



US DOLLAR INDEX APPRECIATION HEDGE

DOLLAR INDEX; FOREIGN EXCHANGE;
OPTIONS; EMERGING MARKET HEDGE

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INTRODUCTION

In an era of growing globalization and higher currency volatility, changes in exchange rates have a significant impact on corporate operations and profitability. Exchange rate swings have an impact on not just local firms in the United States, but also multinational organizations and businesses. Currency risk is significant for businesses to understand and manage, but it is also important for investors to be aware of as it may have a big impact on their portfolios. With 40% of the S&P 500 Index constituent companies' revenue coming from international sources, many seemingly diversified US based portfolios face significant risk from dollar appreciation. Furthermore, investors may seek to gain exposure to speculative high growth foreign markets. While these investors may hedge the direct currency risk with the local currency, there are many other secondary risks which remain unhedged. Therefore, using strategically long optionality, a low cost, high efficacy hedge on the US Dollar Index can be achieved which would allow for investors to take advantage of diverse emerging market opportunities with significantly reduced foreign exchange risks (additionally, domestic investors will be hedged against adverse dollar movements for US multinational exports).

STRATEGY

To gain exposure to the US Dollar Index (USDIX), the strategy will utilize the Invesco DB US Dollar Index Bullish Fund. (UUP). UUP is used rather than using USDIX futures options (FOP) due to the complexity of modeling FOP and the higher liquidity within the ETF options market. The strategy will sell a call option of 101.1% moneyness and purchase two call options of 104.8% moneyness expiring on September 16, 2022, (approximately 160 days). This transaction will bring in net cash of 0.03% of notional value and have a margin requirement of 1.2% of notional. Furthermore, the models noted below denote a return on risk capital of 19% and an expected carry cost of 1.3%. To hedge \$100 of S&P 500 equities exposure, this strategy recommends the purchase of approximately \$9.80 of notional options on UUP. To hedge \$100 of emerging markets exposure, the strategy recommends the purchase of \$89.34 of UUP notional options exposure.

THE US DOLLAR INDEX

The US Dollar Index (USDIX) is a measure of the value of the dollar relative to the value of a chosen basket of currencies that have a significant trading impact on the dollar's supply and demand. These currencies include the Euro, Swiss Franc, Japanese Yen, British pound, Canadian dollar, and Swedish Krona. The index's value is an indication of the dollar's value aggregated across global markets, and its performance can be compared to itself over time to assess the current standing and global macroeconomic position of the US.

The index is weighted, meaning the currencies in the basket which have the largest trade impact have a higher weight in the calculation of the dollar's relative value. For example, the EUR makes up 57.6% of the basket, being the largest currency trading with the dollar.

The index began in 1973 with a base value of 100, and the subsequent values reflect performance relative to this benchmark. USDIX reached its all-time high of 165 in 1984 and had an all-time low of 71 in 2007. Throughout the last 6 years the USDIX has ranged between 90 and 100 and currently stands at 99.82 (04/07/2022).

LEVEL:

99.84

(Reflects data on 4/8/22)

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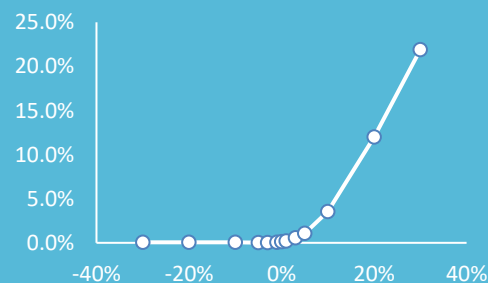
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SUMMARY

Carry Cost (Annual)	1.3%
Sold Strike	\$27.00
Bought Strike	\$28.00
Expiration	9/16/22
Roll-Timeframe	1 month
Underlying Asset	UUP US Equity
Historical Volatility	7.69%

1-Day Strategy P&L Scenario



EMERGING MARKETS

By most measures, the US Dollar is the most powerful currency in the world, and it is the world's dominant reserve currency. Foreign currency prices and the way their values shift relative to the US Dollar reflect macroeconomic performance by country and how the world's economies stack up against each other. Fundamental market changes in interest rates, inflation, trade dynamics, and the global geopolitical climate are the main factors that impact the dollar's strength compared to other currencies. Rising interest rates signal that the dollar will likely perform well in the short run, while high inflation and geopolitical tensions between the US and Russia and China point to weaker dollar performance in the long run.

The Federal Reserve's interest rate decisions, which derive from changes in the Federal Funds Rate, have the most pointed impact on the dollar's performance in the short run. As the world's international trade and supply chains such as the oil market are traded and denominated in the US Dollar, the interest rate charged on borrowing has a very acute effect on the supply and demand dynamics of commodities. Raising interest rates tends to increase the demand for the dollar and make it appreciate, while lowering interest rates does the opposite, leading to the depreciation of the dollar relative to other currencies.

During the years following the Great Recession in 2008, the Fed kept interest rates near 0 to boost macroeconomic recovery. In 2015, we began to see rates spike which caused the dollar to get stronger, with a Federal Funds Rate of roughly 2.5% pre-Covid, and in March 2020, the rates dropped down to 0.25% once again to avoid an economic meltdown. Rates remained near-zero until the Fed's decision on March 16, 2022 to raise interest rates and bring the Federal Funds Rate to 0.5%. The Federal Reserve also announced their decision to continue steadily raising rates, and thus the dollar is expected to appreciate soon as investors earn higher yields for holding the dollar.

Other worldwide dynamics may have effects on the dollar as well, including inflation rates, which have the opposite effect from interest rates on the dollar's performance. Higher rates of inflation tend to cause the dollar to weaken in the long run. US PCE inflation, which calculates inflation based on a basket of chosen goods and services purchased in the US, is at 6.30%, a significant increase from the 1.50% inflation rate seen in Q4 of 2020. The increased inflation reflects the post-pandemic recovery stimulus passed and will likely have an adverse impact on the value of the dollar in the long run.

In addition, the current geopolitical tensions involving Russia and Ukraine, which have led to sanctions on Russia and their trade dynamics, may also cause dynamics to shift in the long

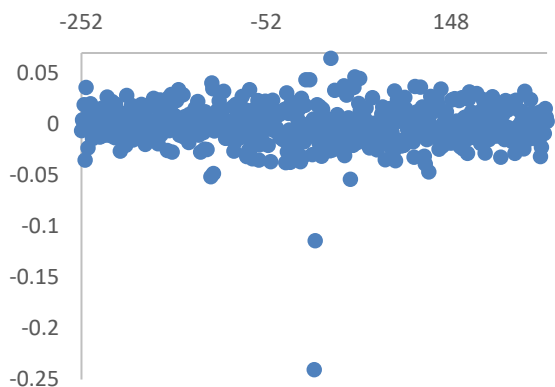
run and may weaken the dollar. The US and other countries in NATO are clearly against Russia's decisions to invade Ukraine and have been able to sanction Russia because of their dependence on the US Dollar for trade, and many predict that countries like Russia and China will begin to shy away from the dollar and decrease their dependence on it in the long term, lowering demand for the dollar and thus causing it to depreciate in the long run.

In the short to medium term, expect the dollar to appreciate because of the increase in interest rates and likely continuation of these increases, and in the long run, depending on the outcome of the current geopolitical uncertainty, expect to see the dollar weaken as the inflationary effects of the post-pandemic spending and sanctions pushing other countries away from the dollar weaken its demand.

Dollar as a Hedge

Emerging Markets

Examining the historical price level of the emerging market assets and USDX since 1991, many studies have concluded a causal inverse relationship between the two. The high interest rate partnering a strong dollar would attract capital from emerging markets to the US domestic market as investors have alternative high yielding options for their wealth. Furthermore, the high interest rate infringes on emerging market countries' ability to borrow from US sources to finance budget needs during the era of development and economic expansion. This is especially important given that over 20% of emerging market sovereign debt is in US dollars. To determine its empirical efficacy of the proposed hedge, the returns iShares MSCI Emerging Markets ETF (EEM) are regressed against the returns of USDX. A priori, it is likely that the USDX level will be a more important indicator for EEM market movements relative to its returns. This relates as it is the general conditions of the dollar serve as a headwind (resp. tailwind). However, empirical data implies return is a better statistically significant variable to use. For technical reasons relating to the linearity of expectations and correlations, the USDX is detrended and adjusted for heteroskedasticity. To determine the higher order effects of USDX, the cross-correlations are assessed over a span of 252 trading days (approximately corresponding to one fiscal year). The Special Whites Test showed the regression significance of p-value 0.0000 implying the existence of heteroskedasticity. Adjusting for heteroskedasticity and auto-regressive effects, yielded a model significant at p-value of 0.000. Additionally, the returns of USDX are significant at p-value of 0.000. The model implies that a 10% increase in USDX results in an 8.93% reduction in the expected return of EEM. This implies that appreciation in USDX plays a significant role in decreasing the returns of EEM shows its usefulness as a hedge empirically.



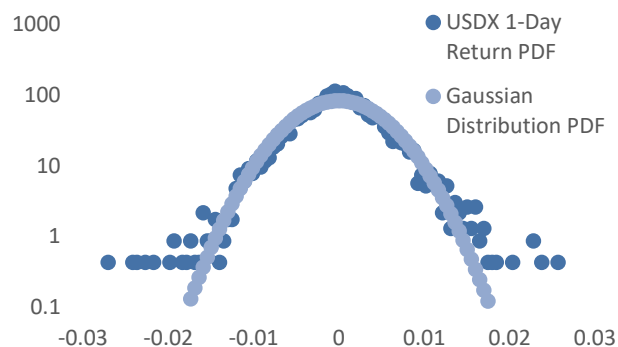
Cross-Correlation Between EEM Returns and USDX Returns

S&P 500 Index

As noted in the introduction, a priori, there is likely significant dollar appreciation risk present in the S&P 500 Index. Indeed, during the market correction of 2016 (when the US Dollar Index was at fourteen-year highs at a level of 103.65) many companies had earnings downgraded due to currency headwinds. Many companies in this time published earnings under a constant currency basis to demonstrate to investors that dollar policy was the cause of their lack of performance. As in the emerging market case, to quantify the relationship between USDX and the S&P 500, the 1-day returns of the S&P 500 are regressed against the returns of USDX. A similar methodology is employed for the S&P 500 as in the emerging markets case to achieve accurate modelling. Like the emerging market case, the Special Whites Test showed statistically significant heteroskedasticity. The adjusted model was significant at p-value of 0.0321. Additionally, the returns of USDX are significant at p-value of .032. The model implies that a 10% increase in the US Dollar Index results in an approximate 1% reduction in the mean return of the S&P 500.

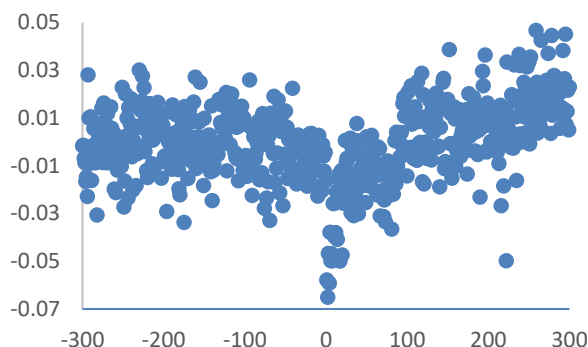
GARAM

The GARAM (General Auto-Regressive Asset Model) is employed and used to fit the Optimal Hedge Monte Carlo (OHMC) model described in the next sections. The model uses historical US Dollar Index levels from 1972 to 2022 as the input and will output realistic path simulations to be used in the OHMC model. Unlike various other stochastic descriptions of the market relations which assume explicitly or implicitly a stationary, log-normal distribution of market returns, the GARAM model explicitly uses the empirical ex-post distribution of the market across all time scales. The GARAM model works by employing two inter-dependent, temporal stochastic processes which model the sign and magnitude of the return using empirical auto/cross correlation matrices. The data derived from these processes is generated utilizing a Cholesky Decomposition. For technical reasons, the data is modeled under a normal distribution and is then transformed into the empirical model using a random variable characterized by $Y(s) := \sup\{t \in \mathbb{R} : F(t) < s\}$ where $F(t)$ is the empirical density and $s \in (0, 1)$.



Log Scale: Normal Distribution vs. USDX Return Distribution

The intuition of the model is based on the well-studied effects that volatility exhibits clustering whereby high volatility is typically followed by high volatility. Additionally, the model accounts for the leverage effect, slow decay of both skewness and kurtosis, and the temporally related asset densities. Using this framework, a Monte Carlo process creates 100,000 future unconditional price paths that are generated for the next 504-days. To account for the effects of recent pricing data, the unconditional price paths are then conditioned on the recent data to better incorporate recent events into the model's predictions.



Cross-Correlation Between USDX Return Sign and USDX Return Magnitude

OHMC

The classic option pricing strategies like the Black-Scholes model or other risk-neutral pricing strategy make dogmatic assumptions about the perfectness of the dynamic hedging, which, in the world of option, summarize various attempts to replicate the option price curve using the underlying assets. Such approaches of utilizing linear instruments to hedge nonlinear financial instruments fail to take into consideration realistic market dynamics like natural quantization of time, transaction cost, and hedge slippage. Due to risk premiums derived by human greed, fear and discrete delta hedging, it's basically impossible to find a perfect static delta hedging strategy; however, the idealistic false assumption serves as the cornerstone of many option pricing theories. In the market of equity options, perfect replications are unattainable mainly

because of two factors: the universal existence of substantial, slow-decaying kurtosis of returns and the irreducible risks from hedging intervals.

As a more realistic alternative of option hedging strategy, the Optimal Hedge Monte-Carlo (OHMC) approach aims to quantify the cost of option replication through explicit evaluation of residual risks and trading costs. Instead of calibrating the pricing model with numerous theoretical assumptions to attain an ideal perfect hedge in the risk-neutral world, OHMC makes use of stochastic processes to simulate asset returns. This practice brings flexibility into the strategy and ensures the later hedging analysis has a solid starting point. Furthermore, when deciding the hedge ratio, rather than focusing on how to price the option, OHMC optimizes a function of change in wealth directly with the simulated P&L distribution of the options while maintaining market neutrality between hedging intervals. Intuitively, the forthright approach not only ties with the intrinsic value of option trading or investment in general but also captures market dynamics like the slow-decaying kurtosis of assets returns, hedge slippage, and transaction cost by adding conditioning variables that quantify factors like hedging cost and residual risk distribution into the optimizing function. Rooted in the objectivity to cope with the real market, OHMC yields promising results in various financial derivative markets.

Model Results

Applying the GARAM model, OHMC as described above provides a curve for the expected sellers' return on risk-capital for the UDX future option chains of various tenors up to six months (options expiring in the same month as their underlying future's expiration). Based on the ability to derive a low-cost tail-risk strategy, the five-month option chain yields the lowest carry compared to other tenors. Further, it is optimal to sell the option with maximal risk premium while buying options with less risk premium. This would ultimately reduce the carry cost of the strategy. When determining the optimal strikes, the issues of reactivity of the bought option and their time decay. An analysis of the five-month tenor through the OHMC-GARAM framework shows that a slight credit is optimal. Thus, the strategy is nominally cash generating.

Model Validation

The significance of the regression models for S&P 500 returns and emerging market returns, show that our assumptions that UDX acts an effective hedge to returns within both the emerging market and S&P 500 returns. Furthermore, the parameter estimates for both show that the expected return is decreased by about 10% of the return of UDX which seems to be a reasonable sensitivity based on exogenous understanding.

As noted previously, the GARAM model relies on empirical asset densities in simulating, the asset prices rather than dogmatically assuming normality. Furthermore, the GARAM model uses empirical data to calculate the term structure of autocorrelation within the returns and allow for the observed slow-decaying higher moments within the USDX temporal asset densities. Further, the GARAM model uses a conditional simulation allowing the pricing paths to contain the ex-ante market conditions. These factors allow the GARAM model to produce "realistic" paths of future pricing which allow for an accurate usage of the OHMC model. The result that GARAM

produces of a slow-decaying term structure of kurtosis and skew shows that the central limit theorem does not hold, which implies that asset performance is not temporally independent. This matches a priori expectations and matches many theories within behavioral economics.

The OHMC portion of the model is not predicated on a risk-neutral assumption and is based on a realistic action of a market participant wishing to minimize the volatility of their P&L using dynamic daily hedging (in full generality OHMC could be looked at over any discrete time interval) which matches a realistic hedge framework.

RISK FACTORS

US Dollar Index is not an Effective Hedge. Historically, the US Dollar Index has an effective record of hedging emerging markets dollar-based risks across many economic cycles. However, in the long term, the price level of the US Dollar Index has exhibited unpredictable performance due to temporary economic shocks. Moreover, increasing government involvement in the market through fiscal and monetary policies because of the pandemic will affect the performance of the US Dollar Index in the foreseeable future. Therefore, using the US Dollar Index as a hedge may prove to be more volatile than we expect.

Market Liquidity of Options. Trading US Dollar Index options opens investors who try to hedge their emerging market portfolio up to an increased level of risk in terms of market liquidity. US dollar has served as the reserve currency for international trading for decades among all major global financial markets, but even still, market liquidity of the US Dollar Index options is a serious risk. With the existence of the foreign exchange market and many more direct ways to take advantage of inequality between currencies, US Dollar Index options have a much lower volume traded than many more popular index options in addition to its time horizon risk. As the options get closer to their strike dates, illiquidity problems are exacerbated by urgency and might lead to extra volatility to the hedging strategy.

Decline of US Dollar Use. As other economic entities from both developed and developing countries have gained strength in the international market, many investors seek alternative currencies that bring better liquidity in their regional market. The unpredictability of the Federal Reserve policy, the rising deficit relative to the slowing down GDP growth, and the bumpy recovery from the supply chain shock all contribute to a decreasing confidence in the US dollars which lead to decline of US dollar use in the international market. Furthermore, with the increased sanctions, it is likely many sanctioned countries will transact in other currencies. The decreasing usage of dollars reduces the inverse relationship between the US dollar index and emerging market portfolio and thus makes the former less attractive as a hedge against emerging market investment risks.

Sudden Macro-Economic Changes. Although historically the US Dollar Index exhibits an inverse relationship with the emerging market assets, with the progress of globalization and specialization among countries in economic activities, the deviation of single economic entity performance from the global economic environment has been diminishing.

Consequently, macroeconomic changes like the Pandemic of Covid-19 and the Suez Canal obstruction that could impact global economic entities in a similar negative manner would cause the US Dollar Index and emerging market assets performance to drift from their normal behaviors and expose the strategy to potential risks.

CONCLUSION

With the irreversible progress of globalization regardless of periodic political turmoil in the international market, cash flow from international sources, and emerging markets acquires growing weight on the portfolio of fund managers and equity firms who constantly hunt for higher returns on their investments. However, due to the natural dynamic of currency exchange investments in emerging markets encounter unavoidable volatility and risks from dollar appreciation and weak international economic performance. Lately, the increasing uncertainty brought by complex geopolitical factors including the tension between Russia and Ukraine, and the foreseeable tight monetary policy implemented by the Federal Reserve exacerbate the risk exposure of emerging market portfolios. Developing a cost-efficient strategy to hedge the excessive risk among both the domestic and international markets become necessary to protect the return and stability of the portfolio. The US dollar has been the world dominant reserve currency whose value reflects the macroeconomics performance of not only the US but also other major economic entities. As a result, the US Dollar Index (USDX) serves as a perfect instrument for this purpose. Applying the Optimal Hedge Monte-Carlo (OHMC) hedging strategy based on the return paths generated by the General Auto Regression Asset Model (GARAM), an optimal hedging strategy on the US Dollar Index is derived which would bring a highly efficient hedge against emerging market portfolio risks with low cost. Furthermore, the market based conditional simulation and the realistic consideration of detailed market dynamics of the model ensures performance consistency of the hedging strategy under the uncertain market conditions.