Dynamic Conservation of Money

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Abstract

Money is an information flow, even coins or bank notes have value by the information written on their faces or face value. System Dynamics' software designed to preserve material flows does not automatically conserve information, thus money preservation requires coflows. The purpose of the paper is to design sustainable financial policies in a model of swapping stocks, which requires money conservation to last. Structure determines and money sustain behavior.

Key Words: money, information, conservation, swapping, coflows

Introduction

The conservation of material and information flows is of great concern in the dynamics of physical systems, like the conservation of mass, energy and other attributes; see for instance (Kondepudi D., Prigogine I., 1998). Outstanding scholars like Low (1977), Lyneis (1980), Bianchi (1996) and many others emphasized the importance of money conservation when designing financial policies to last, because money is sometimes mistaken by a material flow and levels to keep it safe are often missed. Jim Lyneis illustrates this case in his classic book "Corporate Planning and Policy Design", when more inventory decreases delivery delay, rise market share and pump cash; however, inventory' obsolescence siphon money away. If either assets' value decrease or debts' value increase then profit decreases without affecting cash.

Coflows preserve attributes and accounting preserve money, both are essential to keep money safe, which requires looking at cash, profit, assets and liabilities.

The purpose is not to use SD structure to comprehend accounting as it is well done by Melse (2006) and others, but to design sustainable financial policies for money conservation. Redd Tracie, Venkateswaran Srini, Baek Edgar, Shah Deneb(2011) and Venkateswaran Srini, Shah Deneb(2011), present policies to manage assets and liabilities.

Order backlogs are information flows often out of financial statements. Leaks in backlogs mean clients dropping their orders, therefore decreasing future market share. The supplement material contains a simple version of a swapping model in Ithink that applies money conservation to design sustainable financial improvements. Appendix 1 lists the equations in order to facilitate the translation of the model to other dynamic software like Agent Base Modeling.

The conservation of attributes is the first step preserving information flows.

Conservation of Attributes

Attributes conservation requires two simultaneous flows, one carrying material and other carrying material with attribute. The conservation equations of a material flow expresses level to rates interactions, equation 1 expresses a material balance of level **X**, the InputX and OutputX are rates: faucet and drain respectively. Material flow X, may also carry attributes with different amounts of information. Some averages preserve information flows by coflows or its equivalent Hines' average (2005). In the coflow, the material flow and also the product of the attribute by the material flow are simultaneously accumulated. The first flow, Eq 1, carries material, the second, Eq2, carries the information.

At time **t**, **A(t)** is the value of the attribute, therefore,

dX/dt = InputX – OutputX (material flow) Eq 1

dY/dt = InputX***A(t)** – (**Y/X**)*OutputX , (material and information) Eq 2

The average attribute, **Y/X**, leaves the level Y with Output X.

An alternative is the use of Hines' coflow which is equivalent to the coflow formulation, but it dilutes the average Y/X with a variable delay equal to X/InputX. The preservation of the attribute expresses the change of the attribute as a function of the combination of equations (1) and (2):

$$d(Y/X)/dt = ((dY/dt)*(1/X) - (dX/dt)*Y)/(X*X) = (A(t) - Y/X)/(X/InputX)$$

Dilution Time = (**X/Input X)**

This equation is equivalent to, **Average = SMOOTH(A(t), Dilution Time)**

Dilution time memorizes attribute changes, quick changes relate to shorter dilution time. Hines' smooth function is equivalent to coflow, easier to understand by managers not familiar with SD. Nevertheless, the division by Input X might generate divisions by zero when calculating the dilution time.

A fixed delay, for instance, TimeToAverage, will not preserve the attribute; a portion will be forgotten even if there is no output from the material flow.

Next section explains the problems encountered in financial modeling, when accumulations of cash and promises to pay support financial decisions.

Conservation of Money

The accounting system has many superfluous details for policy design, so financial statements are simplified. Money requires a macro conservation equation **F(X) =0**, which involve levels of assets, liabilities and capital:

F(X) = Assets - Liabilities – Capital = 0

In general, Capital is like a debt toward stock holders, a type of liability, so the accounting equation expresses liabilities buying assets:

F(X) = Assets - Liabilities = 0, or, **Assets = Liabilities**

Conservation requires coflow transactions to match assets with liabilities. A simple case is to have Cash and Inventory as Assets, and Capital as Liability. The conservation of money keeps double entries where rates feed two levels simultaneously, always matching changes in assets with changes in liabilities. Therefore, if a rate adds to an asset, then it should either reduce another asset or increase a liability. When a rate reduces an asset, then it must increase another asset or decrease a liability.

Profits accumulate into Capital, while cash flow accumulates into Cash. Cash flow and Profit are both needed, but only Cash makes most business cases. For instance, in Life Insurance, premiums precede many years to claims, cash accumulates until claims take their toll, cash grows while mandatory reserves drain capital, in the long run you might end up with a lot of cash and a lot of loses.

Loans, Backlog, Payables and Capital are Debts or liabilities. Debts buy Assets, which usually take the form of Cash, Inventories and Receivables.

Expanding the conservation equation we have:

Cash + Inventory + Receivables = Loans+Backlog+Payable+ Capital

Assets matching Liabilities validate financial equations. If assets do not match liabilities, then you have missed either a level or an interaction, therefore you have opened the door to money leaks.

Coflow provides numerical conservation, while accounting provides structural conservation, because parallel flows mirror changes on structural equations.

A practical application of the conservation of money combines coflows and accounting to solve a financial problem. This an application of the Sterman' challenge in page 503 of Business Dynamics (2000), where inventory and backlog face price changes. Daily prices do not make profits, because items from previous days remains either in inventory or in backlog. Other averages like smooth prices do not preserve money; in fact, they drive assets away from liabilities. The balance between assets and liabilities reveal money leaks and securely seal your treasures.

Policy Design In a Swapping Financial Operation

A financial firm swaps stocks between local and US securities. The stocks are ADR, American Depositary Receipt, a negotiable certificate issued by an U.S. bank representing a specified number of shares (or one share) that is traded on a U.S. exchange. ADRs are denominated in U.S. dollars, with the underlying security held by a U.S. financial institution overseas denominated in local currency. The price of an ADR is often close to the price of the foreign stock in its' home market.

The company purchases ADRs by an average of 3 million dollars a day. The swapping operates monday to friday. Orders accumulate in a backlog of one to five days. There are periods where the price of the ADR goes up, and periods when it goes down moved by supply_demand pressures. There is a daily markup of 100 in local currency above daily purchase price on each transaction; therefore, profits must be around six thousand millions a day in local currency, but they hanged above one thousand. The problem was profit deterioration in the swapping operation, because the Information System operates carrying an "optimal" level of ADR inventory covering five days of sales.

A SD model identifies the causes of profit deterioration and adds new feedbacks for improvement, where conservation of money is essential. There is a positive price markup every day, but there are items left from previous days in the inventory or in the backlog. The positive price markup at each transaction creates the illusion of sure earnings, however, profit hurts either from carrying inventories when prices fall or from carrying backlogs when prices rise. The new policy keeps either up to five days of ADR inventory if price is rising (large) or up to five days of orders backlog if price is falling (short). Therefore, average markup price expand either by inventory when price rises or by backlogs when prices fall, but it is hurt at price turning points. Higher markup brings trading advantage and increases business volume. This loop, absent in the first version of the model, was included in the second version.

Management Information Systems have implicit rules which may determine behavior, because their implied policies drive the system elsewhere. John Morecroft (1979) developed principles relating SD models with Information Systems, which incorporate model findings into financial operations. Levels turn into files, rates turn into computer programs, and policies turn into trader interfaces to guide decisions. Hines averages, resembling smoothing functions, were better understood by managers.

The information system incorporates the new policy and the management of the new operation requires a group decision making. In the short time, increase in profits comes from better markups, seven days later it comes from better markups and more volume.

Profits are trade volume multiplied by spread, which is the Average Sale Price minus the Average Purchase Price. Both averages of remaining ADRs and Backlog are calculated by coflows. These averages are trivial to any SD practitioner; but, they were brand new to managers.

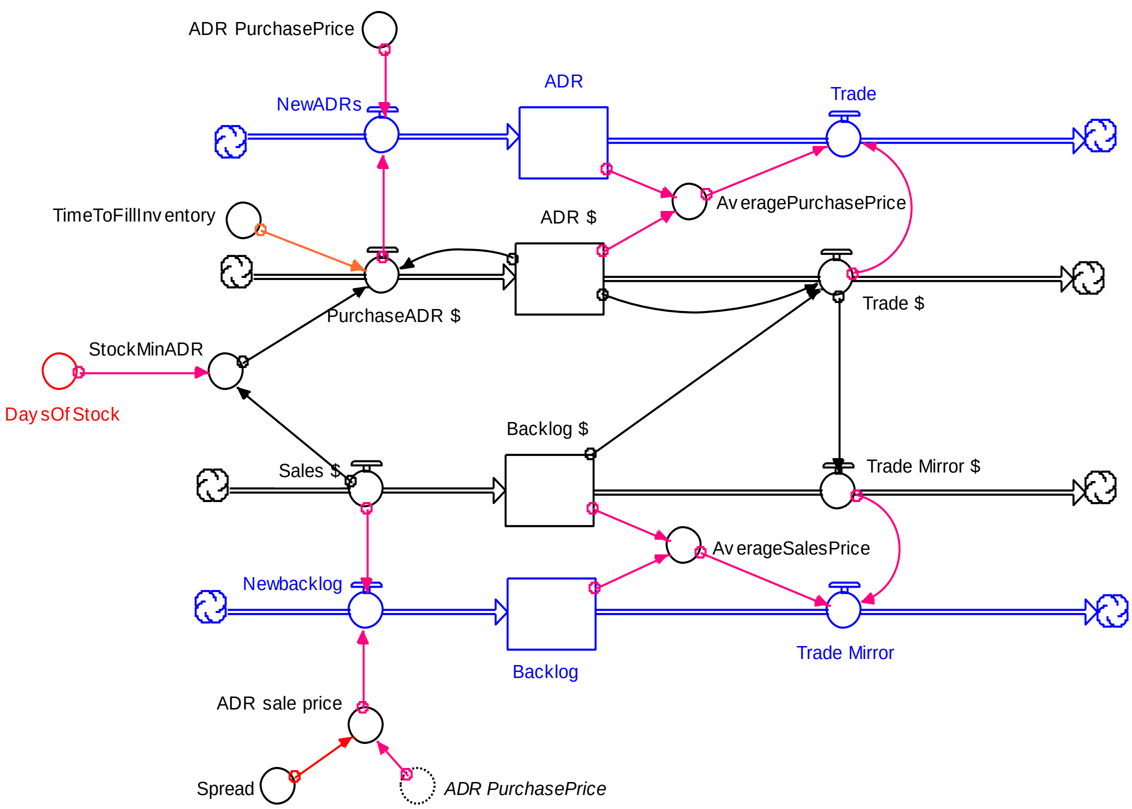

Figure 1. Swapping Operation Model.

Company purchases ADRs, but generates a Loan when cash turns negative, whose interest rate measures the opportunity cost of using the company cash. Negative cash is a free loan, so, it favor carrying more inventory, which swept away profits when prices fall.

CASH an ADRs are Assets, while Orders Backlog, Loan and Accumulated Profits are liabilities, all of them in US$ and also in local currency. Without the conservation equation, for instance, ignoring Loan or Accumulated profits, assets will never match liabilities, and policy design favor "*carrying more ADR' inventory in order to increase customer satisfaction",* which is precisely the cause of the profit deterioration.

Loses come from either carrying inventories when prices are falling or carrying backlogs when prices are rising. The new policy covers either up to five days of inventory if Price is rising (large) or up to five days of orders backlog if price is falling (short).

Profits accumulate into Capital and they are the trade volume by spread:

Profit = Trade $*Average Sale Price – Trade $*Average Purchase Price

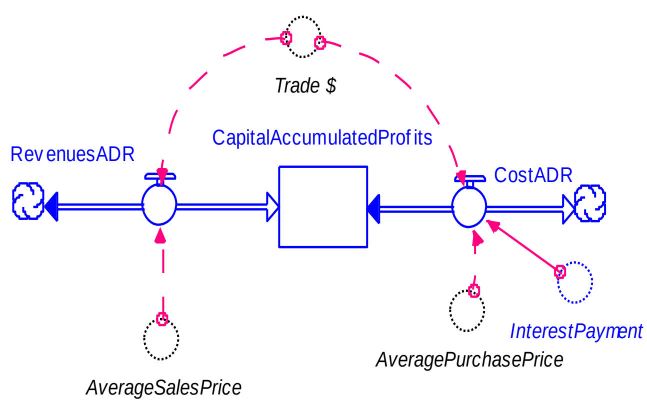

Figure 2. Capital Accumulated Profits

Cash flow comes from purchasing or selling ADR. The accounting equation validates money' conservation by matching assets with liabilities.

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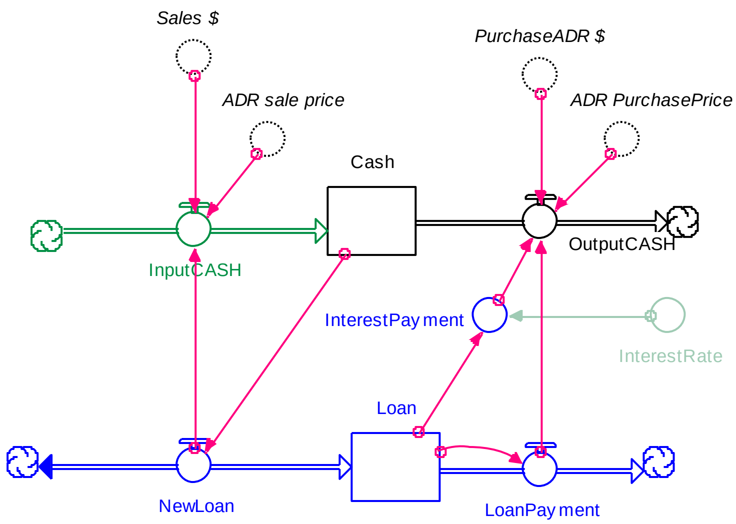

Figure 3. Loan prevents negative Cash

Managers approve the policy after sessions playing with the model, and later it merges into the Information System that handles the operation.

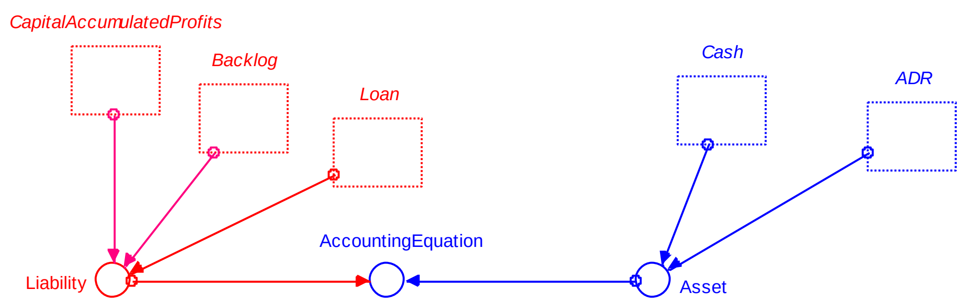

Figure 4. Assets minus Liabilities should be permanently equal to zero.

Figure 5 shows potential improvement using the new policy (blue line), instead the actual policy(red line). The model and results supplement this paper, the new policy is activated by an on-off switch, the reader is encourage to play with the model.

The false perception that a daily positive price markup guarantees profits has prevented improvements. The error, corrected by the new policy based upon two coflows of sell and purchase price, report daily profits and accounting equations complete the conservation structure.

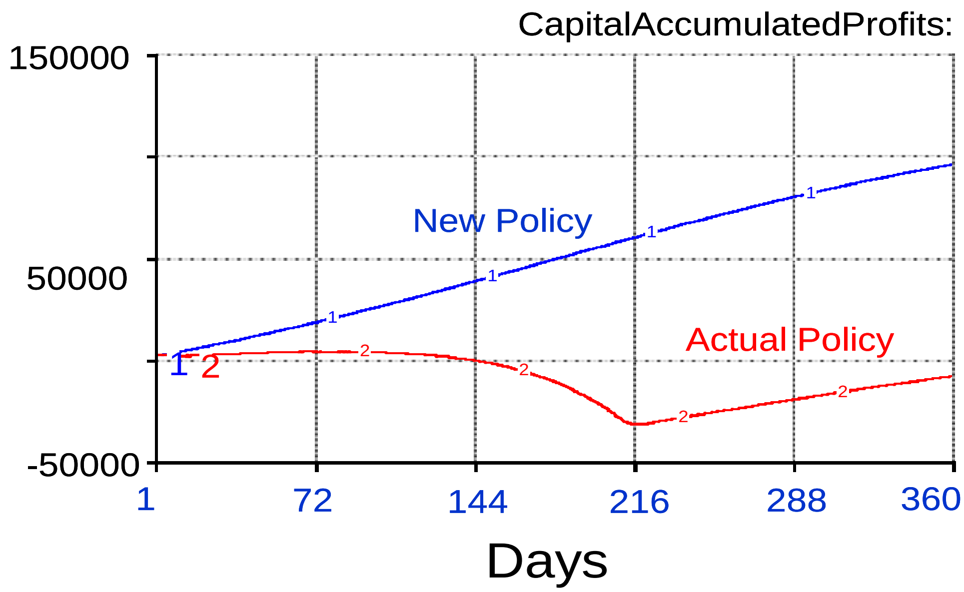

Figure 5. Potential Increase in Accumulated Profits in a Year

Prices change every day, every hour, driven by uncontrollable supply/demand forces; but no matter how they move, backlog bring profits when prices go down and inventory does the same when prices go up, spread exceeds original markup of 100 in local currency, because average cost, carrying either inventory or backlog from previous days, is below the instant cost. The model elicits new sources of profits, so it has experienced several upgrades, like adding also swapping between dollars and euros. The implementation took twenty days and profits increase by many times. The new information system remembers previous prices, preserves money, and new policy generates a daily budget of ADR' purchases, which increase negotiated volume and profits.

The policy creates a train that safely carries traders up and down a profitable roller coaster of prices

Conclusion

Structure determines, but money sustain, behavior. Money is an information flow to preserve, especially when solutions needs stability. Cash flow is not enough for policy design, because assets' depreciation or debts' appreciation may cause loses without affecting cash. Cash misses toxic assets and harmful liabilities.

A model of a Swapping operation support traders decisions in a financial firm by either maintaining desired levels of ADRs when prices grow, or desired levels of backlog when prices fall, the information system implement such policies and the lower average cost of ADR increases markup, which expands competitive advantage bringing more transactions; therefore, profit increases by more volume and better markup.

Price changes along the day, but pressures of hourly supply_demand are more suitable to Agent Base Modeling, because individual transactions act like agents relating to each other in multiple ways. There are potential profits in policy design for hourly operations and also from higher levels of aggregation dealing with supply_demand pressures, a fractal map of new treasures suggest future developments of this adventure of unfolding collective behavior out of individual actions.

System Dynamics provides a unified approach for the counterintuitive behavior of the decision makers, policy design preserves money and financial improvements.

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APENDIX 1. THE EQUATIONS OF SWAPPING

The equation of swapping are included, since there are many SD practitioners who are not familiar with Ithink software. They use instead Vensim, Powersim or Other Software. The list of equations facilitates the implementation in any other SD software.

ADR(t) = ADR(t - dt) + (NewADRs - Trade) * dt
INIT ADR = 0{ MM}
INFLOWS:
NewADRs = PurchaseADR_$*ADR_PurchasePrice{ MM/day}
OUTFLOWS:
Trade = Trade_$*AveragePurchasePrice { MM/day}
ADR_$(t) = ADR_$(t - dt) + (PurchaseADR_$ - Trade_$) * dt
INIT ADR_$ = 0.000001{ MM$}
INFLOWS:
PurchaseADR_$ = (1-off)*(Sign*max(0,(DesiredADR$-ADR_$+Backlog_$+sales)+(1-Sign)*max(0,(Backlog_$-DesiredADR$+sales)))/DaysToBuy) +(off)*max(0,(DesiredADR$-ADR_$+Backlog_$) +sales)
OUTFLOWS:
Trade_$ = min(ADR_$,Backlog_$)/DaysToFillOrder { MM$/day}

Backlog(t) = Backlog(t - dt) + (Newbacklog - Trade_Mirror) * dt
INIT Backlog = 0 { MM}
INFLOWS:
Newbacklog = Sales_$*ADR_sale_price { MM/day}
OUTFLOWS:
Trade_Mirror = Trade_Mirror_$*AverageSalesPrice{ MM/day }
Backlog_$(t) = Backlog_$(t - dt) + (Sales_$ - Trade_Mirror_$) * dt
INIT Backlog_$ = .00001 { MM$}
INFLOWS:
Sales_$ = max(0,sales) { MM$/day}
OUTFLOWS:
Trade_Mirror_$ = Trade_$ { MM$/day }
CapitalAccumulatedProfits(t) = CapitalAccumulatedProfits(t - dt) + (RevenuesADR - CostADR) * dt
INIT CapitalAccumulatedProfits = 1980 { MM}
INFLOWS:
RevenuesADR = Trade_$*AverageSalesPrice { MM/day }
OUTFLOWS:
CostADR = Trade_$*AveragePurchasePrice+InterestPayment{ MM/day }
Cash(t) = Cash(t - dt) + (InputCASH - OutputCASH) * dt
INIT Cash = CapitalAccumulatedProfits{MM}
INFLOWS:
InputCASH = Newbacklog+NewLoan { MM/day}
OUTFLOWS:
OutputCASH = NewADRs+InterestPayment +LoanPayment {MM/day}
Loan(t) = Loan(t - dt) + (NewLoan - LoanPayment) * dt
INIT Loan = 0{MM}
INFLOWS:
NewLoan = IF(Cash<0) then -5*Cash/dt else 0
OUTFLOWS:
LoanPayment = Loan/2{ MM/month }
AccountingEquation = int(Asset-Liability)
ADR_PurchasePrice = 2600+X { VEB/$}
ADR_sale_price = ADR_PurchasePrice+Spread
Asset = ADR+Cash{ MM$/month}
AveragePurchasePrice = if(ADR_$>0) then ADR/ADR_$ else 0
AverageSalesPrice = if(Backlog_$>0) then Backlog/Backlog_$ else 0
DaysOfStock = 3{days}
DaysToBuy = 1 {day}
DaysToFillOrder = 1{ day }
DesiredADR$ = DaysOfStock*SMTH1(sales,5,3) {MM$}
InterestPayment = Loan*InterestRate/12 { MM/day}
InterestRate = .2{ }

Liability = CapitalAccumulatedProfits+Backlog+Loan
off = 0
sales = 2+RAMP(2,0)*NORMAL(1,.03)/1000 { MM$/day}
Sign = if 100*TREND(ADR_PurchasePrice,2,0) >0   then 1 else 0
Spread = 100 { VEB/$ }
X = SINWAVE(1000,180)