A SYSTEM DYNAMICS APPROACH TO ANALYZE THE EFFECT OF HIGH SET UP TIME OF MACHINES ON MARKETING GROWTH THE CASE OF PACKAGES LTD. PAKISTAN

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ABSTRACT

This study aims at exploring the policies for the order arrival rate from decision making bodies in order to smooth down the activities of production by lowering the set up time of machines. The impact of scheduling techniques is examined and production and market operations are observed carefully in order to solve the problem of reduced proportion of machine running time. Everything seems to be okey but the proportion of machine running time has the declining trend. Especially, the production and market operations are considered with the positive and negative feedback loops that influence the proportion of machine running time. Ultimately, the decision is made to solve the problem by the construction of formal System Dynamics Model to analyze the interaction of different components of the company. The model provides a detailed, integrated framework among separate facets of the issue addressed representing the past behaviour of the production sector. Experimentation with the model attempts to identify the appropriate policies concerning proportion of machine running time.

INTRODUCTION

Organizations and their conversion sub-systems are dynamic. New demands are placed on the organization from various sources, managerial processes and actions are continually in motion. Because the different areas are inter-related within an organization. Changes in one facet stimulate changes in others (Forrester, 1964).

In most cases, the behaviour of the sale sector in the industry is customer-oriented. This affects the smooth operations of the production sector (Pegels, 1991). Random arrival of orders disturbs the loading schedule of the machines, resulting in an increase in set up time and set up cost. Set up time is often regarded as a necessary evil. A common measure is to try to render it proportionately insignificant by increasing the batch size (Bassett, 1991). This results in the generation of excessive stock and work-in-progress for those customers whose annual demand is bigger than economic lot size, but orders of loyal customers are from time to time and have rights of priority over new customers whose annual demand is generally smaller than economic lot size, and whose orders are made once or twice in a year. For loyal customers the company can meet the demand if the order size is lower than the economic order quantity because excess inventory can be kept for standard product. However, for new customers if the order size is lower than the batch size then the order can not be accepted as it does not cover the associated cost and operating expenses due to the orders made once or twice in a year, in a manufacturing industry we can meet the demand of customers irrespective of the order size by keeping inventory. For this reason, batch size approach is not appropriate, especially for the Packaging sector where inventory carrying concept is not realistic as sheets are printed according to order booked. Every order is distinct in nature and comes

from the new customer and loyal customer.

Both new customer orders and loyal customer orders arrive at the machine according to two independent streams and form a single queue of pending orders according to the order in which they arrive. More pending orders of a loyal customers develop willingness in them to get the priority over new customer orders by using the priority rights of the loyal customers. This changes the best plan (sequence) to machines. Timely non-availability of input resources such as paper, printing ink and mechanical causes rifts and conflicts among workers when they interact with the concerned departments in the provision of resources. This affects the worker's effectiveness and they take more time to adjust machines. This brings increase in set up cost and decrease in proportion of machine running time. Proportion of machine running time is the ratio of machine processing time divided by time available to workers. Consequently proportion of the machine running time falls down, worker effectiveness declines, resource wastage increases and price with respect to competitors increases. That is why profitability which is good internal efficiency measure of the company has a declining trend indicating reduced profit per unit sheet sold.

OBJECTIVES

The key objectives of this study followed by the model formulation and policy experiments are :

1) To find out organizational factors influencing high set-up cost and low proportion of machine running time.
2) To identify the factors which influence the worker effectiveness.
3) Experimentation with the System Dynamics model to search policies for maximum proportion of machine running time.
4) To develop the guidelines for reducing the set-up time by decreasing the changes in loading schedule of machines.

This study is done through a system dynamics modelling approach developed by Forrester. The model is developed for policy makers in Packaging sector. The framework of the model can be generalized to any industry which has the specific characteristic like, random customer demand, production processes are sale-oriented, job-shop type operations.

MODEL BOUNDARY

The important issues of the model to be addressed define the boundary of the model. The variables which influence the model behaviour but do not have relation directly with the issues to be addressed are exogenous inputs that lie outside the model boundary. The issues are the operation of the machines which is influenced by the effective workforce, change in loading schedule and many other implicit factors, the second issue is the production which is affected by the operation of the machines and third issue is the market sector from where the new customers enter into the system.

Input resources like paper, ink, printing plate and raw materials required for the adjustment of machines are the exogenous variables. The other variables that lie outside the model boundary but they influence the new customer orders are market demand, reputation of the company and printing quality.

Following are the key assumptions implicit in the model structure:

1 Printing quality and reputation of the company are the time dependent parameters but we assume, here, they remain constant over the passage of time.

2 Delay in input resources such as paper, ink, plate and cleaning agents is negligibly small and is normally regarded as zero.

3 Effective workforce loses its performance at the low periods of proportion of machine running time.

4 Worker's efficiency and effectiveness contribute in direct proportion to the machine running time.

5 Loading Schedule of orders is the best plan no other schedule (job-sequence) can optimize the production as planned sequence. Loading schedule software prepares the loading schedule (planned job-sequence) considering job order size, release and due times, gripper adjustment factor and colour sequence of printing.

FEEDBACK STRUCTURE OF THE MODEL

Salesmen-Effectiveness And Market Loop

Because the variables successively determine one another, the description can be started at any point, with the incoming order rate for instance. The incoming order rate adds to the backlog. The delivery delay recognized by market is the sum of the time required for a new order to move through the backlog of work awaiting production, for it to be produced and for it to be shipped to the customer, (Edward B. Robert, 1978). Sales effectiveness begins to decrease. Order rate begins to level off, and revenue no longer supports the rapid expansion of sales force, (Forrester, 1967). The result is, less customers are found and average order booking falls down. This negative loop in its entirety tends to adjust order booking rate equal to the maximum delivery rate.

Capacity Expansion Loop

One of the most important and fundamental decisions facing a growing company is how much to invest in production capacity. Insufficient capacity can result in loss of market share, growth below potential and reduced profits. Excess capacity can lead to low profitability and price cutting.

Investment on capacity expansion does not depend on future demand. In my case, capacity expansion decision is independent of the forecasting aspect and the value of delivery delay higher than the delivery delay management goal compels the management to increase the production capacity to sustain the market share. After the interval of production capacity receiving delay; production increases assuming the machinery installation time is negligibly small. Delivery rate increases and delivery delay falls down. This negative loop tries to adjust the capacity ordering rate towards the delivery delay condition.

Worker-Attrition Loop

This loop is positive feedback loop. Machine running time is affected by changes in loading schedules and it is compounded by effective workers. Labour is a production resource whose lead time and cost also vary widely. Lead time is influenced by the tightness of labour markets and by the length of training delays; cost by skill level and the labour intensity of the product, (Lyneis, 1980). Effective workforce has a direct effect

on the proportion of machine running time.

Low proportion of machine running time delineates that percentage effectiveness per machine crew is lowered that indicate the inefficient use of resources. Changes in perceived level of productivity arise from expected schedule slippage; when the job seems to fall behind schedule, the company tends to lower its estimate of productivity, (Roberts, 1978). Management tights the labour, % equitable benefits cut short, annual special increments are not according to worker's expectations. This demoralize the workers and reduces the worker's energy level. When one's energy level is low, one is easily distracted from the task at hand and prone to erratic performance, (Homer, 1985). The reverse is increased value of % effectiveness is an indicator of worker internalized motivation which improves productivity (Saeed, 1992), lowers worker attrition and further increases in proportion of machine running time is the result; virtuous cycle continues.

Corrections & Modifications Loop

Corrections and Modifications loop is negative feedback loop that negates the external disturbance. Changes due to the corrections and modifications in orders are the result of backlog orders. These changes delay the smooth process of system. The job which has been planned for loading purpose has to be rescheduled in the light of amendments. Frequent changes in the loading schedule influence the worker effectiveness and proportion of machine running time. Consequently, lowered output implies to reduce the salesforce budget assuming there is no other external variable exists. Reduced number of customer found indicates the decreased value of salesforce. As a result average order booking is lowered. Backlog will decline and corrections and modifications will decrease. Consequently proportion of machine running time will increase. It appears that company attitude to change schedule is customer-oriented. High backlog order has less effect on company attitude to change schedule and as a result more changes in loading schedule occurs that decline the proportion of machine running time. Changes due to loyal customers can be zero in the system when the number of loyal customers do not exist. Changes due to corrections and modifications can as well be zero when the order backlog is zero but company attitude to change the schedule always has some value due to orders in process and not yet completed. That is why company attitude to change schedule has the multiplicative effect in the equation of willingness to change the loading schedule and changes due to corrections and modifications and changes due to loyal customers have additive effect as they can be zero.

Actually the low value of proportion of machine running time due to the high backlog order is the main cause of resource wastage. The overall structure of the model in the form of causal relations is depicted in Fig.(1)

Parameter Sensitivity Test

Sensitivity analysis is an element of most formal modelling processes (Randers, 1980). Structure verification and parameter verification are interrelated. Parameter verification means comparing model parameters to knowledge of the real system to determine if parameters correspond conceptually and numerically to real life (Forrester & Senge, 1980). Conceptual correspondence means that parameters match elements of system structure. If a reasonable change in a parameter value causes the characteristic response pattern of a system to shift, the parameter is sensitive (Richmound, 1987). Parameter insensitivity is an important dimension of a model that should be compared with the real system to enhance confidence in the model (Saeed, 1990). Parameters are

tested one at a time keeping all others constant as this test is a controlled experiment. Patterns are observed and results of key variables are summarized in the table (I). The summarized results calculated at the point of time (length = 495 months) provide a criteria for the parameter classification and base to formulate observations which are as follows:

(1) Observation for insensitive parameters is "plus minus fluctuations around the mean value of a parameter do not affect the trend (increasing or decreasing) of percentage error and magnitude of numerical values remain same."

(2) Observation for insensitive parameters is "plus minus fluctuations around the mean value of a parameter do not affect the trend (increasing or decreasing) of a percentage error and magnitude of numerical values do not remain same."

(3) Observation for sensitive parameter is "plus minus fluctuations around mean value of a parameter affect the trend (increasing or decreasing) of the percentage error and one of the parameter has a large value of a percentage error.

EXPLANATION OF SYSTEM BEHAVIOUR

Before simulation experiments are conducted with the model, initial values representing approximate real data of the company are substituted. To test the hypothesis, order rate is stepped up by 20 %. In equilibrium, the order rate was 25600 thousand sheets booked per month. With 20 % step size means now the order size is 31296 thousand sheets per month. The stock of backlog order has the initial value 32600 thousand sheets to be processed. By the 20 % step size, after the month of 25 the backlog order should be equal to 815000 thousand sheets assuming delivery delay rate is zero. But due to the delivery rate and fall in order booking the peak of backlog order stock is 125000 thousand sheets per month. In fact, this 20 % increase in order size has activated negative and positive feed back loops in the system. Sale effectiveness and market loop depicts that with high backlog order, the delivery delay impending increases and customers perceives the delivery delay (delivery delay recognized by market). Ultimately, the effectiveness of salesmen falls down and order booking decreases. This negative feedback loop tends to negate the disturbance. When the order rate is falling, backlog order rate is increasing. At that time, declining order rate (inflow) is still higher than delivery rate (outflow). That fills the stock of order backlog. Backlog order should be high, delivery delay recognized by market must be high with the relative phasing of 10 months equal to time taken for delivery delay recognized by company plus time taken for delivery delay recognized by market as shown in Fig. (2)

Decrease in delivery rate is due to the another negative loop. High backlog means high corrections and modifications in the system. No doubt with high backlog company attitude to change the schedule will be low, but system structure indicates that this behavioural relationship does not shift the dominance of this loop. As a result more changes occur in loading schedule and proportion of machine running time falls down that decreases the production rate. The other variable which influence the proportion of machine running time is percentage effectiveness of machine crew. Percentage of effectiveness does not decline as effect of productivity on worker attrition is not significant. See Fig. (3) When the proportion of machine running time has got its lowest value then fall in effectiveness is negligibly small. Effective workers decrease due to high experience worker attritions and experience workers leave the organization whenever they get the better opportunity. At time month 78, the proportion of machine running time is low.

Delivery rate is conceptually equal to production rate so it also falls down. Lower value of proportion of machine running time is a good indicator of high resource wastage and the high value of cost per sheet. Increase in price with respect to competitors also affects the order booking.

When backlog reaches to the maximum value at period of time 70. Greater changes in loading schedule occurs due to high amendments and modifications. The result is low proportion of machine running time, low production rate, low shipment rate and lower value of cash upto the month 70. Cash is the product of price and shipment and cash borrowing is additive variable in cash flow equation. Company price with respect to competitors can not be so high consequently the cash pattern will similar to the shipment rate. Capacity expansion fraction, no doubt, starts increasing due to high delivery delay condition but it attains maximum value at the time period of 60 months, where as production capacity starts increasing with the increase of capacity expansion fraction and at maximum value of capacity expansion fraction at period of 60 months. Increase in production capacity increases the production rate, consequently sheets shipments increase. Budget allocated for salesforce increases, more salesmen are hired and order booking increased and as a result backlog order stock further piled up. This positive loop gives more strength to the external disturbance. High value of cash, backlog order, production capacity, salesmen, loyal customers and new customers are the good indicators to tell the story that this positive loop is more dominant than other existing negative major and minor loops in the system.

POLICY ANALYSIS

Various policies were tested in the simulations. Primarily policies tested are based on sensitive parameters. Secondly, policy experiments are performed on the basis of mental initution and perception about the problem solution based on the information provided by factory workers and factory managers. The last deals with the combination of some promising policies. The different policies incorporated into the model for generating the reference mode are the following:

A) Personnel Management
1) Worker Training Programmes
2) Slowing Down Worker Recruitment
3) Worker Motivational Schemes
B) Information Management
4) Speed up Information Flow about Price from Market to Shopfloor
5) Speed up Information Flow about Resource Wastage from Rationalization Department to Shopfloor
C) Operations Management
6) Changing Operational Priorities
7) Fixing Target In Resource Wastage
8) Fixing Aggressiveness For Market Operations

The policy no. 6 aims to increase the rigidness to the planned schedule and tells to keep always assumption (no. 5) as a sacred. This policy further extends this assumption that software must have the information about production capacity of machines and total stock of backlog orders. Ratio of new customers and loyal customers is incorporated in the preparation of software. Ratio of backlog orders and production capacity must be used as a indicator in day to day decision making process. This ratio

acts as an input signal to the table function which generates policy and gives information. At what value of delivery delay minimum, upto what extent corrections and modifications are acceptable. In real world, if order booking is based on advertisement or price, its impact is short-term and order booking is seasonal; but if the order booking is as the result of minimum delivery delay or good printing quality then it is more stable and sustainable. The results of experimented policies shown in table (II) indicate that policies based on information management and personnel management are not much effective. The results of policy changing operational priorities are prominent as it increases proportion of machine running time almost 15 % but delivery delay recognized by market increases by 25 days.

CONCLUSION

This study suggests that operations management policies are more effective than policies based on information management and personnel management. Changing Operational Priorities to loading schedule **(Policy run 6)** can only provide the increased value of proportion of machine running time if assumption number (5) is observed. The important finding for recommendation is give more weightage to production people than salesforce. Normally sales people are considered as the bread earner and in every where, treated as special people but my findings are production people are more important and valuable. In real life, people normally emphasize about the personnel management and information management and try to seek solutions of their problems relating these two. But operations management is the important entry point to solve the problem and policies based on operations management are more stable and has long-term impact.

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SENSITIVITY ANALYSIS					
Variables	**Constants (Months)**	**Proportion of m/c R. Time (%)**	**Delivery Delay R. M (%)**	**Sales Effectiveness (%)**	**Resource Wastage (%)**
Worker Training Time **	70	-4.44	54.26	2.865	1.5
Worker Training Time **	90	-4.7	82.94	-3.408	1.398
Vacancy Creation Time **	1.25	5.277	123.2	-3.87	-1.46
Vacancy Creation Time **	0.75	-39.3	-335.9	-3.87	12.3
Vacancy Filling Time **	1.25	-3.11	38.4	-2.46	0.995
Vacancy Filling Time **	0.75	-6.01	116.53	-3.42	2.076
Shipments Time	1.25	-5.53	132.54	-3.875	1.98
Shipments Time	0.75	-1.57	39.5	-2.78	0.49
Customer Transfer Time	20	-2.68	69.3	-3.48	0.79
Customer Transfer Time	40	-6.42	154.4	-3.87	2.34
Salesment Adjust. Time	24	-3.54	91.85	-3.87	1.1
Salesment Adjust. Time	6	-3.54	91.85	-3.87	1.1
Average Equipment Life	260	-3.55	92.05	-3.87	1.1
Average Equipment Life	220	-3.544	91.87	-3.87	1.1
Price Adjustment Time	20	-3.54	91.85	-3.87	1.1
Price Adjustment Time	1	-3.54	91.85	-3.87	1.1
Customer Decay Time **	40	-12.81	260.5	-3.875	5.58
Customer Decay Time **	60	0.771	7.03	-0.739	-0.295
Time to Delivery Delay BM.	12	-3.54	91.85	-3.87	1.1
Time to Delivery Delay BM.	3	-3.54	91.85	-3.87	1.1
Time to New Worker Attrition	3	-3.54	91.87	-3.42	1.1
Time to New Worker Attrition	24	-3.54	91.87	-3.87	1.1
With Test Input					
Variables	**Constants (Months)**	**Proportion of m/c R. Time (%)**	**Delivery Delay R. M (%)**	**Sales Effectiveness (%)**	**Resource Wastage (%)**
Worker Training Time **	70	-0.6616	-0.539	0.0646	0.198
Worker Training Time **	90	0.703	0.629	-0.068	-0.197
Vacancy Creation Time **	1.25	11.57	-12.6	3.09	-3.067
Vacancy Creation Time **	0.75	-35.6	-0.82	0.094	12.33
Vacancy Filling Time **	1.25	0.143	0.00416	0	0
Vacancy Filling Time **	0.75	-0.014	-0.0166	0.004	0
Shipments Time	1.25	-0.0025	0.1	-0.0086	0
Shipments Time	0.75	0.00259	-0.1	0.0129	0
Customer Transfer Time	20	0.248	1.67	-0.184	-9.88
Customer Transfer Time	40	-0.192	-1.34	0.155	0
Salesment Adjust. Time	24	0.0583	4.13	-0.445	-0.0988
Salesment Adjust. Time	6	-0.0466	-2.43	0.285	0
Average Equipment Life	260	-0.173	-2.428	0.285	0
Average Equipment Life	220	-0.175	2.63	-0.287	-0.098
Price Adjustment Time	20	0.007776	0.187	-0.0172	0
Price Adjustment Time	1	-0.0051	-0.0583	0.0129	0
Customer Decay Time **	40	-3.38	50.19	-3.06	0.999
Customer Decay Time **	60	-1.208	-30.64	14.196	0.2976
Time to Delivery Delay BM.	12	-0.03886	-0.0583	0.0086	0
Time to Delivery Delay BM.	3	0.00907	-0.0918	-0.0086	0
Time to New Worker Attrition	3	-0.01036	0.01668	0	0
Time to New Worker Attrition	24	0.0142	0.0125	0	0

Note

(a) Negative Values indicate increase in parameters.
(b) Percentage Error = (Base run value - Sensitivity run value) / Base run value
(c) Double astrick (**) indicates the sensitive parameters.

TABLE I

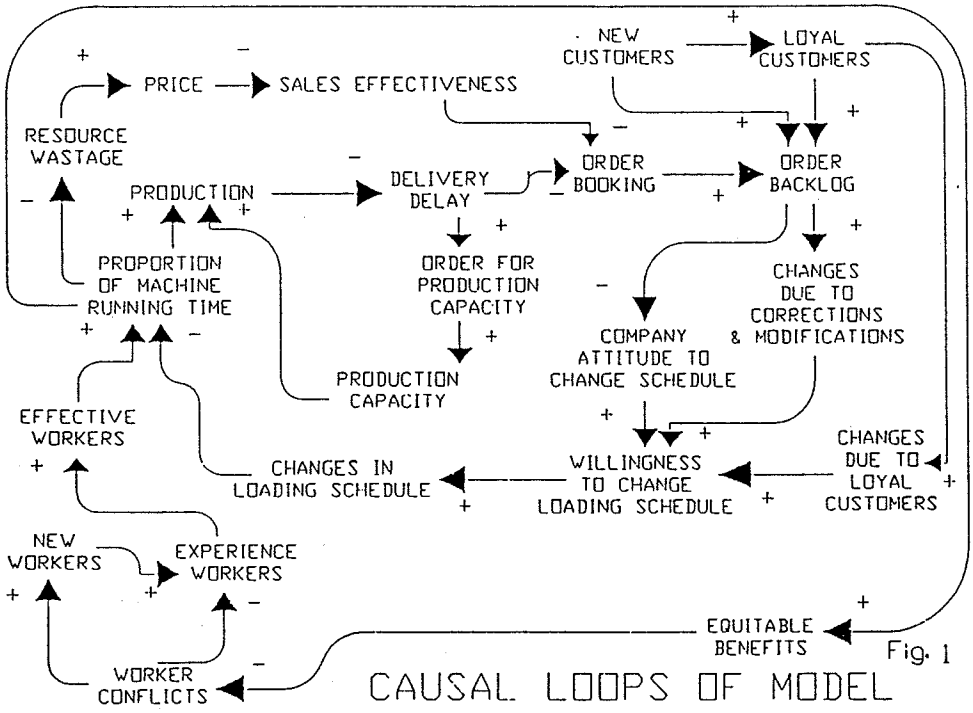

Fig. 1

CAUSAL LOOPS OF MODEL

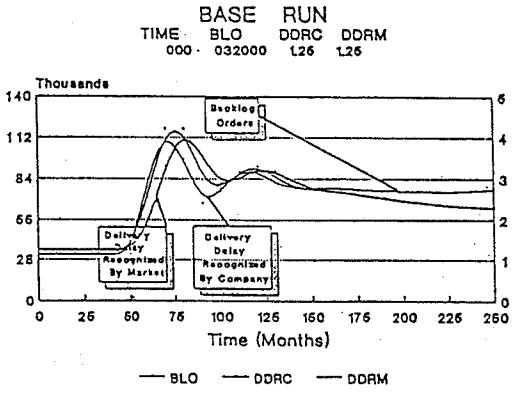

Fig. 2

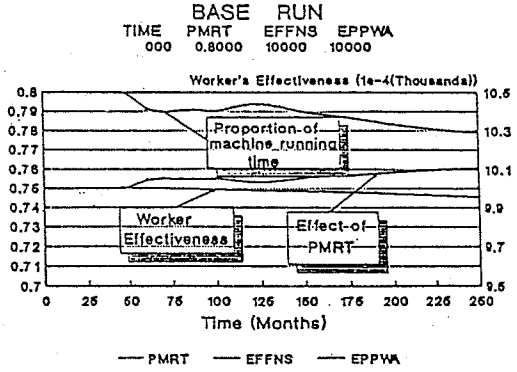

Fig. 3

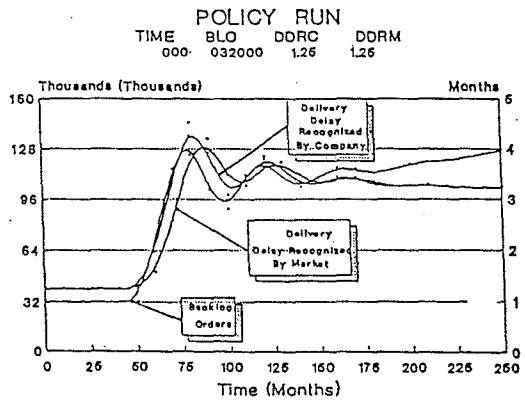

Fig. 4

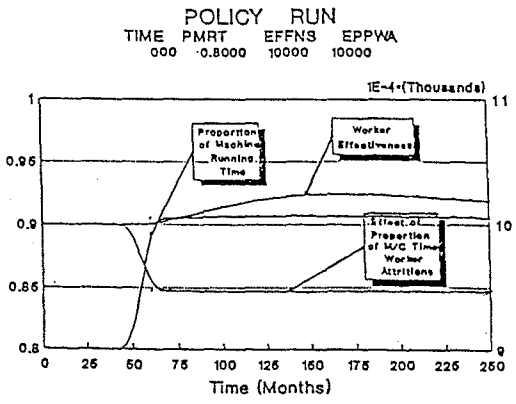

Fig. 5

EXPERIMENTED POLICIES				
Policies	Order Booking (%)	Machine Running Time (%)	Production Capacity (%)	Delivery Delay Recog. By Market (%)
Policy Run 1	-0.401	-2.89	-1.15	-2.75
Policy Run 2	0.024	0.059	-0.0319	-0.0319
Policy Run 3	-2.98	-2.082	-0.9031	-1.86
Policy Run 4	-4.269	-3.01	-1.3	-2.76
Policy Run 5	-3.56	-2.515	-1.09	-2.166
Policy Run 6	-22.09	-14.95	-8.08	-25.5
Policy Run 7	0	0	0	0
Policy Run 8	0	0	0	0
Policy Run 2 & 6	-21.81	-14.73	-8.08	-25.4
Policy Run 2, 4 & 6	-12.73	-6.3	-6.74	-7.75
Policy Run 3, 4 & 6	-12.73	-6.34	-6.742	-7.726

Note: Negative values indicate increase in values of variables from base run values.

Table II