



**The Semiconductor Slowdown: Supply Chain Shortages
and the Implications on the Stock Market**

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1 Introduction

The onset of the pandemic further exposed a necessary trajectory shift in supply chain processes, requiring even more thorough global partnerships, advanced forecasting technology use, and reevaluations of shipping, manufacturing, and distribution hubs in order to keep up with the onslaught of online demand. Inventory levels, employment levels, as well as out-of-stock and shipping rates have shot past historical averages in the past two years, resulting in large shortage and inflationary periods across sectors from semiconductors to travel and leisure to basic necessities. Compounded with consumer behavior trends - both inside and outside of the coronavirus-19 pandemic - towards online shopping and on-demand delivery, corporations are not only paying greater wages in order to maintain their workforce, but also increasing costs in making, shipping, and delivering the goods to the customer.

The Agility Emerging Markets Logistics Index, compiled from a survey of 1,206 executives in international supply chain, pinpoints key stages of manufacturing and shipping disruption with the most delay and strain occurring with 1) congestion at ports and other trans-shipment points, 2) ensuring supply of goods and inputs, and 3) sourcing transportation capacity (Logistic Insights, AHEML Index 2021).

The MHI Annual Industry Report looks at similar stages from a general operations perspective, asking the 1,000 supply chain professionals surveyed to include factors from changes in consumer behavior and day-to-day company logistics. Key

pressures and considerations were sourced mainly from the lack and inaccuracy of current forecasting methods, the inability to hire and retain qualified workers, and consumer behavior shifts: customer demand for lower costs and better response times as well as rising customer service expectations (2021 Annual Industry Report, MHI Deloitte).

Some of these drivers and pain points aren't unique or purely susceptible to public health crises, as seen in historic supply chain shortages resulting from the 2011 Tohoku earthquake and Eastern Asia floods as well as the 2017-2018 China-U.S. trade disputes. After the Tohoku earthquake, due to the size of Japan and its concentration of factories, manufacturing centers, and business hubs across the country's small width, car plants across the world shut down temporarily for a lack of Japanese-made parts and Japan-dependent shipping streams. Japan produces a fifth of the share of global semiconductors, and the highest share of flash memory, serving top line customers such as Apple and Samsung who didn't necessarily see the shortage effect the next week, but by the end of the quarter when new supply shipments arrived unpredictably delayed. Due to the massive globalization of such processes from the late 20th century into the early 2000s meant, manufacturers saw that "lacking some part, even if it costs just dimes or a few dollars, can mean shutting down a factory (Stress Test for the Global Supply Chain, NYT)." Further, specifically in the technology sphere where natural resources play such a unique role, floods in eastern Asia used mass shortages in raw

materials - resin for packing small computer chips in cellphones and silicon ingots which are made into silicon wafers for virtually every type of device produced. Post-disaster reflections highlighted the ever-relevant need for multi-shoring and near shoring as well as the advantages of shrinking the geographic operations footprint of inventory.

U.S.-China trade warfare through the establishment of communications and computer equipment tariffs ramped up in the Trump administration era to stunt China's investment in technological sectors. This immediately began to worry not only the American semiconductor industry but players across the consumer goods field as worries plagued on such tariffs would spread. Although China is not the sole player in these input markets, and prior to 2017 many firms such as Walmart and Lowe's Companies were already starting to look elsewhere towards Vietnam and Taiwan, the looming idea of Asian tariffs as means of a political statement loomed on executives: "You can't just say let's go to Pakistan or North Africa. It's not so easy, it will take years to build out the supply chain (Supply Chain 360, NRF)."

Supply chain efficiency frameworks have been passed around from management consulting firms to industry professionals to trade lobbyists and have landed on a series of evaluation points: sales, inventory and operations planning, sourcing, production, warehousing, transportation, point-of-sale, and consumers. Recognizing the additional tension points put on the international supply chain in the last 18 months on top of

already existent historic issues being further exacerbated, tightening of the supply chain distribution channels, considering the move to bring production closer to home, and increasing the accurate allocation of inventory near shore are necessary to pull the world economy out of such a shortage - all of which will need additional funds in working capital for firms to keep up with. Thus, if so, such abatement of supply strains will snowball into significant balance sheet consequences, cutting profit margins and decreasing the returns on future capital. Additional inflation, rising share prices, and other corporate adjustments related to the specific sector and good sold can have significant implications on the stock market performance, both at large and on specific sectors, and subsequent ideal portfolio allocations.

Given this, we predict that in periods of high supply chain disruptment, the stock market will perceive such impending supply issues, similar to gas and oil prices, and negatively react to the perceived and presumptuous lack of inventory on the shelves or inevitable drastic shortage. We would also expect consumer and producer prices to seamlessly increase during these times in tandem with these crisis peaks and for unemployment rates to directly counteract this idea with a negative correlation, as firms run to the labor market, even for short-term, temporal unemployment as a bandaid solution.

2 Data

Supply chain evolutionary data come from a variety of sources speaking to specific inputs and stages across the supply chain process, including the Purchasing Managers' Index, the BLS Price Change for Air Freight in the U.S. Import/Export Price Index, the Harper Petersen Worldwide Price Development on the Charter Market for Container Ships, and Vessel Operational Costs from global ports data across the world. After analyzing these trends individually and as to how they relate to disruptive staged, Benigno et. al of the New York Fed combined aforementioned indexes together into a weighted Global Supply Chain Pressure Index (GSCPI) to examine holistic fluctuations across major shortages in the past two decades. As GSCPI increases, such inputs to the index are increasing, such as the increase in price for air freight or vessel operational costs, highlighting that the larger the GSCPI value, the larger the, often price related, supply chain disruptment being experienced at that time.

Regression Variables on GSCPI Index

IGE (monthly returns)	iShares North America Natural Resources ETF
IYK (monthly returns)	iShares U.S. Consumer Staples ETF
KXI (monthly returns)	iShares Global Consumer Staples ETF
CPI (monthly observations)	Consumer Price Index
PPI (monthly observations)	Producer Price Index
UE (monthly observations)	Unemployment Rate

Stock market implication data comes from the Wharton WRDS database, specifically the CRSP monthly stock files, where value weighted return on the overall stock market for the 2000-2020 time period is regressed with the GSCPI Index as well as the S&P 500 index return and specific ETFs from the consumer foods, raw materials, and energy sectors. These ETFs are the iShares Global Consumer Staples ETF (KXI), the iShares North American Natural Resources ETF (IGE), and the iShares U.S. Consumer Staples ETF (IYK). Such ETFs were picked in an attempt to illustrate how the stages of supply chain disruptions affect stock market returns, predicting that early 2000s shipping issues will foresee a different type of return response than the pandemic initiated supply bottleneck. Further, in comparing IYK and KXI, there can be an effort to separate the United States impact from the general global impact which will likely be exaggerated - over or under - due to the sheer amount of possible compounding variables.

GSCPI data is also regressed with the U.S. Bureau of Labor Statistics Data to analyze possible implications on the labor market in the United States using the following metrics: Consumer Price Index, Producer Price Index, and Unemployment Rate. CPI and PPI were chosen as a large scale approach to summarize the effects on prices, for both the consumer and prices, during these points in time, recognizing the need to account general inflationary and hyper-inflationary periods whose data will also be reflected. Regarding unemployment rate, it is observed that for a portion of

disruptments discussed above, a mere greater number of workers would sufficiently ease bottleneck issues. Given this idea, it should be seen that unemployment rates dip during these periods as temporary and permanent workers are brought in as the peak of the disruptment starts - the BLS statistic provides the information to do this.

3 Methodology

Using a time series OLS regression, the returns on each index, ETF, or overall market is the dependent variable with the Global Supply Chain Index as the independent variable. These regressions can be represented by the standard linear, time series OLS regression, where Y equals igereturns, iykreturns, kxireturns, s&p_returns, and overallmarket_returns.

The same times series OLS regression was done for BLS data, with the Global Supply Chain Index as the independent variable and Consumer Price Index, Producer Price Index, and Unemployment Rates - all monthly - being the dependent variables.

A sizable portion of analysis is conducted through additionally examining regression effects of such trends graphically, along the shared time period from June 2000 to December 2021. For each graph presented, both overall market return and S&P500 return is represented, despite their close mirroring, as well as the GSCPI index measurement and in Graph 3, the monthly Federal Funds Effective Rate. \\

4 Results

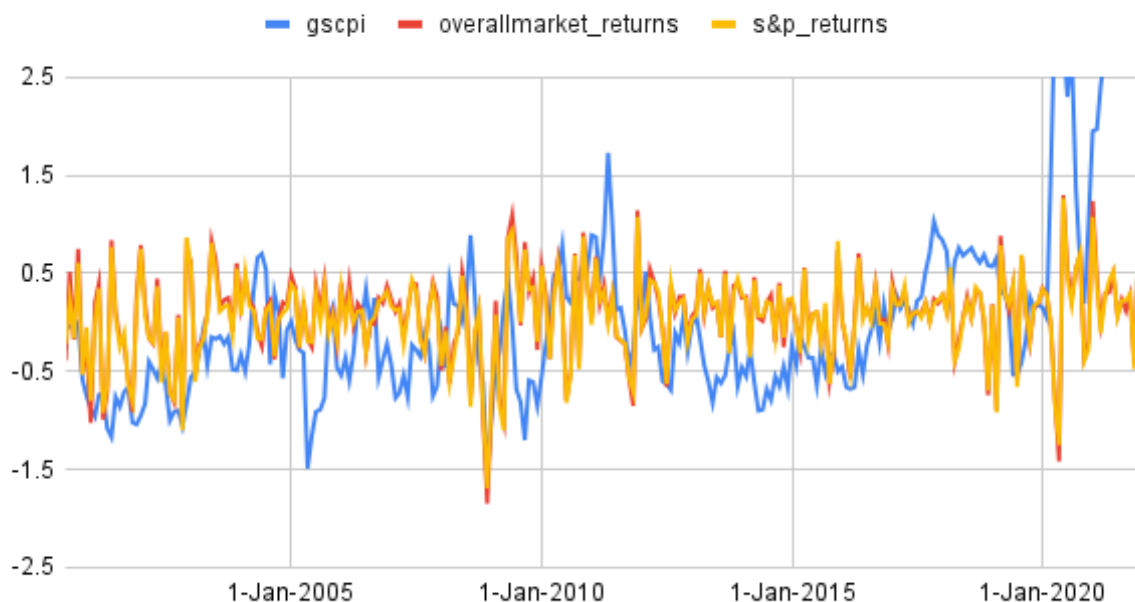
Table 1: Regression Analysis: Global Supply Chain Index Effects on ETF, S&P 500, and Overall Market Returns

	IGE Returns (1)	IYK Returns (2)	KXI Returns (3)	S&P Returns (4)	Overall Market (5)
igereturns	1.40 (0.99)				
iykreturns		3.71* (1.72)			
kxireturns			2.42 (2.33)		
s&p_returns				2.48 (1.49)	
overallmarket_returns					2.12 (1.43)
constant	0.11 (0.07)	0.04 (0.07)	0.25** (0.09)	0.05 (0.06)	0.05 (0.07)
R-sqr	0.008	0.018	0.006	0.011	0.008
dfres	240	265	181	257	257
BIC	718.7	757.8	575.4	761.5	762.1

The range for the GSCPI Index measurement varies from -1.204 to 4.370, with a mean of .067 and a large standard deviation of 1.038— possibly driven by large fluctuations of drops and recoveries in 2011, 2017, 2020, and 2021 some mentioned by aforementioned worldwide supply chain crises and some credited to the ongoing and recent pandemic driven trends. An index value of 0 indicates an average value for the time period while higher values highlight the increase in input values such as PMI or air freight prices. Given the first set of regression results below, with the GSCPI Index variable set to 0, we see ETF return constants of .108, .036, and .252 for the iShares North American Natural Resources ET, the iShares U.S. Consumer Staples ETF, and iShares

Global Consumer Staples ETF, respectively. Using a 5% level of significance, it is seen that a one-point increase in the GSCPI Index measurement results in a statistically significant 3.706 increase in returns for the iShares Consumer Staples ETF (IYK). Regarding the overall market as well as the S&P 500 index, we see a 2.122 and 2.481 increase respectively when there is a one-point increase in GSCPI index measurement, under no statistically significant level.

Fluctuation of GSCPI Index on Stock Market Returns



Graphically, this idea is further illustrated as for the vast majority of the 20 year time period, both the overall market and the S&P follow the trends of GSCPI closely, as small increases in inputs allow for the stock market growth to be reflected through market growth. However, this representation highlights a notion not seen in the regression, that in times of peak GSCPI index values past normal fluctuation,

specifically 2008, 2011 and 2020, stock returns plummet, in the opposite direction of GSCPI. One can understand this when referencing the MHI report and the AHEML index, while small and temporary increases in freight prices or shipping delays represent healthy and manageable industries-wide growth, such extreme and long lasting bottleneck disruptions as seen in these periods negatively affect the stock market at large, easily representing the age-old supply versus demand tale.

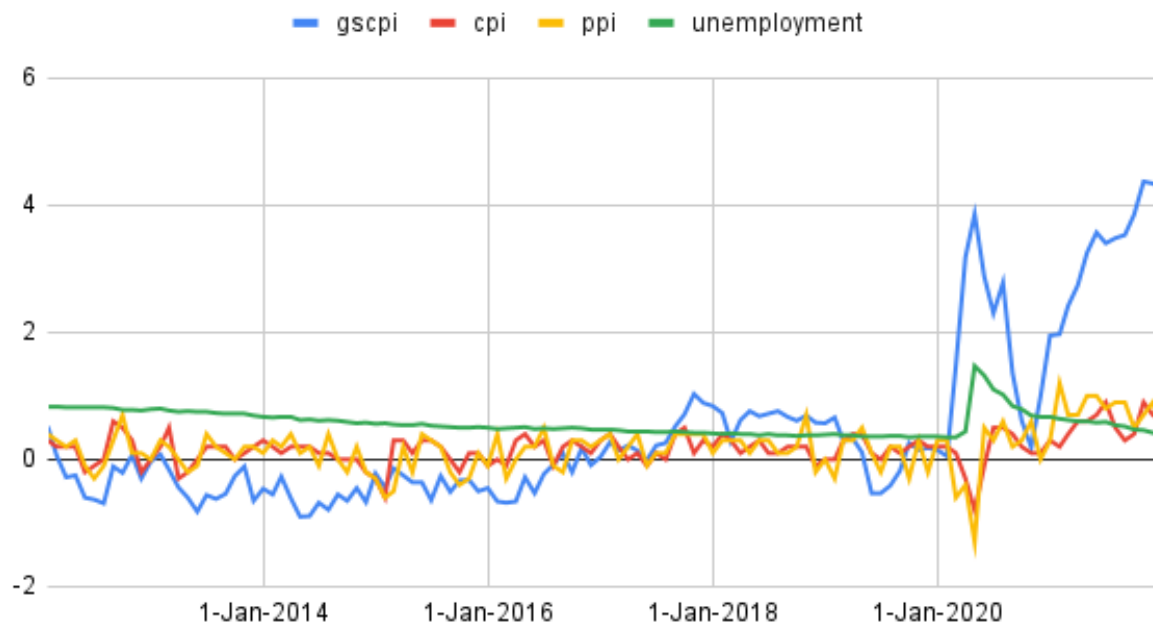
Table 2: Regression Analysis: Global Supply Chain Index Effects on CPI, PPI, and Unemployment

	Consumer Price Index (1)	Producer Price Index (2)	Unemployment (3)
cpi	2.067*** (0.43)		
ppi		1.452*** (0.30)	
unemployment			0.058 (0.06)
constant	0.081 (0.13)	0.182 (0.12)	0.118 (0.37)
R-sqr	0.163	0.161	0.007
dfres	118	118	118
BIC	391.7	391.8	412.1

This next regression examines the impact of the GSCPI Index on labor summary statistics, as mentioned above in the data section. Two of the three - CPI and PPI - are statistically significant at the 1% level while unemployment doesn't see any level of significance. Such regression trends in CPI and PPI align well with the literature as both selling prices drastically increase when supply chain backups worsen as well as the price to the consumer due to limited stock and shelf inventory for the given demand,

especially when that demand is climbing, as seen during the pandemic. Unemployment rate results don't illustrate much of interest, especially given the lack of significant p-value, besides possibly providing more of a general understanding of employment struggles in the past two decades, and that in general through large periods of economic instability from 2012 up until now, such as the remaining effects of the 2008 crisis and into the Trump era, unemployment has seen periods of increase.

GSCPI Fluctuations Against CPI, PPI, and Unemployment



Graphically, this idea is again well emphasized, as leading up to recent times at 2020, the CPI and PPI mirror the trends in GSCPI, while unemployment remains relatively flat, riding out the increases seen from 2008 and seeing a notable low point in 2019 and visually highlighting the lack of correlation. However, there is too an unpredicted observation different to the regression results seen starting in March of

2020 — GSCPI shoots up, as does the unemployment rate, possibly due to the understanding of viable, safe economic interactions becoming uncertain. CPI and PPI in fact drastically decrease, unlike any period before - or after for that matter, to the lowest seen in the past decade.

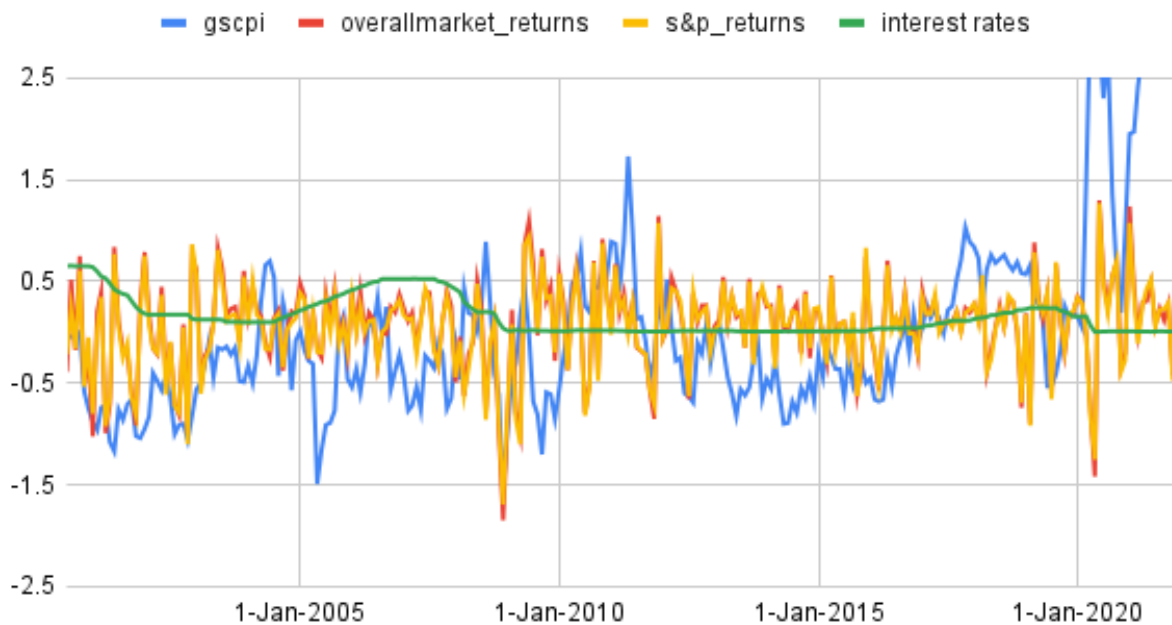
5 Conclusion

At large and across the entire 2000-2020 time period, we see a positive correlation between stock market returns and the GSCPI index, highlighting the opposite of what was originally predicted. In times of incremental, still significant but not drastic, increases in the supply chain inputs, the stock market reacts positively to such changes - possibly observing these trends as a sign of general market growth and gain for all. In contrast, however, in times of drastic, record high supply chain crises, the stock market crashes - maybe realizing these trends to be more permanent and have a likelihood of a longer term, irreversible impact. The trends in data align with one's thinking once we separate significant and drastic supply chain disruptions, and find the level of such inputs which signify the categorization amongst the two.

Regarding this unpredicted effect between market returns and GSCPI, we consider other compounding variables during such supply crises, including lower interest rates as when rates are on the rise, firms will begin to carry less inventory. Looking at Graph 3, as the drastic periods of 2008 and 2020 begin, the interest rates also

begin to decline, leveling out to a rate close to 0% at the peak of supply crisis. While this doesn't follow as closely for other, less drastic periods in 2011 and 2018, this may explain certain pockets of discrepancy between the index valuation and how the stock market reacted.

GSCPI Index on Stock Market Returns, with Interest Rates



Regarding specific ETF's, we see a larger positive correlation with the more significant IYK, the U.S. consumer staples measurement, highlighting the likely large differences in reaction time across countries during these periods. Although ports and country-wide broadband transportation systems in the U.S. are not as strong as Japan or China, in comparison to the world at large, we see that the U.S. can rely on a variety of supply reserves and monetary resources - local, state, and federal - to aid the period of disruptment. As suspected, for North American natural resources, the direct impact

from GSCPI is not as much as from more pressing variable sources such as foreign policy conflicts, reserve supply and allocation, or the impending pressures resulting from alternative energy sources and subsequent policy making.

With respect to producers and consumers, we see similar movements to the stock market in terms of GSCPI but for different reasons. CPI and PPI follow the general trends of increases in supply chain bottlenecks, leading both consumers and producers to pay more as firms struggle to continuously provide ample inventory in the short term. In comparison, and an opposite effect as for the stock market, in 2008, 2011, and 2020 periods, the CPI and PPI plummeted to historic lows, reacting entirely different, driven by reasons unknown to the data and picture provided in this analysis.

In general, supply chain crises aren't that complicated or unpredictable, while different crises cause various inputs to increase versus others, similar patterns follow every crisis peak as well as more repeated, predicted increases during times of high economic growth. However, during such peaks, we observed seemingly unexpected reactions from producers, consumers, and unemployment rates as well as the stock market's overall performance, almost immediately as the crisis hits. This analysis illuminates a need to explore the political and socioeconomic effects of these situations which often supersede and compoundly impact economic interactions such as the stock market more so than raw prices or the path of supply and demand interactions.

6 References

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