ten times, we may generate a summary table in a few seconds by using the Sensitivity Assistant macro add-in in EXCEL.[13] GTP is estimated at 148.5 million baht. Those activities whose optimal level changes the least as we immunize the sub-district from, say, 55 million baht down to 5 million baht of unprotected value added are the best ones for the community to use in its strategy of self-immunization. In this case, "Poultry" is the best immunizer, and "Other tourism and leisure" the worst. Table 8 lists the immunization rank index of activities as a ratio of each activity's level at 5 million baht over its level of 55 million baht.

[13]This is obtainable with the textbook Cliff T. Ragsdale. 2001. **Spreadsheet modeling and decision analysis**. 3rd or subsequent editions, South-Western College Publishing.

Table 7: M OTAD SEM

	Balance with Logic									CSR								
	Irrigated rice	Annual gardens	Livestock	Poultry	Processing of raw products	Textiles/tailors	Health services	Commerce	Massage	Other tourism aned leisure	Other business and service	Rafting and elephants	Construction	Immunize loss good	Immunize loss average	Immunize loss bad	Total vulnerability	ROW TOTAL	LIMIT
Level in simulated starting position	22.5	4.84	14.7	2.3	7.8	3.9	2.0	253.0	14.2	9.4	48.6	29.8	4.0						
Percentage change from start	14%	14%	11%	311%	13%	11%	16%	11%	12%	11%	11%	11%	12%						
Optimal level in Master plan	25.7	5.50	16.4	9.7	8.7	4.3	2.4	280.9	15.8	10.4	53.8	33.0	4.5	-168	8	183	55.00		
Value added	0.9	0.4	0.1	0.9	-	0.2	1.0	0.03	0.97	.2	1.0	0.1	-					฿149	0
Irrigated rice	1.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0	0
Annual gardens	0.0	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0	0
Livestock	0.0	0.00	1.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0					0	0
Poultry	0.0	0.00	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					7	0
Processing of raw products	0.0	0.00	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0	0
Textiles/tailors	0.0	0.00	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					0	0
Health services	0.0	0.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0					0	0
Tobacco and alcohol	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	0.0					0	0
Commerce	-0.1	-0.02	-0.1	-0.1	-0.2	0.0	0.0	1.0	0.0	0.0	0.0	-0.1	0.0					0	0
Massage	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-0.3	0.0	-0.2	-1.0					0	0
Other business and service	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0					0	0
Rafting and elephants	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0					0	0
Construction	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0					0	0
Irrigated land	25.5	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					655	968
Unirrigated land	0.0	9.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					1,244	1456
Orchard	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					707	6980
Labor	14.0	52.83	94.4	229.3	0.0	17.9	8.8	0.3	8.5	1.9	8.8	0.9	0.0					8,478	####
Investible capital	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					126	142
Water pollution (m baht)	0.0	0.00	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					2	4
Deviations in a good year	0.9	0.08	0.5	-0.5	0.9	0.4	0.0	0.0	0.1	2.1	1.3	0.1	1.1	1.0				฿0.00	0
Deviations in an average year	-0.1	-0.26	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.1		1.0			฿0.00	0
Deviations in a bad	-1.0	-0.60	-0.6	0.5	-1.0	-0.4	0.1	0.0	-0.1	-2.3	-1.4	-0.1	-1.2	0.0	0.0	1.00	0.00	฿0.00	0
Total deviations		0.00												0.1	0.5	0.41	-1.00	฿0.00	0
Risk limit		52.83															1.00	฿55.0	55.0

Table 8: Activities ranked by decreasing level of immunization potential

λ	55.0	75.0	65.0	55.0	45.0	35.0	25.0	15.0	5.0	Immunization
Level of VA (m baht)	148.7	153.4	134.1	114.9	95.7	76.5	57.3	38.1	18.0	potential*
Poultry	9.7	9.8	9.5	9.1	8.7	8.4	8.0	7.6	6.5	0.720
Health services	2.4	2.5	2.2	1.9	1.6	1.2	0.9	0.6	0.3	0.153
Irrigated rice	25.7	27.1	23.6	20.1	16.7	13.2	9.7	6.3	2.7	0.134
Water and electricity	4.0	4.2	3.7	3.1	2.6	2.0	1.5	1.0	0.4	0.132
Telephones & commun.	10.3	10.9	9.5	8.1	6.7	5.3	3.9	2.5	1.0	0.130
Annual gardens	5.5	5.8	5.1	4.3	3.6	2.8	2.1	1.3	0.6	0.129
Process raw products	8.7	9.3	8.1	6.9	5.7	4.5	3.3	2.1	0.8	0.119
Schools	15.5	16.2	14.1	12.0	9.9	7.8	5.7	3.5	1.4	0.117
Construction	4.5	4.7	4.1	3.5	2.9	2.3	1.6	1.0	0.4	0.113
Orchards &perennials	6.8	7.3	6.3	5.4	4.4	3.5	2.5	1.6	0.6	0.111
Fish and aquaculture	2.4	2.5	2.2	1.8	1.5	1.2	0.9	0.5	0.2	0.110
Unirrigated agriculture	24.1	25.9	22.5	19.1	15.7	12.3	8.9	5.5	2.1	0.108
Roads/transportation	1.2	1.2	1.0	0.9	0.7	0.6	0.4	0.3	0.1	0.111
Commerce	280.9	302.5	262.7	223.0	183.2	143.4	103.7	63.9	23.7	0.106
Home stay	3.5	3.7	3.2	2.7	2.3	1.8	1.3	0.8	0.3	0.106
Rafting and elephants	33.0	35.6	30.9	26.2	21.5	16.9	12.2	7.5	2.8	0.106
Livestock	16.4	17.6	15.3	13.0	10.7	8.4	6.0	3.7	1.4	0.106
Other handicrafts	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.107
Textiles/tailors	4.3	4.6	4.0	3.4	2.8	2.2	1.6	1.0	0.4	0.106
Other business & service	53.8	57.3	49.8	42.2	34.7	27.1	19.6	12.0	4.4	0.104
Tobacco & alcohol	23.3	20.8	18.1	15.4	12.7	10.0	7.3	4.6	1.9	0.121
Massage	15.8	14.1	12.2	10.4	8.6	6.7	4.9	3.0	1.2	0.113
Housing	2.9	3.2	2.7	2.3	1.9	1.5	1.0	0.6	0.2	0.085
Other tourism &leisure	10.4	2.4	2.1	1.8	1.5	1.1	0.8	0.5	0.2	0.106

* Ratio of level at 5 over 55.

Table 9: Optimized and immunized implementation SEM

	Balance with Logic												CSR					
Optimized and immunized implementation SEM with 30 m baht new investment (IOMM-30) for Por Pieng OBT (m baht)	Irrigated rice	Annual gardens	Unirrigated agriculture	Orchards and perennial flowers	Livestock	Poultry	Processing of raw products	Textiles/tailors	Health services	Water and electricity	Telephones and communication	Tobacco and alcohol	Commerce	Massage	Other tourism aned leisure	Other business and service	Rafting and elephants	Construction
Simulated starting level	22.47	4.84	21.68	6.09	14.74	2.35	7.77	3.91	2.04	3.48	9.06	20.71	253.00	14.18	9.38	48.58	29.75	4.00
Percent change	0.14	0.14	0.11	0.12	0.11	3.11	0.13	0.11	0.16	0.14	0.14	0.12	0.11	0.12	0.11	0.11	0.11	0.12
Optimal level in Master plan	25.66	5.50	24.11	6.79	16.37	9.66	8.74	4.34	2.38	3.97	10.30	23.28	280.95	15.83	10.41	53.85	33.04	4.47
Value added	0.86	0.40	0.14	0.62	0.14	0.88	0.00	0.22	1.00	1.00	1.00	0.00	0.03	0.97	0.21	1.00	0.13	0.00
Irrigated rice	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.04	0.16	0.00	0.00	0.00	0.00
Annual gardens	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	0.04	0.00	0.00	0.00	0.00
Unirrigated agriculture	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	21.5	0.00	0.00	0.00	0.00	0.00
Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.3	0.05	0.00	0.00	0.00	0.00
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.00	0.00	0.00	0.00	0.00
Processing of raw products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.76	0.00	0.00	0.00	0.00	0.00
Textiles/tailors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.00
Health services	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water and electricity	0.00	0.00	0.06	0.00	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.01	0.00	0.00	0.15	0.00
Commerce	2.50	0.10	1.62	0.84	1.05	0.83	1.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.82	0.00
Massage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	3.33	0.00	5.49	4.47
Rafting and elephants	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Construction	0.18	0.00	0.00	0.00	0.64	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00
Irrigated land	26	6	24	7	16	10	9	4	2	4	10	23	281	16	10	54	33	4
Unirrigated land	655	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchard	0	50	1194	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labor	0	0	0	707	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Investible capital	1356	98	478	920	377	497	0	13	21	15	91	0	76	134	20	476	30	0
Environmental pollution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.7 Step 7: The Implementable Immunized Optimum Money Matrix, 30 Million New Investment (IIOMM-30)

While the overall direction of the plan is clear, local leaders, businessmen, farmers and economists find a mathematical spreadsheet intimidating and hard to understand. A complete "implementation matrix" identical in units and structure to the initial matrix (Table 2), but showing the new optimal levels of investment, sales and purchases in each cell would be an enormously practical blueprint for local planners and economists, and enhance communication and trust between them. Such a matrix, shown as the INOMM-0 (Table 9), is easily generated by multiplying the optimal levels of row 6 in Table 7 by the entire UEBM matrix of Table 4.

With such a matrix, planners could even convene the businessmen and producers of each sector to announce what the 5-year plan target levels in each cell of the matrix could be, as compared with the corresponding initial number of the UNMM matrix of (Table 2a).

4 Conclusions

This paper has shown that constrained optimization under multiple constraints can be used to optimize the Master Plan that each sub-district and province in Thailand is currently being asked to prepare. Seven steps were presented that could take sub-district leaders, local planners and the university economists who advise them from the un-optimized non-immunized current situation before additional investment to a clear and implementable immunized optimal SEM for the period 2007-2011 under the assumption of a 30 million baht injection of new investible capital and the simultaneous application of the King's philosophy.

Several methodological innovations characterize this research. First, most analyses of social accounting matrices stop at generating and analyzing multipliers; with the danger that the investments with the largest multipliers may actually violate real-world resource, social, or ethical constraints. Even if they do not, multiplier analysis depends upon trial-and-error and rarely achieves an optimal mix of investments. This study is one of the rare cases where social accounts have been

optimized in the form of a philosophically consistent sufficiency economy matrix (SEM). The second innovation of this research is the re-conversion of the optimized SEM into a palpable implementation blueprint readily operational by local leaders, producers and businessmen. Third, the linked nature of EXCEL spreadsheets allows implementation matrices to be automatically updated for any set of new conditions, or level of immunization, that local leaders may wish to explore. Finally, Thai economists, planners and social practitioners have long been calling for practical tools to implement the King of Thailand's Sufficiency Economy Philosophy. To our knowledge, this is the first tool that does so in completely quantitative terms to guide application and *ex post* evaluation of the success of Master Plans. However, it should also be cautioned that the quantitative results of optimizable SEMs should serve primarily as general indications of the direction of Pareto improvements rather than hard, precise quantitative facts because of the limitations of linear programming and the fixity of coefficients in a social accounting matrix.[14]

5 Suggestions for Further Research

This research is a pilot study of one sub-district composed of 8 villages in Northern Thailand. It has been used to train 130 sub-district level staff from the entire Northern region of Thailand under a major grant from the National Economic and Social Planning Board (NESDB). It could be adapted to other parts of Thailand by data collection in a sample sub-district in each of the three other regions of the country (Northeast, Central, Southern); and then used for training of staff from virtually every sub-district in the country.

But we should recall that the sub-district is not the only level of planning and decision-making in Thailand. Indeed, it is the lowest; and we have started with this level because of the unique bottom-up focus of operationalizing the SEP. The next step is clearly to apply the seven-step procedure to provincial level SEMs, both for individual provinces, and to explore the possibilities for specialization, trade, and

[14]We are thankful to two anonymous reviewers for their comments on the previous versions of this paper.

globalization in the exchange of capital, people, goods and services among provinces within and outside of Thailand.[15]

Future researchers are further invited to develop Bayesian analyses to replace the prior probabilities with posterior probabilities based on updated predictions of rainfall or market conditions for a given year of the plan. In addition, the model presented could be made non-linear in its objective function and or constraints, adding more realism to the functional forms. A formal goal programming model could also be developed to the extent that planners are able to separately weight negative deviations from each goal. Such non-linear goal programming models could be solved using GAMS, GINO or other software. It would seem appropriate to develop these relatively sophisticated models at the national and possibly even provincial levels, but less so at the district level where software availability is far more restricted.

Finally, this paper has treated only a sample subset of Sufficiency Economy concepts and indicators. Other indicators could be added so as to make each SEM more complete and internally valid, while allowing for better comparisons (external validity) among sub-districts and provinces over both space and time. Notably, the monastic sector could and should be added in the institutional bloc as both a row and a column, with the amount of charitable offerings from the lay population constituting the main source of income and the poverty-alleviation and orphanage expenditures constituting the principal outlays. The optimal size of the monastic sector in a society fully reflecting the King's SEP could then the determined.

References

Anderson, T. M., (2008), "The Scandinavian Model—Prospects and Challenges," *International Tax and Public Finance*, 15, 45-66.

Boulding, K. E., (1981), "Agricultural Economics in an Evolutionary Perspective," *American Journal of Agricultural Economics*, 63, 788-795.

[15]Such a project is currently under way at the Faculty of Economics, Chiang Mai University with a major funding grant from the Thailand Research Fund. It links six provinces along the East-West Economic Growth Corridor (EWEC), ranging from Moulemyain in Myanmar to Da Nang in Vietnam, and connecting Pitsanulok, Khon Kaen and Mukdaharn in Thailand, and Yunnan in China.

Calkins, P. H., (1981), "Nutritional Adaptations of Linear Programming for Planning Rural Development," *American Journal of Agricultural Economics*, 63, 247-254.

Hazell, P. B. R. and P. L. Scandizzo, (1974), "Competitive Demand Structure under Risk in Linear Programming Models," *American Journal of Agricultural Economics*, 56:235-44.

Lin, W., G. W. Dean, and C. V. Moore, (1974), "An Empirical Test of Utility vs. Profit Maximization in Agricultural Production," *American Journal of Agricultural Economics*, 56, 497-508.

Porter, R. B., (1973), "An Empirical Comparison of Stochastic Dominance and Mean-Variance Portfolio Choice Criteria," *The Journal of Financial and Quantitative Analysis*, 8, 587-608

Loucks, D. P., C. S. Revelle, and W. R. Lynn, (1967), "Linear Programming Models for Water Pollution Control," *Management Science*, 14, 161-181.

Loulou, R. and A. Kanudia, (1999), "Minimax Regret Strategies for Greenhouse Gas Abatement: Methodology and Application," *Operations Research Letters*, 25, 219-230.

Ragsdale, C. T., (2000), *Spreadsheet Modeling and Decision Analysis*, 3rd edition, South-Western College Publishing.

Wiboonpongse, A., S. Sriboonchitta, N. Therakul, K. Kanmanee and P. Prabripoo, (2009), "The Research - Development Project on Agriculture and the Community Enterprise System Based on the Sufficiency Economy Philosophy," Report submitted to Thailand Research Fund, Multiple Cropping Center, Chiang Mai University.