Construction of Econometric Planning Models for Business Units

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Abstract

This paper describes a method for constructing econometric planning models that can translate macroeconomic information into projected income statements for each of a corporation's various business units. Each business unit is modeled by equations expressing historical relationships between micro variables of interest (sales, various costs, net income) and their macro and/or internal determinants. The text provides guidelines for designing a model structure, specifying and estimating major equations, and using the model.

I. INTRODUCTION

Practically every major U. S. corporation is now linked, via computer time-sharing technology, to at least one macroeconomic forecasting service. Such a service will provide forecasts for each major final demand component of GNP and, typically, for prices, production, and investment by two-digit (SIC code) industry. This paper describes a method for constructing "satellite" econometric models that can translate this macroeconomic information into projected income statements for each of a corporation's various profit centers or business units. This methodology has been applied to business units (representing a variety of market structures and production technologies) within the Westinghouse Electric Corporation, and reference will be made to this experience.

Each business unit is modeled by a set of equations expressing historical relationships between micro variables of interest (sales, various costs, net income) and their macro and/or internal determinants. Each model is, typically, highly disaggregated with respect to organizational sub-units (i.e., divisions, products), and the amount of line item detail provided for each sub-unit. Consequently, these models can serve the traditional management function of "top-down" control; while, simultaneously, providing independent and timely inputs to the corporation's "bottom-up" strategic planning process. The sections that follow will provide guidelines for:

Section II. designing a model structure to serve both control and planning functions,

III. specifying and estimating major equations within constraints imposed by accounting data,

IV. using the model to impart consistency, simulative capability, and precision to the business unit's planning process.

II. MODEL STRUCTURE

Input-Output Detail

Each Westinghouse business unit model has been implemented on a time-sharing computer system, and can be accessed by the business unit's planning staff via a relatively simple interactive program. A new forecast may be generated by:

(i) inserting new values for exogenous (macro and/or micro) variables, and/or

(ii) inserting new values for the add-factors attached to the various stochastic equations.

The "macro" exogenous inputs consist primarily of projected market demand indicators and material price indexes supplied by an outside macroeconomic forecasting service. "Micro" inputs consist of projected manpower compensation rates and other in-house information supplied by the business unit. Table I provides an example of inputs required by a model for a Westinghouse business unit serving the construction market. Given these inputs, computations within the model move recursively from industry shipments to sales to various costs and, finally, to net income. Table II lists the model's major output. Projections (current plus five years ahead) for these income statement items are, in some cases, used to drive "cash flow" and balance sheet models.

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Table I

EXAMPLE OF INPUTS REQUIRED BY A "SINGLE PRODUCT" BUSINESS UNIT MODEL

MACRO INPUTS

(a) Gross national product, 1972 dollars.

(b) Rental price of capital – structures.

(c) Rental price of capital - equipment.

(d) Expectations variable for real output.

(e) Ratio of interest payments on debt to cash flow (nonfinancial corporations).

(f) WPI (Wholesale Price Index) for textile products.

(g) WPI for rubber and plastics products.

(h) WPI for lumber and wood products.

(i) WPI for pulp, paper products.

(j) WPI for metals and metal products.

MICRO INPUTS

(k) Index of hourly compensation rate.

(ℓ) Index of salaried compensation rate.

(m) Other income.

(n) Tax credits.

(o) Foreign exchange (gains or losses).

(p) Noncontrolled (i.e., allocated) costs.

Table II

LIST OF MAJOR OUTPUT FOR A [illegible] BUSINESS UNIT MODEL

(a) Industry Shipments (current & constant $)

(b) Sales Billed (current & constant $)

(c) Price Index

(d) Direct Product Costs

(e) Operating Managed Costs

(f) Strategic Managed Costs

(g) Depreciation – Lease Expense

(h) Insurance/Taxes/Holidays/Vacations

(i) Noncontrolled Costs

(j) Cost of Goods Sold

(k) Operating Profit

(ℓ) Foreign Exchange – gain or loss

(m) Interest Expense

(n) Total Costs

(o) Income Before Taxes

(p) Income After Taxes

A novel feature of Table II is the degree to which "Cost of Goods Sold (j)" has been disaggregated into its various components (d through i). This allows management to establish objectives by line item and then provide a detailed performance evaluation. Aside from facilitating management control, such disaggregation also enhances the model's strategic planning capability by giving the user control over a larger set of variables.

Product Submodels

A typical Westinghouse business unit will bring together products which, though similar with respect to ultimate function and end-markets, are often quite dissimilar with respect to production process. For purposes of management control over day-to-day operations, these products are usually segmented, by production process, into divisions. Thus, from the standpoint of achieving homogeneity with respect to cost structure, the business unit model might be disaggregated in terms of division submodels. Unfortunately, the larger business units conduct their strategic planning in terms of market segments, where the latter may require the participation of two or more divisions.

Thus, if the model is to serve both management control and strategic planning functions, submodels must be defined by aggregating product lines with similar cost structures, subject to the constraint that every product within a submodel be cross-referenced by the same market segment and division.

A further distinction occurs with respect to the level at which various performance measures can logically be modeled. Prices, sales, and "variable" costs can be modeled at the level of a product submodel. "Fixed costs," however, are (by definition) common to a set of products and should, therefore, be modeled at the division or even at the business unit level. If demanded, forecasts for these fixed costs can be allocated back to the submodels via the same (arbitrary) factors used by the controller's department.

Each business unit mode, in short, has been structured so that forecasts for divisions (control function) and market segments (planning function) can be obtained by aggregating across relevant product submodels. When aggregating to the business unit, an "X-elimination algorithm" may be needed to net-out intra-unit sales and costs.

III. SPECIFICATION AND ESTIMATION OF MAJOR EQUATIONS

Data Limitations

Parameter values for all major behavioral equations are estimated by regression technique from annual historical data. Data problems at the business unit level are, of course, nontrivial. A sales history of sufficient length to yield efficient parameter estimates can usually be obtained with relatively little difficulty.

The construction of a consistent cost history, however, is often constrained by changes in both organization structure and accounting conventions; not to mention the accountant's aversion to keeping any record for more than a few years. Consequently, cost functions require a relatively parsimonious specification so as to conserve degrees of freedom.

For the sake of exposition, each business unit submodel can be decomposed into three modules relating to sales, costs, and net income equations. The following pages describe the specification and estimation of major equations within each module.

Sales Module

The sales module translates macro forecasts into projections for each submodel's market price, industry shipments, and product sales. There are almost as many different price equation specifications as there are markets. A very general specification, encompassing a variety of market structures, is given by

$$P_1' = a_o + a_1 w_1 + a_2 m_1 + a_3 d_i + a_4 \text{ time} \qquad (1)$$

where:

P_i' = market price index for product (i.e., submodel) i,

w_i = index of industry wage rate,

m_i = composite index of material prices,

d_i = measure of market level or "tightness,"

time = time trend (measure of ignorance),

a_o, a_1, a_2, a_3, a_4 = coefficients to be estimated.

For any given product, one or more of the coefficients may be zero. The majority of equations express variables as "percent changes" to mitigate collinearity. The composite index of material prices, m, is a weighted average of various "Bureau of Labor Statistics" Wholesale Price Indexes" and, thus, captures the impact of commodity-based inflation. The weights themselves are typically derived from an input-output table [1], and represent the relative contribution of the corresponding material to the products' total material costs. All right-hand variables are treated as (if) predetermined and, consequently, ordinary least squares is used to estimate parameter values.

"Value of industry shipments" (VIS) specifications also vary. Products produced by industries in which Westinghouse participates are, with a few exceptions, sold to other industries (rather than to households). If the product is sold on current account, the following specification is typical.[1]

$$\left(\frac{VIS(t)}{P(t)'}\right) = a_o + a_1 \left(\sum_j b_{ij} \, FRB(t)_j\right) + a_2 \, Z(t), \qquad (2)$$

where:

b_{ij} = percent of i^{th} industry's output consumed on current account by the j^{th} industry during a sample year, $(\sum_j b_{ij} = 1)$,

$FRB(t)_j$ = Federal Reserve Board index of Production for j^{th} buying industry,

Z(t) = macroeconomic variable(s), in constant dollars,

a_o, a_1, a_2 = coefficients to be estimated.

The b_{ij} weights are derived either from an input-output table or from in-house information. The macro variable(s), Z(t), will capture changes in the sample year (fixed) weights arising from product substitutions, the business cycle, changing import-export balances, etc. If, on the other hand, the product is sold on capital account (i.e., as "producer's durable equipment"), then one of two approaches may apply:

(a) The j^{th} buying industry's "Investment in Plant & Equipment (IP&E) becomes the regressor.

(b) The factors which <u>determine</u> the j^{th} buying industry's investment become the regressors.

The first approach leads to the following specification,

$$\left(\frac{VIS(t)}{P(t)'}\right)_i = a_o + a_1 \sum_j c_{ij} \, IP\&E(t)_j + a_2 \, Z(t), \qquad (3)$$

where:

c_{ij} = percent of i^{th} industry's output purchased on capital account by j^{th} industry during a "typical" year,

$IP\&E(t)_j$ = Investment in Plant & Equipment by j^{th} industry in constant dollars.

The c_{ij} are calculated from a Department of Commerce capital flows table [5], or, in some cases, from a Battelle Memorial Institute study [6].

Unfortunately, construction expenditures and electric power industry IP&E forecasts provided by the macro forecasting firms are seldom sufficiently disaggregated to be of use to business units selling to these two sectors. In such cases, VIS is modeled as a function of those variables which determine the buying industry's "net" and replacement investment. Thus, for example, the following

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[1] Similar specifications and illustrations are provided by [2] and [3]. An alternative, and more general approach, is to solve the I-O model for coefficients representing cents worth of output from i required directly and indirectly to support one dollar of (each) final demand. Applying these coefficients to each final demand series produces a "generated output" series to be regressed against VIS. See [4].

specification will hold for certain products related to electric power "transmission and distribution,"[2]

$$\left(\frac{VIS(t)}{P(t)}\right) = a_o + \sum_{n}^{T} \omega_n \cdot H\&MHUSTS(t-n) + a_2\, K(t-1)_i,$$

$$n = 0, 1, \ldots T \text{ time periods}, \quad (4)$$

where:

$H\&MHUSTS(t-n)$ = housing starts and mobile home shipments during the t-n[th] period,

$K(t-1)_i$ = proxy for beginning-of-period stock of product i held by utilities,

ω_n, a_2 = coefficients to be estimated.

Current and lagged levels of housing starts are used to explain the utilities' new customer demand for the product. The stock variable captures replacement demand. The ω_n coefficients are estimated by the method of polynomial distributed lags [8, pp. 294-98].

Finally, the business unit's i^{th} product line sales (constant dollars) will be related to its industry counterpart by the following general specification,[3]

$$\log \left(\frac{SALES(t)}{P(t)}\right)_i = \log b_o + b_1 \log \left(\frac{VIS(t)}{P(t)}\right)_i + b_2 \log z, \quad (5)$$

where:

sales(t) = business unit sales billed for the i^{th} product group,

z(t) = predetermined variable(s) operating on market share independently of market level,

b_o, b_1, b_2 = coefficients to be estimated.

[2] VIS equations for construction-related products are modeled along lines suggested by the "neoclassical" investment function [7]. Regressors include current and lagged macro real output variables, plus measures of cost-of-capital and availability-of-funds.

[3] Manufacturing lead times for some types of electric power equipment are long enough so that "orders backlogged" can be used to produce (three to five years ahead) sales projections.

Since $Ship(t)_i$ is a component of $VIS(t)_i$, ordinary least squares estimates will suffer from "simultaneous equation bias."[4] Where this is deemed a serious problem, a two-stage estimation procedure employing "fitted" values from the $VIS(t)_i$ equation has been utilized [8, p. 380]. Current dollar sales are obtained by applying the price forecast, $P(t)_i$, to the constant dollar sales projection. Aggregation across relevant submodels then produces a (current and constant dollar) sales projection for each division, market segment, and, of course, for the business unit.

Cost Module

The cost module combines the sales projections with various macro and micro exogenous forecasts (relating primarily to input prices) to generate projections, at the level of a product submodel, for the "variable" cost items and, at the division or business unit level, for the remaining "fixed" costs. The former can be further divided into:

(i) Production costs (item d, Table II),

(ii) Managed costs (items e, f Table II).

The distinction is made on the basis of relative management control. Given sales and factor prices, management's control over production cost items (direct labor, materials, factory expense) will be constrained by technical relationships embodied in the "production function." These technical constraints can be summarized by the following (short-run) "Cobb-Douglas" function

$$\left(\frac{SALES(t)}{P(t)}\right)_i = A\, L_i^{\alpha}\, M_i^{\beta}\, E(t)_i^{\lambda}, \quad (6)$$

where:

L(t) = labor input,

M(t) = material input,

$E(t) = \sum_{t=0}^{\tau} \left(\frac{SALES(t)}{P(t)}\right)$ = cumulative production,

$A, \alpha, \beta, \lambda$ = parameters.

[4] Briefly, the regressors in (5) cannot be presumed to be independent of the (implicit) disturbance term. This being the case, a necessary condition for obtaining unbiased least squares estimators has been violated [8, p. 341]. Note that the coefficient b_1 measures the elasticity of the business unit's sales with respect to the market. Thus, if the market is growing, the i^{th} market share will be growing, constant, or declining according to whether b_i is greater than, equal to, or less than unity.

The relationship between input and output is allowed to shift upward (i.e., a given level of inputs produces a larger output) in response to technical progress. It is assumed that the latter is a function of "learning-by-doing" or repetition; which, in turn, is measured by cumulative constant dollar sales.[5] Production costs are defined to be

$$DPC(t)_i = w(t)\ L(t)_i + m(t)\ M(t)_i, \qquad (7)$$

where:

$DPC(t)$ = Direct Product Costs,

$w(t)$ = wage rate (exogenous),

$m(t)$ = material price (exogenous).

A production cost function is derived by assuming that (7) is minimized subject to (6). This requires that the following familiar first-order condition be met,

$$\frac{\frac{\partial}{\partial L}}{\frac{\partial}{\partial M}} = \frac{\beta}{\alpha}\frac{L(t)}{M(t)} = \frac{m(t)}{w(t)}. \qquad (8)$$

That is, the relative usage of labor and material must be proportional to their relative prices. Following Nerlove [12, p. 106], we can solve (6) and (8) in terms of the inputs, $L(t)$ and $M(t)$, and then substitute the results into (7). After collecting terms, the operation yields

$$DPC(t)_i = k \left(\frac{SALES(t)}{P(t)}\right)_i^{\frac{1}{r}} w(t)^{\frac{\alpha}{r}}\ m(t)^{\frac{\beta}{r}}\ E(t)_i^{-\frac{\lambda}{r}}$$

where:

k = constant (composed of A, α, β),

$r = \alpha + \beta$.

This function is homogeneous of degree one with respect to input prices (i.e., $\alpha/r + \beta/r = 1$). In order to insure that the estimated version of (9) retains this desirable trait, one input price, say, $w(t)$, is arbitrarily chosen as a deflator. Taking logs, we have,[6]

$$\log\left(\frac{DPC(t)}{w(t)}\right)_i = \log k + \frac{1}{r}\log\left(\frac{SALES(t)}{P(t)}\right)_i + \frac{\beta}{r}\log\left(\frac{m(t)}{w(t)}\right) - \frac{\lambda}{r}\log E(t)_i. \qquad (10)$$

The production cost function thus accounts for: (a) factor substitution in response to relative price changes, (b) scale or "volume effects,"[7] and (c) technical progress. One or more of these attributes may, of course, be negligible for any particular product. Given the limited number of observations typically available, this specification will usually be superior to less parsimonious (albeit, more elegant) models like the "translog" cost function [13]. Finally, if demand grows exponentially (so that current and cumulative output variables approach a constant ratio) and inputs can be assumed to be combined in fixed proportions, then the following specification is preferable,

$$\log\left(\frac{DPC(t)}{CI(t)}\right)_i = \log k + \delta \log\left(\frac{SALES(t)}{P(t)}\right)_i \qquad (11)$$

where:

$CI(t)$ = composite index of labor and material prices,

δ = coefficient to be estimated.

The coefficient δ will reflect both "volume" and "learning" effects. The dependent variable may be viewed as a "total (variable) factor productivity index." By taking advantage of the collinearity between current and cumulative production, this specification turns what is usually viewed as a "problem (i.e., multicollinearity)" into an advantage.

Turning now to the "managed costs," we can differentiate between,

(i) Operating Managed Costs (item e, Table II)

(ii) Strategic Managed Costs (item f, Table II)

The distinction is, again, made, on the basis of relative management discretionary control. Operating Managed Costs (OMC) are comprised, primarily, of salaries for engineers, marketing staff, and manufacturing supervisors. Growth in this salaried work force tends to be (relatively)

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[5] The classic treatise on learning-by-doing is [9]. Our model differs, however, in that: (a) factor substitution is allowed, (b) progress is not restricted to that embodied in new machinery. Thus, our specification encompasses the "learning curve" phenomenon [10], and its generalization, the "experience curve" [11].

[6] The material price index will typically be a composite of several WPI's. Westinghouse uses the "direct costing" accounting system whereby variable costs are "carried in inventory" until product shipment. Factor prices in (10) must, therefore, be suitable lagged (or averaged) to reflect the fact that costs recorded in the current period were actually incurred during earlier periods.

[7] The estimated coefficient for sales (i.e., 1/r) is likely to capture both secular changes in plant scale and cyclical changes in the utilization of a given plant scale. The function is, therefore, best interpreted as measuring points on a series of short-run cost curves. An exception to this interpretation arises when manufacturing lead times are long enough to allow "load leveling" via orders queing. In such cases, time series sales observations are more likely to reflect secular capacity growth.

insulated from all but the most severe cyclical sales movements, but is sensitive to (perceived) changes in secular or "normal" sales growth. Consequently, the following specification is often appropriate:

$$\log \left(\frac{OMC(t)}{s(t)}\right)_i = \log c_o + c_1 \log \left(\frac{\overline{SALES}(t)}{P(t)}\right)_i \qquad (12)$$

where:

OMC(t) = Operating Managed Costs,

s(t) = index of salaried compensation rates,

$\overline{SALES}(t)$ = moving average of sales (a proxy for perceived "normal" sales),

$\log c_o$, c_1 = coefficients to be estimated.

Strategic managed costs (SMC) constitute a special problem in that they represent investments in process and/or product innovations (as well as expenditures to publicize the latter); the benefits from which will presumably accrue over future periods. Again, however, data limitations dictate a parsimonious model. Given that management can exercise significant control over SMC, the following specification is often applicable:

$$\log \left(\frac{SMC(t)}{d(t)}\right) = c_o + c_1 \left|\frac{1}{\left(\frac{SALES(t)}{P(t)}\right)}\right|$$

where:

SMC(t) = Strategic Managed Costs.

d(t) = an appropriated deflator (r&d costing rates being one possibility),

c_o, c_1 = coefficients to be estimated.

This function yields an "S"-shaped forecast that approaches a maximum SMC value (= e^{c_o}) set by the user. Various other nonlinear curves (i.e., the "logit" or "pearl" curves) can also be used to build an asymptotic limit into the forecast.

Finally, various "fixed" costs are modeled and projected at the division or business unit level. These costs may be categorized into:

(i) committed costs (g, h)

(ii) allocated costs (i, ℓ, m).

The various "committed" categories are related to plant scale and can, therefore, usually be modeled as a function of "Net Plant & Equipment" (or a suitable proxy).[8] The "allocated" category contains costs which have been incurred at a higher organizational level (i.e., group, company, and corporate overhead expenses) and then allocated back to constituent sub-units. These costs are usually exogenized. As noted earlier, factors supplied by the controller's department are used to allocate all "fixed" costs back to the various submodels. Such an allocation is made solely for the purpose of placing the model's forecast on a comparative basis with the business unit's formal "Five-Year Plan."

[8]Net Plant and Equipment may itself be endogenized by using the sales forecast to drive a balance sheet model. Further disaggregation of the "committed costs" category may be warranted if such items contribute significantly to total costs.

Net Income Module

Given projections for sales and costs, the "bottom-line" is reached via a series of non-stochastic equations:

$$OPER = SALES - COGS, \qquad (14)$$

$$IBT = SALES + OI - TC, \qquad (15)$$

$$S\&L\ TAXES = SLIT \times IBT \qquad (16)$$

$$FED\ TAXES = FIT \times (IBT - S\&L\ TAXES) - CREDIT, \qquad (17)$$

$$IAT + MINC \times (IBT - S\&L\ TAXES - FED\ TAXES), \qquad (18)$$

where:

OPER = Operating Profit,

COGS = Cost of Goods Sold,

IBT = Income Before Taxes,

OI = Other Income (exogenous),

TC = Total Costs,

S&L TAXES = State and Local Income Taxes,

SLIT = State and Local Tax Rate (parameter),

FED TAXES = Federal Income Taxes,

FIT = Federal Tax Rate (parameter),

CREDIT = Investment Tax Credits (exogenous),

MINC = Minority Income Factor (≤ 1),

IAT = Income After Taxes.

Values for Other Income (primarily royalties) and Credits are taken from the business unit's formal "Five-Year Plan." This is done to focus attention on discrepancies between Plan and model IAT projections which arise from the sales and cost forecasts. Ex post (i.e., sample period) simulations can be used to establish probable direction and magnitude of forecast error within this module.

IV. USING THE MODEL

A Caveat

Proper use of an econometric planning model requires an appreciation of its inherent limitations. First, it should be remembered that the model abstracts from many of the myriad variables which influence business performance. Some of these variables are excluded (or, more accurately, subsumed in the error term) because they are simply considered relatively unimportant; others because the necessary theoretical understanding is absent. Second, it is implicitly assumed that the fundamental relationships which are described by the model exhibit stability over time. While this stability hypothesis can be tested against the historical data, its validity over the forecast period must be accepted (or rejected) on faith.

These two limitations mean that the validity of the model's projections will be contingent not only upon the accuracy of its inputs, but also upon both the continuation of historical relationships described by the equations and the continued unimportance of variables excluded from these equations. The model's projections, therefore, should be viewed as ("business as usual") simulations of what <u>would</u> occur if fundamental historical relationships continue, rather than forecasts of what <u>will</u> occur.

<u>Contributions to the Planning Process</u>

Given the above caveat, the model's contributions to the business unit's (and corporation's) strategic planning process can be categorized as follows:

(i) Consistency,

(ii) Simulative Capability,

(iii) Reduced Forecast Variance.

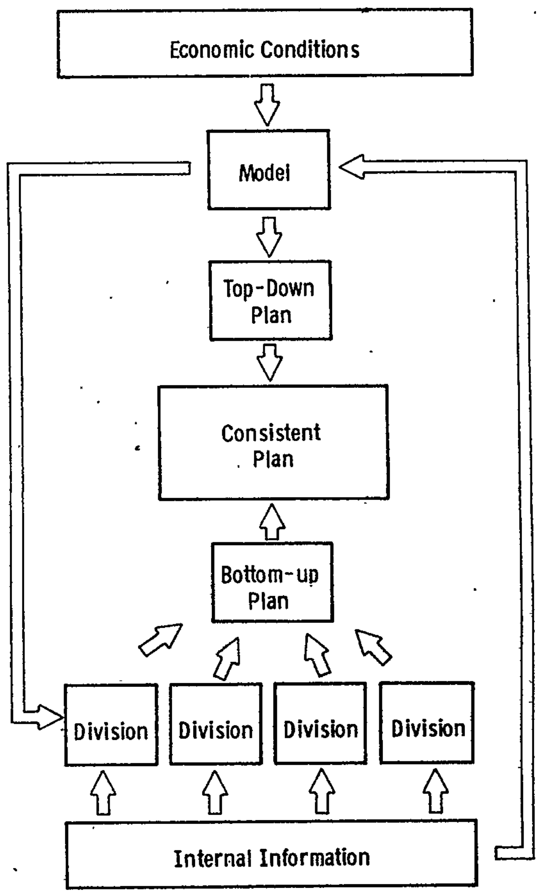
To elaborate, the fact that the model combines macro inputs with internal information means that the model's proforma income statement can aid in the establishment and evaluation of organization objectives which are consistent with both the external environment and with internal resources. As illustrated in Chart I, the model can serve in both a "top-down" and "bottom-up" role. When used in the former mode, it provides a check on the consistency of division plans (in toto) with the macro environment. The model can also "red flag" those bottom-up plans which apparently imply significant deviation from historical internal relationships. Perhaps more importantly, the model's disaggregated output can provide consistent inputs to the bottom-up plans themselves.

The phrase "simulative capability" refers to the fact that the model can perform a number of "what if?" calculations at various levels of the organizational hierarchy without imposing a significant bookkeeping burden on the user. For example, the implications of alternative "states-of-nature" can be quickly assessed, and the sensitivity of a performance measure (e.g., profit) to certain of its determinants (e.g., material prices) can be isolated.

Similarly, a model projection based upon the "most likely" macro forecast can be treated as a (business-as-usual) base case. A number of plausible alternative macro forecasts can then be inserted and the results then compared to the base case to assess the sensitivity of the formal business unit Plan (or a subset of objectives) to "unforeseen" changes in the macroeconomic environment. Indeed, this has been the task most

CHART I

CONSISTENT PLANNING



adapted from [16, p. 27]

frequently assigned to Westinghouse planning models.

Finally, it is suggested that the model can contribute to an increase in the precision (i.e., a reduction in the variance between actual and objective values of the business unit performance measures) of the bottom-up strategic planning process. This suggestion is based on the premise, set forth by Nelson [15, p. 217], that each plan flowing up from a division (or any other subunit) may be viewed as a composite forecast derived from a <u>portfolio</u> of predictions.

Given this premise, it follows that the variance of this composite forecast will be reduced by assigning a positive weight (however small) to any new prediction whose information is not completely subsumed in the other predictions. Assuming, therefore, that the macro and internal information contained in the model's sub-business unit forecasts is not totally redundant, the latter should contribute to an increase in the precision of the business unit's strategic planning process.

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