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■ RESEARCH ARTICLE

Using Market Indices to Optimize Company Supply Chain

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ABSTRACT: The Supply chain triangle – Service, Cost, and Cash – is the core of any business. Providing the best service for customers, while reducing the supply chain cost and maximizing cash on hand are the three pillars of business operation. Businesses are constantly balancing among these three pillars of operation. Not being able to balance the three pillars of operation leads to the risk of developing bad service, high cost, or low cash.

Business planning is the act of using forecast market conditions to prepare future business operations and mitigate risks related to service, cash, and cost. A recent example is the COVID-19 pandemic's impact on businesses worldwide. Rapid changes in global demand and supply and government fiscal and monetary policies led to high inflation in prices. Now, more than ever, companies must incorporate market conditions into their planning to balance their supply chain triangles.

Risk pooling is a statistical concept that suggests that supply chain variability is reduced if one can aggregate variability across locations, products, or time. Modern Portfolio Theory (MPT) seeks to minimize non-systemic risk via a pool of diversified portfolios. Although MPT is frequently used in investment and finance, it is not found in supply chain management literature. This paper formulates a business supply chain plan as a portfolio optimization problem, which maximizes savings of inventory portfolios subject to constraints on inventory turns (service demand/inventory). This approach can further be used to achieve flexible operations by optimizing inventories for high-volume, low-variability materials to take advantage of economies of scale and/or optimizing inventories for low-volume, high-variability materials to pool the risks.

KEYWORDS: Supply Chain Triangle (Service, Cost, Cash), Supply and Demand, Risk Pooling, Market Indices, Modern Portfolio Theory (MPT), COVID-19 Pandemic, flexible operation.

■ Introduction

As an analogy, businesses are like ships floating in a vast ocean of the global economy (see Figure 1). In this ocean, it contains storms, such as inflation/deflation and politics/trade, that disrupt business operations. To fight against adverse market conditions, businesses need to control their "motors" (i.e., operation) and "steering" (i.e., planning) in order to navigate to success.

Figure 1: An analogy of a business in the global economy.

A core concept in economics is supply and demand.[1] On a macro level, two key situations have been impacting the current state and development of the world economy. Firstly, climate change has effects on different parts of the world including unexpected natural disasters and abnormal weather patterns. Pertaining to businesses, this causes plants to shut down and transportation disruptions.[2] Secondly, in the recent years of 2020-2021, the COVID-19 pandemic has caused people to lose jobs, due to quarantines worldwide.[3] Pertaining to businesses, consumer demand has been at an all-time low which then caused producers to bring supply down to very low levels as well. Although the markets are beginning to recover from in demand, supply cannot catch up, causing an imbalance in supply and demand and rapid rising in inflation4 (see Figures 2 and 3).

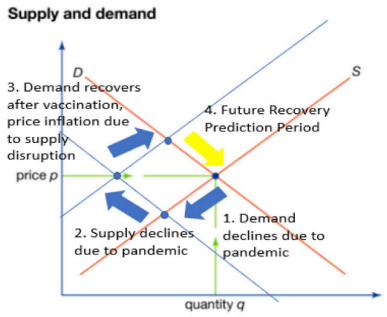

Figure 2: Supply and demand dynamics due to COVID-19.

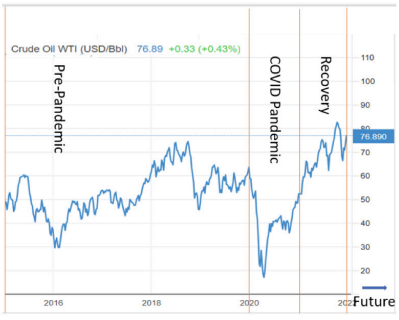

Figure 3: Crude oil WTI price volatility due to COVID-19[5]

DOI: 10.36838/v4i6.3

Although situations such as climate change and the COVID-19 pandemic represent systemic risks that businesses may not be able to control, businesses do have control over non-systemic risks by diversifying their portfolio. *Risk pooling is a statistical concept that suggests that supply chain variability is reduced if one can aggregate variability across locations, products, or time.*[6] *Modern Portfolio Theory (MPT),*[7,8] *which seeks to minimize non-systemic risk via a pool of diversified portfolio, can be applied to supply chain to find an optimal balance among services, cash, and cost.*

Traditionally, sales (the service side) will want to do anything to gain and maintain customers, which may force an increase in inventory and/or buying of materials even when costs are high. This may lead to a shortage of cash for a company. Finance (the cash side) will want to keep the inventory low and cash on hand as high as possible to keep the business afloat. This may limit sales in that they will not have products immediately available when customers need them. Procurement (the cost side) will want to base their decisions on predictions of market risk. When forecasts predict procurement costs will rise, they will want to buy early. Manufacturing and Logistics (the cost side as well) will both want to maximize operation efficiency and capacity utilization to process large batches/loads. This may conflict with sales when market demands are volatile, and conflict with procurement when market supplies are volatile[9] (See Figure 4).

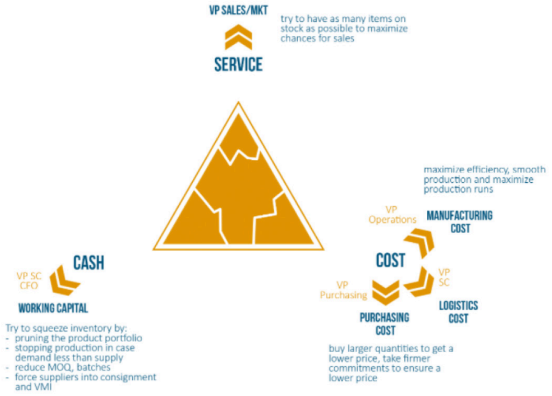

Figure 4: Breakdown of Supply Chain Triangle

This paper focuses specifically on the cash aspect (inventory) of the supply chain triangle and formulates the balance of the supply chain triangle as a portfolio optimization problem, which maximizes the savings of inventory portfolio subject to constraints on inventory turns (service demand/inventory). This approach can further incorporate the flexible operation rules by optimizing inventories for high volume-low, variability materials to take advantage of economies of scale at the secondary plants/warehouses and optimizing inventories for low-volume, high-variability materials to pool the risks at the primary plants/warehouses.

Methods

In this paper, PortfolioVisualizer.com[10] was used to solve portfolio optimization problems. WTI, PPI, CPI historical, and forecast data were obtained from TradingEconomics. WebDigitizer.[11]

Assuming the three materials have equal service demands and inventory turn 5~6, and have prices linearly correlated to Energy Market crude oil WTI, Producer Market PPI, and Consumer Market CPI, respectively (see Figures 5, 6).

Figure 5: Supply Chain

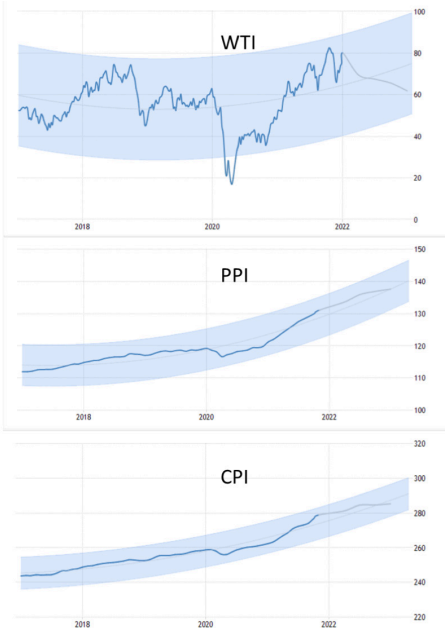

Figure 6: History and forecast time series of WTI, PPI, CPI

Results and Discussion

The objective of the proposed optimization is, like any investment portfolio optimization, to assemble a group of assets so that the portfolio has the highest return. In the context of the inventory portfolio, the objective is to stock a portfolio of materials as inventory so that it can provide maximum cost savings. Moreover, service and cash requirements are enforced by the constraint on inventory turn (service demand/inventory), (see Figure 7). Note, in the real world, there are many more constraints such as production/shipment constraints, product demand volume, variability constraints, etc.

Figure 7: A portfolio optimization approach for Supply Chain Planning

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Mathematically, the supply chain inventory portfolio optimization is formulated as follows:

$$maximize_{\alpha_1,\ldots,\alpha_n} = (\alpha_1 r_1 + \cdots + \alpha_n r_n)$$

Is subject to

$$\alpha_1 + \cdots + \alpha_n = 1$$

$$\alpha_k^{lower} \le \alpha_k \le \alpha_k^{upper}, for\ i = 1, \ldots, n$$

where r_1,…,r_n are returns of materials in the inventory portfolio, α_1,…,α_n are percentages of materials in the inventory portfolio, and

$$\alpha_k^{lower} = \left(\frac{demand_k}{demand_{total}}\right)\left(\frac{turn^{lower}}{turn^{upper}}\right)$$

$$\alpha_k^{upper} = \left(\frac{demand_k}{demand_{total}}\right)\left(\frac{turn^{upper}}{turn^{lower}}\right)$$

are lower and upper bounds of material k percentage in the inventory portfolio, which is material demand percentage multiplied by inventory turn lower-to-upper ratio and upper-to-lower ratio, respectively.

Table 1 summarizes the savings by using inventory portfolio optimization vs using equal weighted inventory. There is a range of inventory cost savings from 0.3% to 3%.

Table 1: WTI, PPI, CPI Data Records of Pre-Pandemic, and Post-Pandemic Percentages

	Pre-pandemic (2015-2019)	Pandemic before vaccination (2019-2021)	Recovery after vaccination (2021-2022)	Forecast (2022 -2023)
WTI portfolio %	36.82%	35.64%	39.94%	28.00%
PPI portfolio %	29.54%	32.60%	32.04%	40.00%
CPI portfolio %	33.64%	31.76%	28.02%	32.00%
maximum return vs equal weighted	10.05% vs 9.22%	5.58% vs 5.31%	24.13% vs 21.25%	4.38% vs 4.15%
Saving	~1%	~0.3%	~3%	~0.3%

Figure 8 shows that because the optimal inventory portfolio diversifies non-systemic risks, it mainly reflects systemic risks, i.e., the inflation shock wave due to the COVID-19 pandemic. Percentage holding of WTI-correlated material shows that the shock wave first peaks in the energy market (in 2021-2022), while percentage holding of PPI-correlated material shows the ripple effect of the shock wave that starts to peak in the producer market in (2022-), with percentage holding of CPI-correlated material starting to pick up speed to reach peak.

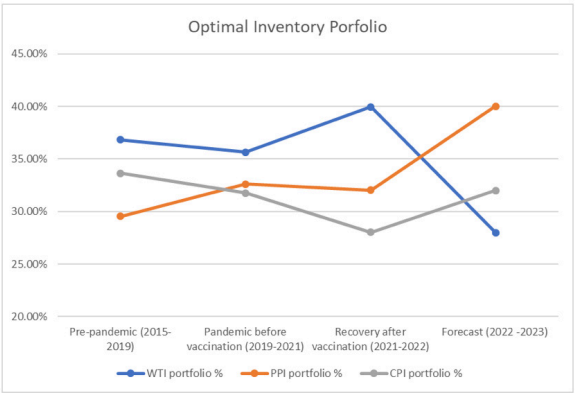

Figure 8: Optimal inventory portfolio links to market inflation shock wave due to COVID-19 (see Table 1)

In the above example, the market indices mainly reflect market systemic risks, with WTI the most volatile and with aggregate PPI and CPI the least volatile. Most individual businesses are connected to many market indices that reflect non-systemic risks of specific supply chain businesses and are volatile in between the two extremes. So, the expected saving of inventory portfolio optimization can be much larger than the results shown here. Future research can be to apply the method to a specific business, such that its non-systemic risks can be reduced and optimal balance among service, cash, and cost achieved.

Conclusion

Businesses are like ships floating in a vast ocean of the global economy subject to dynamic risk waves of supply and demand. Risk pooling is a statistical concept that suggests that supply chain variability is reduced if one can aggregate variability across locations, products, or time. Modern Portfolio Theory (MPT) offers a methodology to pool a diversified portfolio to minimize non-systemic risks to find a balance among services, cash, and cost of supply chain triangle. This paper formulates a balance of the supply chain triangle as a portfolio optimization problem, which maximizes savings of the inventory portfolio subject to constraints on inventory turns (service demand/inventory). This approach can further be used to achieve flexible operations by optimizing inventories for high-volume, low-variability materials to take advantage of economies of scale and/or optimizing inventories for low-volume, high-variability materials to pool the risks.

Acknowledgements

Thanks to Alex Tentopoulos and Vincent Lafrado from SUEZ WTS for their support in this science fair project.

References

1. Hubbard, R. G., & O'Brien, A. P. (2008). Economics. Upper Sad dle River, N.J: Pearson Prentice Hall.
2. How Climate Change Is Disrupting the Global Supply Chain https://e360.yale.edu/features/how-climate-change-is-disrupting-the-global-supply-chain
3. Coronavirus: How the pandemic has changed the world economy https://www.bbc.com/news/business-51706225
4. Covid-19 Related Inflation Surpasses 40 Year Record: How Long Will It Persist? https://www.forbes.com/sites/mikepatton/2022/04/13/covid-19-related-inflation-surpasses-40-year-record-how-long-will-it-persist/?sh=2da297eb1a82
5. TradingEconomics.com. https://tradingeconomics.com/
6. Simchi-Levi, D. (2013). Operations Rules: Delivering Customer Value through Flexible Operations. The MIT Press
7. Bodie, Z., Kane, A., & Marcus, A. J. (2011). Investments. New York: McGraw-Hill/Irwin
8. Markowitz, H. (1952). Portfolio Selection, The Journal of Finance, Vol. 7, No. 1, pp. 77-91
9. https://blog.arkieva.com/balancing-cash-cost-service-supply-chain-triangle/
10. PortfolioVisualizer.com. https://www.portfoliovisualizer.com/
11. WebDigitizer. https://apps.automeris.io/wpd/

Author

Charley L. Wan is an 11th-grade student at Central Bucks East High School. This science fair project was inspired by his

investment club, where he used portfolio optimization for the Wharton business school investment competition. He is passionate about integrating a growth mindset and neuroplasticity with business decision-making and organizational behavior.

DOI: 10.36838/v4i6.3