Balance Sheet Forecasting

A simple walk through

Overview

1. **Background**

2. **Implementation - Prototype**

Challenge of Balance Sheet Forecasting

- **Forecasting a Balance Sheet is not a standard time-series problem** because its components are not independent. They are governed by strict, non-negotiable accounting rules.
  - **Core Equation**
    - $\mathit{Assets} = \mathit{Liabilities} + \mathit{Equity}$ must hold.
    - Independent forecasts for each component will never satisfy this equation.
  - **Connection with Income Statement (IS) and Cash Flow Statement (CF)**
    - Example: $\mathit{RetainedEarning}(t+1) = \mathit{RetainedEarning}(t) + \mathit{NetIncome}(t) - \mathit{Dividends}(t)$
    - RetainedEarning from BS
    - NetIncome from IS
    - Dividends from CF
  - **Circular Reference**
    - Higher InterestExpense $\rightarrow$ Less NetIncome $\rightarrow$ Less Cash $\rightarrow$ More Debt $\rightarrow$ Higher InterestExpense
- A successful model must treat the Balance Sheet as an **interconnected state-space system**, using accounting identities as hard constraints, not statistical correlations.

The "Plug" Approach

- To ensure the model output will respect the core equation ($A = L + E$).
- The "plug" is **a residual term to absorb the difference** to enforce the core equation.
- Approach (cash as the "plug")
  - Forecast all other attribute in the BS except the cash
  - Cash = Forecasted (Total Liabilities + Total Equity) - Forecasted (All Other Assets)
- **Advantage**: fast, easy to implement, and must produce a balanced statement
- **Limitation and Risks**
  - **Hides the erro**r: any numerical error will counts towards the plug, which is hard to detect.
  - **Loss of financial implication**: like the cash should be the results of cash inflows and outflows, not just the difference.
  - **Bad solution for the circular reference**.

A Sequential, Non-Circular Approach

- Velez-Pareja's paper provides a robust methodology for forecasting financial statements that **explicitly avoids plugs and circular references**[1].
- **Sequential Causality**:
  - Built **a sequential, three-statement process, with the Cash Budget (CB)** acting as the central engine connecting the other statements.
  - Income Statement(t+1) $\rightarrow$ Cash Budget(t+1) $\rightarrow$ Balance Sheet(t+1)
  - Breaks the interest-debt circle by forecasting and constructing next state step-by-step
- **Approach**
  - **Forecast the Income Statement IS(t+1)** based on data in t and extraneous variable
    - Starting with sales forecasts and historical margins.
    - Build IS from top (revenue) to bottom (net income)
  - **Forecast the Cash Budget CB(t+1)** based on data in t and extraneous variable
    - Start with NetIncome(t+1) and consider deficit or surplus.
  - **Construct BS(t+1)** based on IS(t+1) and CB(t+1)

Implementation - Data

- **Company Chosen**: Microsoft Corp. (MSFT)
- **Base Year**: June 30, 2021
- **Balance Sheet Attributes**
  - **Total Assets**
    - **Current Assets** (Cash Cash Equivalents And Short Term Investments, Receivables, Inventory, Hedging Assets Current, Other)
    - **Non-Current Assets** (Net PPE, Investments and Advances, Goodwill and Other Intangiable Assets, Other)
  - **Total Liabilities**
    - **Current Liabilities** (Payables And Accrued Expenses, Pensionand Other Post Retirement Benefit Plans Current, Current Debt And Capital Lease Obligation, Current Deferred Liabilities, Other)
    - **Non-Current Liabilities** (Long Term Debt And Capital Lease Obligation, Non Current Deferred Liabilities, Tradeand Other Payables Non Current, Other)
  - **Total Equity**
    - **Capital Stock, Retained Earnings, Gains Losses Not Affecting Retained Earnings**

Implementation - Data

- **Income Statement Attributes**
  - Total Revenue
  - Cost of Revenue
  - Gross Profit
  - Operating Expenses
  - Operating Income
  - Net Non Operating Interest Income Expense
  - Other Income Expense
  - Pretax Income
  - Tax Provision
  - Net Income Common Stockholders
- **Cash Flow Attributes**
  - Capital Expenditure
  - Depreciation Amortization Depletion
  - Cash Dividends Paid

Drivers

- **Growth Driver**
  - `Sales Growth Rate`: An exogenous input, set to 5% for growth scenarios or 0% for steady-state analysis.
- **Profitability Driver**
  - `Operating Margin`: A historical ratio assuming stable profitability, calculated as *Operating Income(t) / Sales(t)*.
- **Investment Drivers**
  - `Depreciation Rate`: A historical ratio linked to the asset base, calculated as *Depreciation(t) / Net PPE(t)*.
  - `Capex Rate`: A historical ratio linked to revenue, calculated as *Capex(t) / Sales(t)*.
- **Financing Drivers**
  - `Interest Rate on Debt`: A historical ratio for debt servicing costs, calculated as *Interest Expense(t) / Total Debt(t)*.
  - `Effective Tax Rate`: A historical ratio assuming stable tax expense, calculated as *Tax Provision(t) / Pretax Income(t)*.

Drivers

- **Policy Drivers**
  - `Dividend Payout Ratio`: A policy decision on profit distribution, calculated as *Dividends Paid(t) / Net Income(t)*.
  - `Minimum Cash Required`: A policy decision for liquidity, set to the ending *Cash* balance of the base year.

Forecast the IS

- **Forecast Sales**
  - $\text{Sales}(t+1) = \text{Sales}(t) \times (1 + \text{Sales Growth Rate})$
- **Forecast Operating Income**
  - $\text{Operating Income}(t+1) = \text{Sales}(t+1) \times \text{Operating Margin}$
- **Forecast Interest Expense**
  - $\text{Interest Expense}(t+1) = \text{Total Debt}(t) \times \text{Interest Rate}$
  - *Key Insight:* This uses the known debt from the previous period's balance sheet.
- **Calculate Pretax Income**
  - $\text{Pretax Income}(t+1) = \text{Operating Income}(t+1) - \text{Interest Expense}(t+1)$
- **Forecast Tax Provision**
  - $\text{Tax Provision}(t+1) = \text{Pretax Income}(t+1) \times \text{Tax Rate}$
- **Calculate Net Income**
  - $\text{Net Income}(t+1) = \text{Pretax Income}(t+1) - \text{Tax Provision}(t+1)$

Cash Budget Framework

Principle: This step reconciles the accounting profit (Net Income) into actual cash flow and then determines the financing needed or the surplus available. This replaces the traditional "plug."

- **The Reconciliation and Decision Logic:**
  - **Calculate Cash Flow from Operations (CFO)**
    - We start with the *Net Income* from the IS and add back non-cash charges.
    - CFO(t+1) $\approx$ Net Income(t+1) + Depreciation(t+1)
  - **Calculate Cash Flow from Investing (CFI)**
    - This is primarily the cash outflow for *Capex*, driven by our investment rate assumption.
    - Capex(t+1) = Sales(t+1) * CapexToSales
    - CFI(t+1) = -Capex(t+1)
  - **Calculate Scheduled Financing Outflows**
    - DividendsPaid(t+1) = NetIncome(t+1) * DividendPayoutRatio
    - CFF(t+1) = -DividendsPaid(t+1)

Cash Budget Framework

- **Calculate Net Operational Cash Flow:**

$$\text{NetCashFlow}_{\text{pre-financing}}(t{+}1) = \text{CFO}(t{+}1) + \text{CFI}(t{+}1) + \text{Scheduled CFF}(t{+}1)$$

- **Determine Provisional Cash Position:** This step projects the cash balance before any new financing activities.

$$\text{ProvisionalCash}(t{+}1) = \text{Cash}(t) + \text{NetCashFlow}_{\text{pre-financing}}(t{+}1)$$

- **Compare to Liquidity Policy:** The projected balance is checked against the minimum required cash reserve.

$$\text{Surplus/Deficit} = \text{ProvisionalCash}(t{+}1) - \text{MinimumCash}_{\text{required}}$$

- **Execute Financing Decision:** A binary decision is executed based on the previous step's outcome.
  - **If Deficit:** Calculate the precise *NewDebt* to meet the minimum cash requirement.
  - **If Surplus:** Calculate the precise *NewSTInvestment* to be made with the excess cash.

Constructing the BS (t+1)

The new Balance Sheet for Year $(t+1)$ is constructed by the IS, CB in above.

- **Update Key Asset Accounts:**
  - *Cash:* Set to the final balance from the cash budget.

$$\mathrm{Cash(t{+}1)} = \mathrm{Cash(t)} + \mathrm{NetCashFlow}_{\text{pre-financing}}\mathrm{(t{+}1)} + \mathit{NewDebt} - \mathit{NewSTInvestment}$$

  - *Net Property, Plant & Equipment (PPE):* Updated with depreciation and capital expenditures.

$$\mathrm{NetPPE(t{+}1)} = \mathrm{NetPPE(t)} - \mathrm{Depreciation(t{+}1)} + \mathrm{Capex(t{+}1)}$$

  - *Short-Term (ST) Investments:* Increased by new investments calculated from surplus cash.

$$\mathrm{STInvestments(t{+}1)} = \mathrm{STInvestments(t)} + \mathit{NewSTInvestment}$$

Constructing the BS (t+1)

- **Update Key Liability & Equity Accounts:**
  - *LT Debt:* Increased by new debt raised to cover cash deficits.

$$\text{LTDebt(t+1)} = \text{LTDebt(t)} + \text{NewDebt}$$

  - *Retained Earnings:* Increased by net income and decreased by dividends paid.

$$\text{RetainedEarnings(t+1)} = \text{RetainedEarnings(t)} + \text{NetIncome(t+1)} - \text{DividendsPaid(t+1)}$$

- **Carry Forward Static Accounts:**
  - All other accounts (e.g., Goodwill, Common Stock) are carried forward unchanged, per simplifying assumptions.

The Final Validation: The Balance Check

- Finally, we sum all assets and all liabilities & equity independently. We then assert that the accounting equation holds, proving the model's internal consistency and integrity.

$$|\text{Total Assets} - (\text{Total Liabilities} + \text{Equity})| \leq 1 \times 10^{-4}$$

Time-Series Formulation

The deterministic forecasting model can be formulated as a discrete-time, non-linear state-space system. The evolution of the company's financial state from one year (t) to the next $(t+1)$ is defined by the function f:

$$\mathbf{y}_{t+1} = f(\mathbf{y}_t, \mathbf{x}_t) + \mathbf{n}_t{}^1 \tag{1}$$

where the components are defined as follows:
The state vector $\mathbf{y}_t \in \mathbb{R}^n$ represents the complete Balance Sheet at the end of year t.

$$\mathbf{y}_t = \begin{pmatrix} \text{Cash}_t \\ \text{NetPPE}_t \\ \text{TotalDebt}_t \\ \text{RetainedEarnings}_t \\ \vdots \end{pmatrix} \tag{2}$$

[1] $\mathrm{n}_t = 0$ in this case, deterministic model

Time-Series Formulation

The vector $\mathbf{x}_t \in \mathbb{R}^m$ represents the set of external drivers and policy assumptions for year t. In our baseline model, these are constant for all t.

$$\mathbf{x}_t = \begin{pmatrix} \text{SalesGrowthRate}_t \\ \text{OperatingMargin}_t \\ \text{CapexRate}_t \\ \text{DividendPayoutRatio}_t \\ \vdots \end{pmatrix} \tag{3}$$

Time-Series Formulation

The function f represents the complete set of accounting identities and forecasting rules implemented in the `_forecast_single_year` method. It is a series of calculations that maps the state and drivers at time t to the new state at $t+1$. Key calculations within f include:

$$\text{Sales}_{t+1} = \text{Sales}_t \times (1 + \text{Sales Growth Rate}_t) \tag{4}$$

$$\text{Net Income}_{t+1} = g(\text{Sales}_{t+1}, \text{Total Debt}_t, \mathbf{x}_t) \tag{5}$$

$$\text{Cash Flow}_{t+1} = h(\text{Net Income}_{t+1}, \text{Sales}_{t+1}, \text{Net PPE}_t, \mathbf{x}_t) \tag{6}$$

$$\text{New Debt}_{t+1}, \text{New Inv.}_{t+1} = d(\text{Cash Flow}_{t+1}, \text{Cash}_t, \mathbf{x}_t) \tag{7}$$

where g, h, and d are sub-functions representing the Income Statement, Cash Budget, and Financing Decision logic, respectively.

Time-Series Formulation

The entire system is subject to the hard constraint that the output vector $\mathbf{y}_{t+1}$ must satisfy the accounting identity, which is validated post-calculation:

$$\mathbf{A}_{t+1} - \mathbf{L}_{t+1} - \mathbf{E}_{t+1} = 0 \tag{8}$$

where $\mathbf{A}$, $\mathbf{L}$, and $\mathbf{E}$ are the corresponding aggregated components within $\mathbf{y}$.

Remarks

This baseline is build upon several key simplifications.

- Static Working Capital
  - Accounts Receivable, Accounts Payable, and Inventory are assumed to remain constant.
  - This simplifies the Cash Flow from Operations calculation
- Simplified Capital Structure
  - All New Debt Needed is assumed to be long-term
- Constant Ratio
  - All key drivers are assumed to be constant based on the base year
  - This create a baseline model but unrealistic forecast.

References

[1] I. Vélez-Pareja, "Forecasting financial statements with no plugs and no circularity," *The IUP Journal of Accounting Research & Audit Practices*, vol. 10, no. 1, 2011.